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urban and spatial planning, architecture, housing, building, geodesia, environment

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SCOPE AND AIMS

The review is concerned with a multi-disciplinary approach to spatial, regional and urban planning and architecture, as well as with various aspects of land use, including housing, environment and related themes and topics. It attempts to contribute to better theoretical understanding of a new spatial development processes and to improve the practice in the field.

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EDITORIAL

Dear readers,

The process of editing a journal is an amalgam of rational, experienced, emotional, fearless, wishful and intuitive endeavours. Needless to say, sometimes it is accompanied with 'speed bumps' on the road.

"Ever tried. Ever failed. No matter. Try again. Fail again. Fail better."

- Samuel Beckett, from his short prose *Worstward Ho!*

This issue of *Spatium* (No. 54) would not be in front of you, dear readers, without the support of our Guest Editor for this issue, Dr. Sanja Simonović Alfirević. She took complete care of the second and third articles presented in the Contents. She also provided many useful insights from her professional and personal experience, which, I believe, brought additional kindness and comprehension to our editorial team – so I thank her for that as well!

There were a number of aspirants who wished to publish their articles in this issue of *Spatium*. Yet, in the end, we managed to present only 6 articles based on the highest scientific rigour. Our authors come from Algeria, Iran, Turkey, and Serbia, whose original research is based on a variety of themes and topics related to spatial planning, tourism, urban systems, the urban fabric, housing, and indicators by which the digital and physical realms merge.

We hope that the scientometric evaluators of our journal will acknowledge our efforts this year to enhance the quality of *Spatium*. All being well, the results of their work will help us to maintain, if not to improve, the present journal ranking and categorisation of *Spatium*.

A brief presentation of the journal's statistics according to the OJS statistics for *Spatium* is: 86 articles were submitted to the journal in 2025. Out of those articles, 68 received a desk rejection (79%) and 5 received a rejection after review (5.8%). The acceptance rate is 15%. During 2025, the average time spent on the evaluation process from the initial submission until the paper's acceptance for publishing was **5.9** months.

Jasna Petrić
Editor-in-Chief

EFFECTS OF A MATRIX ROUTE ON THE THIRD DIMENSIONALITY OF A TOWNSCAPE

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Street systems are fundamental elements of cities, and they include many hierarchies that determine the structure of the urban fabric. It is possible to identify some basic typologies of streets as routes found in all spontaneous building fabrics. The matrix route is the oldest and most important one, as it has led to the development of settlements and often formed naturally without a planned design. The study focuses on the matrix route's three-dimensional impact on the urban form, specifically analyzing Karakolhane Street's role in shaping the Yeldeğirmeni district in Kadıköy, Istanbul. The street was chosen due to its evolution being traceable on historical maps, and the changes in its three-dimensional structure can be identified based on zoning laws and personal observations. The analysis methodology comparatively focuses on the street structure and nodes, height changes, height differences at polar nodes, and their impact on the urban landscape. The inquiry aims to document these changes using historical maps, records, texts, illustrations, and photographs. Historical maps are the primary source of information as they display the layout of streets, urban blocks, and buildings, preferably dating back to the 18th century.

Key words: urban morphology, matrix routes, townscapes.

INTRODUCTION

Streets are fundamental elements in the formation and development of urban landscapes. Whether deliberately planned or organically produced, they structure the patterns of urban fabrics and influence spatial organization at multiple scales. The classification and analysis of street structures based on both quantitative and qualitative characteristics have long been central to urban morphology (Panerai and Castex, 1970; Krier, 1979; Hillier and Hanson, 1984). As Lynch (1960) argued, streets are also primary perceptual elements, through which individuals understand and navigate the city. From a configurational perspective, they constitute the underlying system of movement and potential, shaping the distribution of activities and densities (Hillier, 1996). Although this study acknowledges these conceptual foundations, its primary focus is on the *matrix*

route – the generative path that precedes and organizes urban development – and its relationship to the three-dimensional urban landscape.

Urban morphology has traditionally been examined through two-dimensional plan analysis. Conzen's (1960) classic town-plan approach, for example, emphasized street systems, plot patterns, and building arrangements at the ground plane. However, cities are not solely two-dimensional entities; the vertical dimension is equally critical in producing urban character, perception, and identity. Scholars have increasingly emphasized the need to understand cities through their three-dimensional structures, particularly as new technologies facilitate volumetric and height-based analysis (Ratti *et al.*, 2005; Xu *et al.*, 2017). Despite the methodological advances, studies explicitly connecting the role of matrix routes to three-dimensional transformations remain limited.

A growing body of research demonstrates how verticality, building height, and volumetric growth reflect broader urban processes. Domingo *et al.* (2023) conducted two- and three-dimensional analyses of Spanish cities using cadastral and

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LiDAR data, revealing significant increases in urban volume despite a reduction in average building height. Similarly, Rao *et al.* (2020) integrated horizontal and vertical metrics to examine growth patterns in 58 Chinese cities, highlighting the importance of clustering, height, and compactness in understanding contemporary urbanization. Shen *et al.* (2024) showed how three-dimensional morphological data can capture spatial complexity at neighborhood scales, offering valuable insights into local development dynamics. These studies underscore the importance of three-dimensional analysis for understanding long-term change, density patterns, and sustainable development strategies.

In addition to volumetric approaches, the urban block continues to serve as a central morphological unit. Historically, European cities were shaped by medieval fabrics until the 18th century, after which the city block became a dominant organizational element (Panerai *et al.*, 2004). Advances in digital technologies have enabled more detailed analysis of block structures, built-unbuilt ratios, and height patterns (Vanderhaegen and Canters, 2010). Complementing these approaches, the Urban Parterre Modeling (UPM) technique developed by Psenner and Kodydek (2018) demonstrates the inadequacy of purely planar cadastral maps, and highlights the need to integrate streets, ground floors, and courtyards to reveal three-dimensional relationships.

A range of methodological approaches has been developed to analyze the three-dimensional morphology of cities. These techniques are increasingly vital for understanding and managing urban landscapes, especially where vertical precision is required to assess urban character. Ren *et al.* (2020), for example, proposed an approach that integrates building footprints obtained through the Maps Static API with height information from the ALOS World 3D model. This method enables the calculation of key morphological parameters – including the sky visibility factor, building coverage ratio, building volume density, and frontal area density. When applied to the highly complex urban context of Hong Kong, their methodology proved both accurate and broadly applicable. In a related contribution, Koomen *et al.* (2009) developed a framework for quantifying urban volume using detailed elevation data and topographic information. Their case studies in Amsterdam and four major Dutch cities demonstrated how urban-volume indicators can reveal patterns of spatial expansion, intensification, and the emergence of multi-core development structures.

Within these broader morphological traditions, Istanbul presents a distinct historical trajectory. 19th Century reconstruction efforts, particularly following major fires, introduced new street geometries and spatial interventions (Çelik, 1996). Architect Luigi Storari's implementation of rhomboid junction forms, beginning in 1854, played a critical role in shaping certain neighborhoods, producing widened nodes that function as small urban squares within the street network. Such nodes are significant elements for understanding the spatial rhythm of matrix routes, as they create character zones, influence plot arrangements, and often concentrate building height variations – an aspect emphasized by urban space theorists concerned with node behavior and spatial intensity (Bentley *et al.*, 1985; Carmona *et al.*, 2003; Gehl, 2011).

Despite increasing attention to the three-dimensional structures of cities, the influence of matrix routes on vertical urban character remains insufficiently investigated. Urban form commonly develops around a primary structure of routes, yet how these routes – together with their architecturally and morphologically distinct nodes – shape the three-dimensional landscape has not been fully explored. Do nodes along matrix routes function as focal points of vertical differentiation? How do height variations correspond to parceling histories, zoning regulations, and spatial typologies?

To address these questions, this study focuses on Karakolhane Street, a central matrix route in the formation of the Yeldeğirmeni district in Kadıköy, Istanbul. The evolution of this route can be traced through historical maps, while its distinctive rhomboid nodes – originating from Storari's post-fire interventions – provide key character zones for examining plot transformations, building heights, and three-dimensional urban relationships. By analyzing these elements together, the study aims to reveal how matrix routes and their nodes contribute to the vertical articulation of urban form.

METHODOLOGY

Caniggia and Maffei (2001) highlight the foundational role of matrix routes in the emergence and evolution of urban form. These primary paths typically precede building activity and structure the development of the surrounding fabric, yet they cannot be understood independently of their contextual relationships. Strappa (2018) similarly argues that the urban plan is produced through the interaction of routes and textures, and that reading the system of routes is essential for interpreting the morphological structure of the city.

Drawing upon this theoretical framework, the present study examines the role of the matrix route, its nodes, and its poles in shaping the three-dimensional urban landscape of the Yeldeğirmeni district in Kadıköy. Karakolhane Street was selected as the primary case study due to its historical role as a generative path and its distinctive spatial characteristics. Functioning as the main matrix route of the neighborhood, the street organizes the surrounding urban fabric through its continuity, alignment, and morphological depth. Critically, it incorporates several rhomboid-shaped nodes, introduced during architect Luigi Storari's post-fire reconstruction interventions beginning in 1854 (Çelik, 1996). These widened junctions behave as micro-squares within the linear route system, forming character zones that influence plot formation, building typologies, and vertical articulation. Their spatial distinctiveness and concentration of activities make them central to analyzing two- and three-dimensional morphological transformations.

Accordingly, the research seeks to answer the following questions:

- How has the development of the matrix route influenced the urban structure and plot configuration within the study area?
- How does the matrix route affect building heights? In which segments do height variations become

pronounced, and do rhomboid nodes function as focal points for vertical differentiation?

- How have changes in zoning regulations over time shaped height patterns and vertical development along the matrix route?

To address these questions, the analysis proceeds through several complementary dimensions:

- the street structure of Karakolhane Street and the identification of character-defining nodes,
- plot subdivision processes and their effects on urban blocks,
- vertical changes resulting from successive zoning regulations, and
- height differences observed at polar and rhomboid nodes, and their implications for the three-dimensional urban landscape.

To supplement the morphological reading and provide a quantifiable basis for evaluating the built environment, the study incorporates the Spacemate method developed by Berghauer Pont and Haupt (2021). This analytical framework assesses urban form using four parameters: the floor space index (FSI - intensity) (floor area/ground area), ground space index (GSI - coverage) (built up area/ground area), building height (L), and open space ratio (OSR - spaciousness) (non-built ground area/floor area). Together, these indicators enable a systematic examination of density in both two and three dimensions. Within the context of Karakolhane Street, Spacemate serves as a complementary tool for understanding how the matrix route and its rhomboid nodes structure volumetric intensity. By measuring variations in plot occupation, building coverage, and average storey height, the method helps identify local concentrations of built form and clarifies vertical transitions along the route. This quantitative layer reinforces the interpretation of street sections and silhouettes, enabling a deeper reading of the urban landscape and its sustainability implications.

In the analysis of nodes, the one with the beveled corners – Node A – was selected to understand the importance of them for the matrix routes. Node A – located at the intersection of Karakolhane Street and İskele Street – was selected because it represents the most spatially and morphologically distinctive point along the matrix route. Unlike ordinary right-angled junctions, Node A exhibits the rhomboid, beveled geometry introduced through Storari's 19th century post-fire interventions, creating a micro-square condition that expands both movement and visibility. Historical maps (Goad, 1906; Pervititch, 1937) consistently show that this junction attracted larger plots, amalgamations, and taller buildings earlier than other parts of the neighborhood. As a result, Node A functions as a focal point of three-dimensional specialization, where shifts in height, massing, and density are most pronounced. These characteristics make it the ideal micro-area for understanding how the matrix route generates vertical transformation and the structuring of hierarchies in the Yeldeğirmeni urban fabric.

To document morphological and vertical transformations, the study draws upon historical maps, archival records,

textual sources, illustrations, and photographs. Historical maps constitute the primary dataset, as they reveal shifts in street alignments, block structures, and building footprints from the 18th century onward. Particularly significant are the fire insurance plans prepared by Goad (1906) and Pervititch (1937), which offer detailed representations of the built environment during the late nineteenth and early 20th centuries. These sources make it possible to trace the evolution of the matrix route, identify the emergence of rhomboid nodes, and analyze plot-level changes.

Plot patterns and building configurations were examined through comparative layer analysis, allowing the study to track changes in the façade alignment, building depth, and height regulations across different periods. Street sections and silhouettes were employed to identify vertical discontinuities along the route, with special emphasis on the spatial behavior of nodes. By combining morphological theory, cartographic evidence, zoning analysis, and Spacemate-based density assessment, the methodology provides a comprehensive framework for understanding the three-dimensional articulation of Karakolhane Street.

BEGINNING OF THE CITY: THE MATRIX ROUTE

The urban organism is formed by the combination of the city's street layout and structures. The concept that governs this aggregation is the urban fabric, which provides order to the urban system through streets and buildings. Streets typically develop around pre-existing routes; the initial path that structures urban formation often precedes built development and establishes the basic framework for subsequent growth. In some cases, these formative routes originate from deliberate design interventions (Strappa, 2018), while in other cases they emerge from repeated movement between significant destinations. Such original paths – referred to as matrix routes – connect two poles of particular importance, as exemplified by the Via del Corso in Rome.

Along these matrix routes, the presence of continuous side walls ensures the alignment and juxtaposition of building façades, thereby fostering the aggregation processes that generate the urban fabric (Caniggia and Maffei, 2001). The modular rhythm of building façades contributes to the structural modularity of the block, establishing morphological continuity among similar building types across different periods of development. Typically, this aggregate module takes the form of a continuous rectangular pattern, with the shorter side running parallel to the matrix route and the longer sides oriented perpendicularly, although variations do occur (Caniggia and Maffei, 2001). Secondary routes, often positioned two plot depths away from the main street, are usually arranged perpendicular to the matrix route, and their intersections create nodes that structure the fabric (Strappa, 2018).

Maretto (2018) identifies routes, nodes, and textures as the three primary components of urban structure. From the perspective of spatial hierarchy, he argues that routes exert a stronger influence on the organization of urban life than other elements. Strappa (2018) similarly views routes as the principal analytical device for understanding urban form

and territorial organization. The degree of specialization that urban elements acquire – whether at the level of buildings or nodes – depends on the hierarchical status of the route to which they belong. Routes determine the gradation of nodality and the prominence of urban poles (Maretto, 2018). Highly specialized buildings typically occupy the matrix route that links the city's principal poles. Moving outward from the matrix route, building functions gradually shift toward predominantly residential uses as the route loses nodal intensity. A comparable pattern can be observed in building height, which tends to increase near nodes and diminish along anti-nodal segments (Maretto, 2018).

Like matrix routes, nodes are essential for understanding the evolving character of the city during the construction process. A node may be defined as the point at which two continuities intersect, where one continuity branches into another, or where a discontinuity disrupts a linear sequence. In this sense, nodes represent the structural connections among the components of the urban organism. These connections may take the form of axes, intersections, or enclosed spatial configurations, and they often emerge through the individualization of routes and textures (Strappa, 1998). In certain cases, the initial or terminal nodes of matrix routes acquire a heightened significance, functioning as poles – points of intensified urban meaning and activity.

Lynch (1960) describes nodes as junctions or strategic points where particular characteristics accumulate. While he does not assign special importance to ordinary intersections, he emphasizes that nodes gain significance when they exhibit polar qualities, contributing strongly to the imageability of the city. Thus, major squares, elongated linear spaces, and even entire districts may function as poles within the urban structure. As places of convergence and concentration, the impact of nodes becomes particularly pronounced when they possess a distinct spatial form.

CONTEXT

Karakolhane Street in the Yeldeğirmeni neighborhood of Kadıköy represents a characteristic example of the historical evolution of a matrix route within 19th century Istanbul. Extending from the center of Kadıköy toward the northern parts of Yeldeğirmeni, the street gradually emerged as a principal structural axis, shaping and connecting the spatial organization of both areas. As part of the broader development of Istanbul's residential quarters during this period, Karakolhane Street is distinguished by several prominent junctions that reveal its morphological significance within the urban fabric.

Morphological development of Yeldeğirmeni

Yeldeğirmeni constitutes one of the key focal zones of Kadıköy, marked by its accessibility to transportation, cultural amenities, commercial services, and educational institutions. Owing to its strategic location, the district has sustained its vitality and continued to benefit from urban regeneration initiatives. Its connectivity – linking the Anatolian and European sides by sea, land, and rail – reinforces its role as a major urban node within Istanbul.

The name "Yeldeğirmeni" derives from the four windmills constructed during the late 18th century by Hafız İbrahim Ağa, chief architect under Sultan Abdülhamid I (1774–1789) (Giz, 1988). These windmills were established to meet the flour needs of the army, the palace, and the local population (Akbulut, 1994). The district occupies part of the former Haydarpaşa Meadow, an area that served multiple functions following the conquest of Istanbul, including military training, seasonal recreation, and various social activities (Türker, 2008).

The earliest permanent settlements in the area appeared between the 15th and 16th centuries in the form of garden houses. The construction of the Osman Ağa Mosque in 1612 intensified development in the parts of Yeldeğirmeni closest to the Kadıköy center (Türker, 2008). During the reign of Selim III (1789–1807), the number of houses increased and the first traces of a recognizable street network emerged (Barkul, 1993a; 1993b). Helmuth von Moltke's map (1852) indicates that the settlement expanded parallel to the shoreline along the slopes of Yeldeğirmeni.

The Tanzimat era had significant implications for Istanbul's urban fabric. The extension of certain social and urban privileges to minority communities shaped the morphology of districts such as Galata, Pera, Harbiye, Moda, Üsküdar, and Kadıköy, including Yeldeğirmeni (Eyüboğlu, 1991; Çiçek, 2015). The establishment of Kadıköy's first post office in 1845 on İzzettin Street indicates that the district was already undergoing organized urban development (Şimşek, 1987). The later introduction of the tram system further accelerated movement and migration, leading to increased settlement during the second half of the 19th century.

By this period, two and three-storey buildings – constructed in accordance with contemporary regulations – began to integrate with and reshape the traditional fabric of Yeldeğirmeni. The arrival of Greek, Armenian, and Jewish communities contributed to demographic growth and expanded building activity, prompting the construction of some of the earliest apartment buildings on the sea-facing slopes in the early 18th century (Şahin, 2013). The construction of the Haydarpaşa Railway Station further transformed the district, attracting German and Italian engineers, whose settlement in the area added to its cultural and social diversity.

At the beginning of the 20th century, the district began to assume its present-day urban form (Şendur, 2010). The Goad (1906) map shows that the previously organic urban fabric had transitioned into a grid pattern, producing more regularized streets and geometric blocks (Figure 1). In 1947, the infilling of Kadıköy Bay enabled the creation of a coastal road connecting Kadıköy and Üsküdar, reinforcing the district's accessibility. Although the intensive urbanization of the 1980s did not result in substantial changes to the overall plan structure, it led to the demolition of many historical low-rise buildings and their replacement with 5–6-storey apartment blocks, altering the district's architectural character at the building scale. By the 1990s, most vacant plots had disappeared, marking the district's full transition into a mature urban neighborhood.

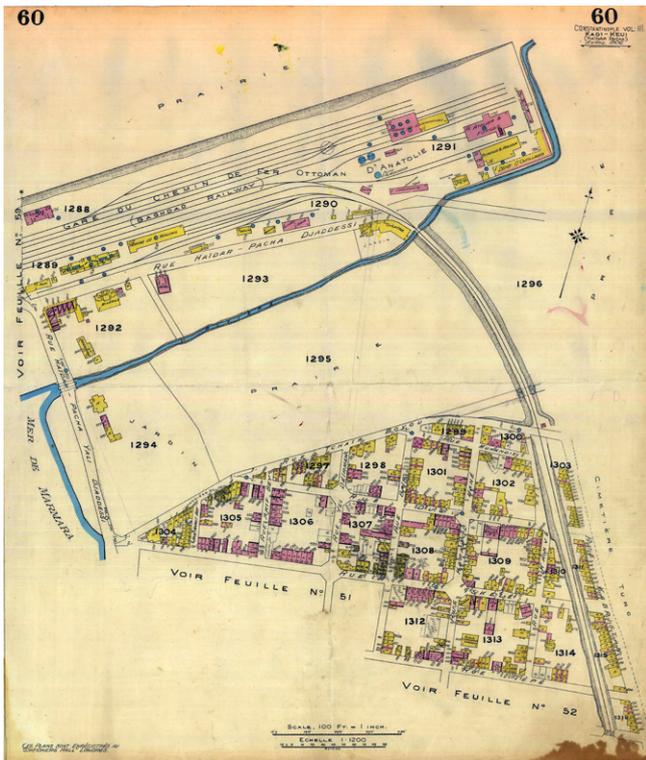


Figure 1. Plan d'assurance de Constantinople: Kadıköy (Source: Goad, 1906)

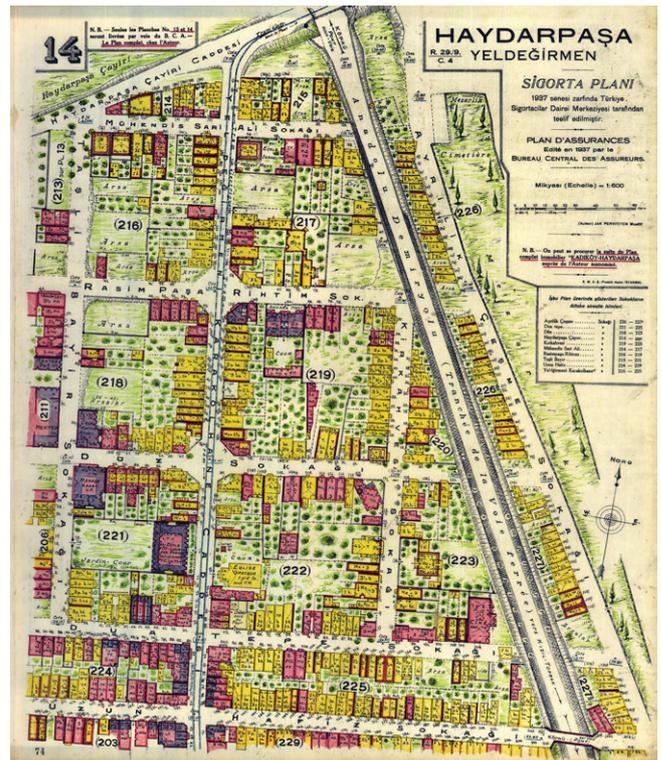


Figure 2. Sigorta Planı. Haydarpaşa. Yeldeğirmen. No: 14 (Source: Pervititch, 1937)

Impact of town planning rules

Although no major planning interventions affected Yeldeğirmeni during the Pre-Tanzimat period, the regulations, zoning laws, and planning frameworks introduced during the Tanzimat era, and later in the Republican period, had a profound influence on the district's morphological development. In particular, zoning plans shaped the neighborhood's density, functional organization, and physical growth. Prior to the Tanzimat reforms, comprehensive spatial planning was not practiced in the Ottoman Empire; regulatory measures emerged mainly in response to the frequent and destructive fires that plagued Istanbul.

The 18th century marked the first attempts to introduce more systematic regulatory measures. Following the devastating Cibali fire, dense and contiguous construction were prohibited and it was required that workplaces be built of masonry. Additional regulations during this period mandated the use of masonry construction and limited buildings to two storeys (Sakaoğlu, 1994). In 1725, another ordinance established differentiated height limits: Muslim houses were restricted to 12 zira (approximately 9 m), while non-Muslim houses were limited to 9 zira (approximately 6.75 m) (Ergin, 1995; Günergün, 1998). Despite these attempts, a holistic approach to urban replanning did not emerge before the 19th century, and reconstruction in fire-damaged areas generally adhered to existing spatial patterns (Çelik, 1996).

The most substantial transformations in spatial regulation and urban planning occurred between the Tanzimat period and the establishment of the Republic. Rapid population growth, increasing density, and repeated fires made legal

regulation imperative. Systematic codification began with the Ebniye Declaration (Divan-ı Hümayun, 1848), the first zoning ordinance applicable to Istanbul. A revised version followed in 1849 (Divan-ı Hümayun no. 2, 1849), but these early regulations proved insufficient to guide urban development, prompting the enactment of the Regulation on Streets and Buildings (Devlet-i 'Aliyye-i 'Osmāniyye, 1864). The most comprehensive of these, the Ebniye Law (Devlet-i 'Aliyye-i 'Osmāniyye, 1882), established detailed rules governing street widths, building heights, and construction materials.

The 1848 regulation classified roads into three categories – major (7.5 m), ordinary (6 m), and minor (4.5 m) – and prohibited architectural projections over the street. It also introduced limits on building height: 13.5 m for wooden structures and 16.5 m for masonry buildings. The accompanying Ebniye Declaration (Divan-ı Hümayun, 1848) modified these heights to 10.5 m and 15 m respectively. The 1849 regulation (Divan-ı Hümayun no. 2, 1849) further refined these limits, setting the height of wooden buildings at 14 zira (≈10.5 m) and masonry buildings at 20 zira (≈15 m), while prohibiting wooden construction between masonry structures. The 1864 regulation classified streets into four categories and required that redevelopment in fire-damaged zones follow rectilinear plot arrangements. The Ebniye Law (Devlet-i 'Aliyye-i 'Osmāniyye, 1882) expanded these classes to five, ranging from 6 to 15 m, and established new height limits based on street width: 18 m for masonry and 12 m for wooden buildings on streets 6–7.5 m wide, and 21 m and 13.5 m respectively on streets 9–11.25 m wide. This law remained in force until the Municipal Building and Roads Law (No. 2290) of 1933 (Türkiye Büyük Millet Meclisi, 1933) was enacted (Denel, 1982).

During the early Republican period, the Ebnîye Law (Devlet-i 'Alîyye-i 'Osmanîyye, 1882) continued to be applied with amendments until Municipal Building and Roads Law No. 2290 (Türkiye Büyük Millet Meclisi, 1933) came into effect in 1933. This legislation, the first zoning law of the Republic of Türkiye, mandated right-angled block corners and specified block dimensions of 50–80 m in width and 150–200 m in length. It also required streets to be no narrower than 9.5 m, with 4.5 m allocated for sidewalks (Ersoy, 2017). In 1957, Law No. 6785 (Türkiye Büyük Millet Meclisi, 1957) replaced the 1933 law, and in 1985, Law No. 3194 (Türkiye Büyük Millet Meclisi, 1985) became the principal zoning legislation.

Several planning decisions directly affected Yeldeğirmeni during the late 20th century. The Kadıköy Rasimpaşa Neighborhood Zoning Plan of 1971 (İstanbul Belediyesi, 1971) established a maximum height of 18.50 m for plots facing Rıhtım Street and 15.50 m for interior plots, with additional requirements for plots adjacent to historical monuments. The 1/5000 Kadıköy Centre Master Plan, approved in 1994 (İstanbul Büyükşehir Belediyesi, 1994), designated plots along Kadıköy–Haydarpaşa Rıhtım Street as commercial areas, retaining the 18.50 m height limit, while maintaining the 15.50 m limit for interior blocks. This framework was further detailed in the 1998 Rasimpaşa Conservation Zoning Plan (1/1000 scale) (İstanbul Büyükşehir Belediyesi, 1998), which reaffirmed the commercial designation of Rıhtım-facing plots and set height limits in accordance with the street silhouette for historical buildings and their surroundings. Since then, Yeldeğirmeni has not undergone any major zoning changes, apart from regulations associated with railway-related planning interventions within the district's boundaries.

MORPHOLOGICAL STRUCTURE OF KARAKOLHANE STREET

Jacques Pervititch's insurance plans from the 1930s provide one of the most detailed visual records of the structural configuration of Karakolhane Street (Pervititch, 1937). The evolution of the street can be traced through a sequence of historical maps – from those of Kauffer in 1786 (Kauffer, 1786) to contemporary cartographic sources. While early maps offer only limited information on the district's development, they nonetheless reveal key morphological foundations. Plan de la ville de Constantinople (Kauffer, 1786), for instance, illustrates the basic formation of streets and avenues in the center of Kadıköy. At this stage, Halitağa Street appears as the initial element from which Karakolhane Street would later emerge, though it initially extended only as far as Taşköprü Lane. The 1815 map by Kauffer and Lechevalier shows a similar situation (Kauffer and Lechevalier, 1815).

A more developed pattern begins to appear in Helmuth von Moltke's map (1852), which shows coastal construction parallel to the shoreline and depicts Halitağa Street connecting to Acıbadem via Taşköprü Street. However, the existence of Karakolhane Street is not yet evident. Engineer Hübner's map (1876) marks the first clear indication of a branch extending from Halitağa Street into Yeldeğirmeni, accompanied by increasing construction activity toward the northern parts of the neighborhood. Substantial progress is documented in Plan de Constantinople (Stolpe, 1882), where

a street branching from Halitağa Street is shown connecting to Ayrılık Çeşmesi, suggesting that the foundational alignment for Karakolhane Street had by then been established.

In the early 20th century, Goad Pasha's fire insurance plans further illuminate the urban layout of Yeldeğirmeni (Goad, 1906) (Figure 1). These maps demonstrate the application of grid planning principles – likely shaped by experiences of earlier fires – resulting in a more regularized urban form. The plans clearly indicate that Karakolhane Street functioned as a matrix route: construction density along the street was markedly higher than along the Rıhtım, and the built-up area expanded northward in response to the development of Haydarpaşa Station. The presence of institutional buildings, including a school and a church, reinforces the route's role as a structurally and socially significant axis.

Pervititch's insurance maps for Kadıköy, prepared in 1937, depict a continued rise in construction intensity along Karakolhane Street (Pervititch, 1937) (Figure 2). The introduction of the tram line further enhanced the street's importance, strengthening its function as a main route. This transportation improvement not only facilitated movement but also contributed to the street's growing attractiveness for commercial uses, solidifying its status as a central spine within the district's urban fabric.

Nodes of Karakolhane Street

Karakolhane Street incorporates several significant nodes of varying scales, one of which is a square-like junction with beveled corners located in the northern section of the route. This junction functions as a key point along the matrix route, offering an advantageous position from which to observe morphological changes in both two and three dimensions. It is embedded within an urban fabric characterized by notable buildings and distinct spatial configurations. Within this context, the primary spatial system components include the urban block, open space, and the development of plot and building textures. The physical components of the urban fabric – such as building depth, the relationship between buildings and the street, and building height – play a crucial role in shaping the character of the area. Morphological transformations in floor-area density, surface area, and façade composition are documented across major periods of the city's development, with street sections and silhouettes serving as essential analytical tools.

Analysis of the three-dimensional structure of the node

The analysis is grounded in a comparative examination of the physical characteristics, historical and spatial development, planning decisions, and morphological structure of the neighborhood. This evaluation uses the Goad maps (1906), the Pervititch insurance plans (1937), and current maps (İstanbul Büyükşehir Belediyesi, 2023) that document spatial changes within the four selected urban blocks.

Street–urban block geometry

Following major fires in Istanbul, new planning approaches were introduced, leading to the adoption of more regularized grid patterns in many neighborhoods. In Yeldeğirmeni, the grid texture evident on Goad's 1906 map has remained largely unchanged. The street–block structure reflects this regularity, with Karakolhane Street functioning as

Three dimensional structure: density and building height

The Spacemate framework, developed by Berghauer Pont and Haupt (2021), conceptualizes compactness through the relationship between built-up area and total urban block area. The Goad (1906), Pervititch (1937), and current (İstanbul Büyükşehir Belediyesi, 2023) maps demonstrate a consistent increase in the proportion of built-up surfaces within the four examined blocks, accompanied by a corresponding decline in open space (Table 1). This trend reflects a gradual intensification of the neighborhood’s spatial fabric.

Table 1. Open space ratio of urban blocks 1308, 1309, 1312, 1313

Pressure on Non-built Space - Spaciousness (Open Space Ratio-OSR)	Urban Block No.	1906	1937	2023
		1308/218/206	0.51	0.59
	1309/219/207	0.65	0.67	0.12
	1313/222/210	0.65	0.58	0.17
	1312/221/211	0.78	0.27	0.11
	Average	0.65	0.5	0.12

Changes in the area’s three-dimensional structure – particularly building height – are also observable across the same temporal sequence (Figure 5). Significant formal transformation has occurred as a result of vertical expansion. In the Goad map (1906), the average building height within the four blocks ranges from two to three storeys. By the time of the Pervititch plans (1937), the average height had risen to three storeys, despite the presence of several taller structures such as the five-storey Ankara Apartment, the six-storey Celal Muhtar Apartment, and the four-storey St. Louis Primary School. In the current map (İstanbul Büyükşehir Belediyesi, 2023), building heights have increased substantially, with most structures reaching four to five storeys and high-rise buildings occupying all corner parcels – indicating a strong upward shift driven by growing spatial demand.

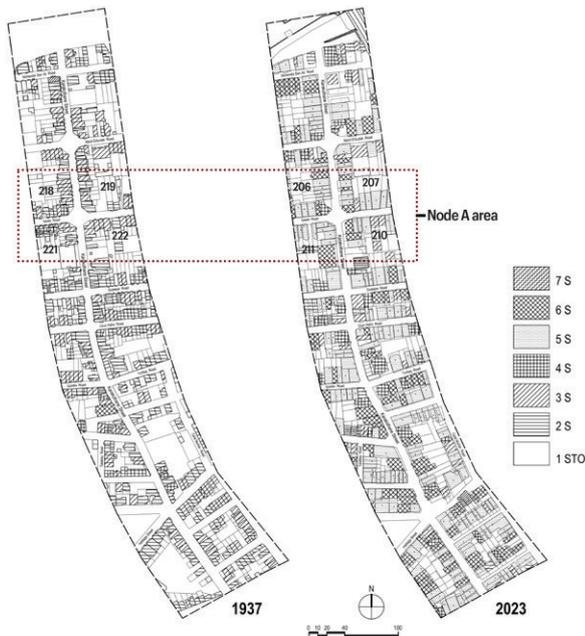


Figure 5. Karakolhane street building height-third dimension 1937-2023 and Node A area (Source: Authors, 2025)

Density values derived from the Spacemate parameters confirm this vertical intensification. Increases in the ratio of total building floor area to urban block area (Table 2) indicate a marked rise in three-dimensional density, surpassing the horizontal compactness already evident in the earlier maps. The comparison of floor area and building height therefore reveals a pattern of uncontrolled vertical growth that has reshaped both the massing and the silhouette of the neighborhood.

Table 2. Density change in urban block 206, 207, 210, 21

Intensity (Floor Space Index-FSI)	Urban Block No.	1906	1937	2023
		1308/218/206	1.11	1.08
	1309/219/207	0.94	0.91	3.03
	1313/222/210	0.92	0.98	2.54
	1312/221/211	0.87	1.67	3.06
	Average	0.95	1.16	2.89

Three dimensional structure: street sections

The A-A section serves as a key analytical tool for understanding the three-dimensional structure of the neighborhood. This section is centered on Karakolhane Street – the district’s matrix route – and extends across Taşlıbayır and Kırkahvesi streets (Figure 6). A comparative reading of the street sections derived from the Goad (1906), Pervititch (1937), and current maps (İstanbul Büyükşehir Belediyesi, 2023) reveals notable transformations. In the Goad map, buildings along the section range from two to three storeys, with expansive courtyards separating the blocks. The zoning regulation closest in time to the Goad map (1906), the Ebniye Law (Devlet-i ‘Aliyye-i ‘Osmāniyye, 1882), prescribed maximum building heights of 12–18 m along streets such as Karakolhane Caddesi and İskele Sokak, both of which have widths of approximately 10 m. Although the precise heights of the buildings depicted on the Goad map are not documented, their two and three-storey profiles appear consistent with these regulatory limits.

The Pervititch map illustrates a gradual increase in building heights and a reduction of open spaces, as plot consolidations and infill development introduced new structures into previously vacant courtyards (Pervititch, 1937). The map also indicates general compliance with the building envelopes established under the Ebniye Law (Devlet-i ‘Aliyye-i ‘Osmāniyye, 1882). The subsequent Municipal Building and Roads Law No. 2290 (Türkiye Büyük Millet Meclisi, 1933) required that sidewalks measure at least 4.5 m in width; however, the absence of detailed sidewalk representation in the Pervititch plans limits a full assessment of compliance at that time.

Later zoning plans from Istanbul Metropolitan Municipality (İstanbul Belediyesi, 1971; İstanbul Büyükşehir Belediyesi, 1994; 1998) established a uniform maximum building height of 15.5 m for most of the district. The current map confirms that buildings along the A-A section have largely reached this height limit, demonstrating a progressive vertical intensification consistent with successive regulatory frameworks.

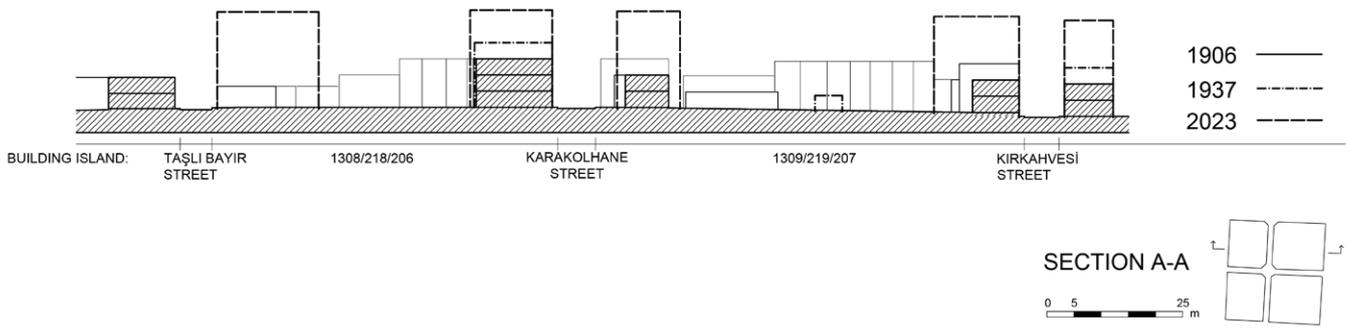


Figure 6. Change of heights, section A-A, Karakolhane Street
(Source: Authors, 2025)

DISCUSSION

The findings reveal that the three-dimensional transformation of Yeldeğirmeni is strongly organized by the enduring influence of Karakolhane Street as the district's matrix route. While the street's alignment and role have remained stable since the 19th century, its vertical profile has undergone substantial intensification. Buildings that averaged 2–3 storeys in the Goad period have progressively risen to 4–5 storeys in the present, reaching the 15.5 m height limit established by late 20th century zoning plans (İstanbul Büyükşehir Belediyesi, 1998). This vertical shift confirms that the matrix route functions not only as a generator of horizontal fabric but also as a catalyst for height concentration.

The rhomboid-shaped nodes along Karakolhane Street play a decisive role in shaping these height alterations. Their expanded geometry supports higher functional intensity, and consequently, buildings facing these nodes exhibit consistently greater heights and larger massing than those located along interior streets. This aligns with theoretical claims that nodes act as spatial attractors, where architectural specialization and volumetric differentiation become most pronounced (Strappa, 2018; Lynch, 1960). The dominance of high-rise corner structures in these zones reinforces their role as vertical landmarks within the district.

Plot dynamics further amplify three-dimensional variation. Increases in plot fragmentation have enabled more infill construction, while targeted amalgamations – especially along the matrix route – have produced larger building footprints capable of supporting higher structures. The application of the Spacemate method confirms this: rising FSI and GSI values, along with reductions in OSR, indicate a steady transition from low-rise, courtyard-based morphology toward a denser, vertically defined urban form.

Zoning regulations have simultaneously constrained and stimulated vertical growth. While earlier laws – e.g., the Ebniye Law (Devlet-i 'Alīyye-i 'Osmāniyye, 1882) – imposed material-based height limits, later current plans (İstanbul Büyükşehir Belediyesi, 2023) formalized a consistent maximum height regime. The current morphology demonstrates that these limits have been fully reached, particularly along Karakolhane Street and its nodes, where market pressures align with regulatory allowances to produce a uniform mid-rise profile.

Overall, the study shows that 3D height alteration is the central driver of Yeldeğirmeni's contemporary morphological transformation. The persistence of historical street geometry contrasts with rapid vertical expansion, producing a landscape where identity is increasingly shaped by building height, nodal intensification, and the cumulative effects of regulatory frameworks. The challenge for future planning lies in managing this verticality while preserving the spatial coherence generated by the matrix route and its characteristic nodes.

CONCLUSIONS

Routes occupy a central role in shaping urban form, as numerous scholars in urban morphology have emphasized. The urban fabric emerges in relation to them, and spatial hierarchies are structured through their alignment, continuity, and connectivity. Among these, the matrix route stands out as the most formative element, functioning as the structural backbone of a settlement. Throughout history, the configuration of routes has developed in response to topography, environmental constraints, and socio-economic dynamics. While natural conditions often promote linear or multidirectional patterns, deliberate human intervention can impose new geometries onto the landscape, producing routes that redefine the urban order. The orientation and hierarchy of routes are therefore closely tied to their nodal points, which gain significance through a combination of physical position, accessibility, and social function.

Karakolhane Street in Yeldeğirmeni illustrates this process with remarkable clarity. As construction expanded from the center of Kadıköy, different routes emerged toward key destinations on the Anatolian side and toward the north and west. Karakolhane Street, positioned close to the district's commercial and transport core, benefited from these conditions and became a major structural corridor. The route bears the imprint of Ottoman modernization, functioning as a *cardo-like* axis within a grid system, hosting the rhomboid nodes attributed to Italian engineer Luigi Storari's post-fire planning interventions. These nodes, with their distinctive geometric form, served as spatial attractors that shaped both the ground plan and the vertical profile of the district.

The development trajectory of Karakolhane Street demonstrates how a matrix route not only organizes horizontal morphology but also drives three-dimensional intensification. Over time, plots facing the route accommodated taller buildings, reflecting commercial demand and the functional specialization of nodal points. Diagonal buildings at the square corners differentiated themselves through both architectural expression and height, reinforcing the route's prominence in the urban landscape. Yet, as population pressures increased and zoning regulations shifted, these height distinctions gradually diminished. The mid-rise homogenization of recent decades has altered the skyline, weakening the once-pronounced vertical hierarchy that defined Yeldeğirmeni's character. Today, the most visible remnant of the matrix route's historic role is the street's width, which remains greater than the narrower building routes that intersect it.

This pattern echoes a broader challenge identified by Whitehand (2007) – while historical routes often survive within modern urban fabrics, their morphological significance is seldom fully appreciated in planning practice. Urban landscapes are frequently managed through the protection of individual monuments or designated conservation areas, rather than through a holistic understanding of the interconnected systems that give cities their form. The matrix route, however, is not an isolated relic but a primary structuring axis that carries the spatial memory of the city and informs its three-dimensional evolution. Treating it merely as a circulation line overlooks its deeper function as a generator of urban identity.

Understanding the matrix route therefore requires a comprehensive analysis of its vertical dimension – its height logic, nodal intensities, and the ways in which building massing responds to its hierarchy. This study shows that such an approach provides critical insights for managing historic urban landscapes, particularly those undergoing rapid transformation. The preservation and thoughtful adaptation of matrix routes and their nodes can offer a powerful framework for sustaining urban character while accommodating contemporary needs. In this sense, the matrix route is not only a historic artifact but a strategic guide for future urban development, offering a structural and morphological continuity that can anchor the evolving three-dimensional city.

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FROM LIVED PHENOTYPE TO CULTURAL GENOTYPE: A SPACE SYNTAX ANALYSIS OF SOCIAL HOUSING APPROPRIATION IN TAZOULT, BATNA, ALGERIA

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Algerian social housing, inherited from modernist paradigms, is undergoing extensive appropriation as residents modify standardized architectural phenotypes. While often dismissed as informal disorder, this study reframes these transformations as deliberate acts of cultural inscription. The authors posit that these appropriations, far from being random, follow a deep structural logic and converge towards an identifiable socio-spatial configuration. To test this hypothesis, a mixed-methods approach was deployed in Tazoult, Batna. First, a qualitative survey of 150 units documented and modeled 17 recurring “lived phenotypes.” Subsequently, these configurations were quantitatively compared against the original “designed” plans and traditional houses, serving as a cultural benchmark using Space Syntax. Comparative analysis reveals a distinct trajectory: lived phenotypes systematically diverge from the initial designed genotype, which is characterized by tree-like topologies and the dominance of circulation spaces. Instead, they converge towards a local genotype defined by the primacy of ring-like structures, the centrality of living spaces, and a dialectic of integration and segregation. These principles bear striking similarities to traditional housing, particularly in their recreation of the *Ghorfat n’ilmas* (the polyvalent central hearth room). Ultimately, this research provides quantitative evidence that appropriation acts as a cultural rewriting of space. By translating qualitative needs into objective configurational principles, this study offers an empirical knowledge base for designing adaptable and socially relevant housing.

Key words: architecture, phenotype, social housing, space syntax, Algeria.

INTRODUCTION

Mass-produced social housing presents an enduring paradox. While it effectively addressed a quantitative crisis, it simultaneously engendered a profound qualitative inadequacy a phenomenon widely documented from both sociological and architectural perspectives (Madanipour, 2003). Algeria serves as an emblematic case study in this regard. Its housing stock, largely derived from a standardized modernist genotype, has produced millions of uniform architectural phenotypes (Bachar, 2018). As highlighted by Frampton (1983), the imposition of such universal

forms often fails when it neglects regional specificity. As demonstrated by Çelik (1997), these models frequently conflict with local modes of inhabitation. Yet, faced with this disjuncture, residents have not remained passive. The widespread transformations they undertake are not mere disorder; rather, they constitute a vital signal. Following Mouaziz-Bouchentouf (2014), this study argues that these appropriations represent a cultural rewriting of space. They manifest a fundamental need for identification: the process by which inhabitants transform a generic dwelling into a meaningful home, as theorized by Serfaty-Garzon (1999) and underscored by Cooper (1974).

Scholarly literature has extensively explored this phenomenon. Foundational works, such as those by Segaud (2010), theorize the universal need to transform

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one's environment, while specific Algerian case studies by Mezrag (2015) and Tebib (2008) detail the nature of these alterations. Furthermore, housing studies link appropriation directly to well-being and place attachment (Low and Altman, 1992). Recent research has significantly advanced this understanding. Mlote *et al.* (2024), in a systematic review, emphasize that adaptability is no longer optional, but rather is a critical requirement for extending building lifespans. This aligns with the work of Ozler and Gucyeter (2024), who propose criteria-based approaches to quantitatively evaluate adaptability. Furthermore, Zeković *et al.* (2023) highlight the crucial distinction between functional adaptability and spatial flexibility, arguing that static designs fail to meet dynamic user needs. Finally, Kamara *et al.* (2020) identify the specific social, economic, and environmental "change factors" that drive residents to modify their environments, a dynamic clearly visible in the Algerian context.

However, despite confirming the urgency of the issue (Djafri *et al.*, 2019), this body of work remains predominantly qualitative. Consequently, a critical gap persists: the absence of a quantitative analysis of the configurational logic underlying these appropriations. This limitation hinders the ability to translate valuable insights into objective design principles (Gifford, 2007).

This gap frames the central research question in this study: do these spatial transformations converge towards a common configurational model? It is hypothesized that these modifications represent a collective rejection of the standardized designed genotype in favor of a local socio-spatial genotype. Drawing on theories linking form to culture (Rapoport, 1972) and space to social relations (Hall, 1978), this paper posits that this local genotype specific to the Batna region exhibits structural affinities with traditional Aurès housing. Specifically, it is argued that the residents' quest for a large, integrated central living space is a contemporary recreation of the socio-spatial logic of the *Ghorfat n'ilmis* (the polyvalent central hearth).

The objective of this paper is to empirically test this hypothesis using Space Syntax (Hillier and Hanson, 1984) as a decoding tool. This study offers two original contributions. First, it provides the first quantitative modeling of cultural convergence in Algerian social housing, establishing an evidence-based framework for adaptable and socially sustainable design (Manzi *et al.*, 2010). Second, it demonstrates that this convergence explicitly recreates the logic of a specific traditional archetype. The article proceeds by presenting a theoretical and methodological framework, detailing the comparative analysis, and finally discussing the broader implications of these findings.

THEORETICAL AND METHODOLOGICAL FRAMEWORK

To test the hypothesis, an analytical framework was constructed that bridges concepts from the sociology of housing and environmental psychology with quantitative spatial analysis.

From appropriation to genotype: A theoretical lens

The analysis begins with the phenomenon of appropriation. Following Segaud (2010), residents' transformations are not viewed here as mere modifications, but as fundamental anthropological acts through which inhabitants seek to found a place. As theorized by Serfaty-Garzon (1999) and environmental psychology (Proshansky *et al.*, 1983), this process can be interpreted as a mechanism of spatial appropriation, aiming to adapt a generic dwelling to specific cultural needs. To analyze the structural logic of these acts, the analytical lens of Hillier and Hanson (1984) is adopted, distinguishing between:

- **the architectural phenotype:** the observable, unique, and material building. In the present study, this corresponds to each individual floor plan analyzed, whether in its initial designed state or its transformed lived in state
- **the spatial genotype:** the deep, recurrent organizational logic, the set of rules, and the spatial relations that encode a culture of inhabitation. Unlike the phenotype, the genotype is not directly visible but must be deduced from the statistical consistencies found across a sample of phenotypes (Hillier and Hanson, 1984).

This distinction allows for transcending aesthetic style and uncovering the underlying rules that generate culturally specific forms, a central goal of architectural morphology (Steadman, 2008). The objective is to deduce this genotype through the comparative analysis of multiple phenotypes, moving from the documentation of individual acts to the modeling of the cultural grammar they collectively express.

Space syntax as an analytical instrument

Space syntax was selected as the primary method because of its proven capacity to move beyond geometry and reveal the "social logic of space" (Hillier and Hanson, 1984). Its strength lies in quantifying the relationship between spatial configuration and social life. Its relevance for studying the socio-spatial logic of dwellings has been consistently demonstrated in contemporary research (Cunha, 2012) and validated across diverse global contexts (van Nes and Yamu, 2021). To operationalize this approach, a battery of syntactic indicators was deployed, systematically distinguishing for each its spatial logic (the measured property) from its social logic (its interpretation in terms of human interaction). Table 1 provides a synthetic definition of these indicators and their application in this study.

Spatial structure: Topology and space types

To operationalize the analysis, the architectural plans were first translated into justified graphs. Following the typological analysis principles outlined by Heckmann *et al.* (2018), the focus was on identifying functional zoning and circulation patterns within these graphs. This initial analysis seeks to understand the fundamental nature of circulation within the dwelling.

Spatial logic: It was determined as to whether the system is tree-like (acyclic, hierarchical) or ring-like (cyclic, networked). The distribution of space types (A, B, C, D) further characterizes this structure: Types A and B define linear sequences of control, while Types C and D create circuits of choice.

Table 1. Definitions and interpretations of Space Syntax indicators used in the analysis
(Source: Authors, 2025).

Indicator	Definition and calculation logic	Socio-spatial interpretation
Justified graph (Topology)	Represents the layout as a network of nodes (spaces) and edges (connections). Spaces are categorized by type: A (dead-end), B (passage), C (simple ring), D (complex ring).	Choice and flexibility: Tree-like (Types A+B): Enforces control and linear sequences. Ring-like (Types C+D): Offers route choices and spatial flexibility.
Mean Depth (MD)	The average number of topological steps required to reach all other spaces from a given root space.	Accessibility: A basic measure of isolation. High depth signifies a space that is topologically distant and often associated with privacy.
Integration (i) / RRA	A normalized measure of centrality based on Real Relative Asymmetry. It standardizes the Mean Depth relative to a theoretical system of the same size (Dk), allowing comparison across different buildings. Note: Integration (i) is the inverse of RRA.	Centrality and potential movement: The primary predictor of social interaction. High Integration (Low RRA): Identifies living cores and social hubs. Low Integration: identifies segregated zones (retreat/privacy).
Control Value (CV)	A local measure of connectivity. Each space distributes a value of 1 equally among its neighbors. CV is the sum of values a space receives.	Local power: Identifies spaces that govern local circulation. High CV (>1): indicates a strong distribution role (e.g., a "gatekeeper" hall or corridor controlling access to neighbors).
Difference factor (H / H*)	Based on Shannon's entropy, H measures the spread of integration values. H* normalizes this to compare systems of different sizes.	Differentiation: Quantifies the strength of the social code. Low H*: strong functional differentiation (structured/heterogeneous system). High H* (near 1): Functional ambiguity (homogeneous system).
Point Depth Entropy (PDE)	Measure of the distribution of visual depth from a single location (VGA).	Visual surveillance: Low PDE: indicates a space offering a strategic, unobstructed visual field over the system (high surveillance potential).
Clustering Coefficient (CC)	Measure of the inter-visibility (convexity) of the visual neighborhood (VGA).	Conviviality: High CC: Indicates a convex space where people can easily see each other, fostering static social interaction (gathering potential).

Social logic: A tree-like structure encodes a logic of control and segregation, typical of formal institutions. Conversely, a ring-like structure encodes a logic of choice, integration, and flexibility, fostering encounters and fluidifying social relations.

Social hierarchy: Centrality and control

This analysis measures the position of each space within the social system of the dwelling.

Spatial logic: Integration (i) was calculated, which quantifies topological centrality (mean depth from all other spaces), and Control (CV), which measures local dominance over immediate neighbors.

Social logic: Integration is a powerful predictor of human interaction (Penn *et al.*, 1998), identifying social hubs (highly integrated "warm" spaces) versus spaces of retreat (segregated "cold" spaces). Control, in turn, reveals the spatial "gatekeepers," the obligatory points of passage that govern circulation and surveillance.

Perceptual experience: Visibility Graph Analysis (VGA)

Finally, the visual experience of space was analyzed.

Spatial logic: Visibility Graph Analysis (Turner *et al.*, 2001) was used to measure visual permeability via Point Depth Entropy (PDE) and the convexity of the visual field via the Clustering Coefficient (CC).

Social logic: This approach reveals two key social properties. PDE identifies strategic surveillance points (low entropy) and visual refuges (high entropy), informing privacy management. The CC reveals potential "hearths" for

social gathering (high CC) and spaces of transit (low CC), allowing for an analysis of spatial conviviality (Bellal and Brown, 2003; Assassi and Bellal, 2016).

FIELD RESEARCH PROTOCOL: CONSTRUCTING THE ANALYTICAL CORPUS

The empirical research focuses on social housing estates in Tazoult, located in the Batna province of Algeria (Figure 1). Specifically, the study focuses on the "200 Logements" estate, commissioned by the OPGI (Office of Real Estate Promotion and Management) and delivered in 1984. This estate comprises a homogeneous set of 5-story buildings (Ground floor + 4), primarily consisting of 3-room (F3) apartments. To facilitate a rigorous comparative analysis, a stratified corpus was established encompassing three distinct phenotype families:

Designed phenotypes: This category includes the original architectural plans of two dominant social housing typologies: the standard public rental model (LSL) and the participatory model (LSP). Constructed between 1980 and 2000, these estates epitomize the standardized mass housing produced by the Algerian state.

Lived phenotypes: This core dataset is derived from an in-depth qualitative field study. Although an initial stratified sampling strategy targeted two major estates, privacy constraints necessitated a controlled snowball sampling procedure to access domestic interiors. Consequently, this method yielded a final sample of 150 units, selected to preserve variability across floor levels and orientations. Using a Grounded Theory approach (Glaser and Strauss,

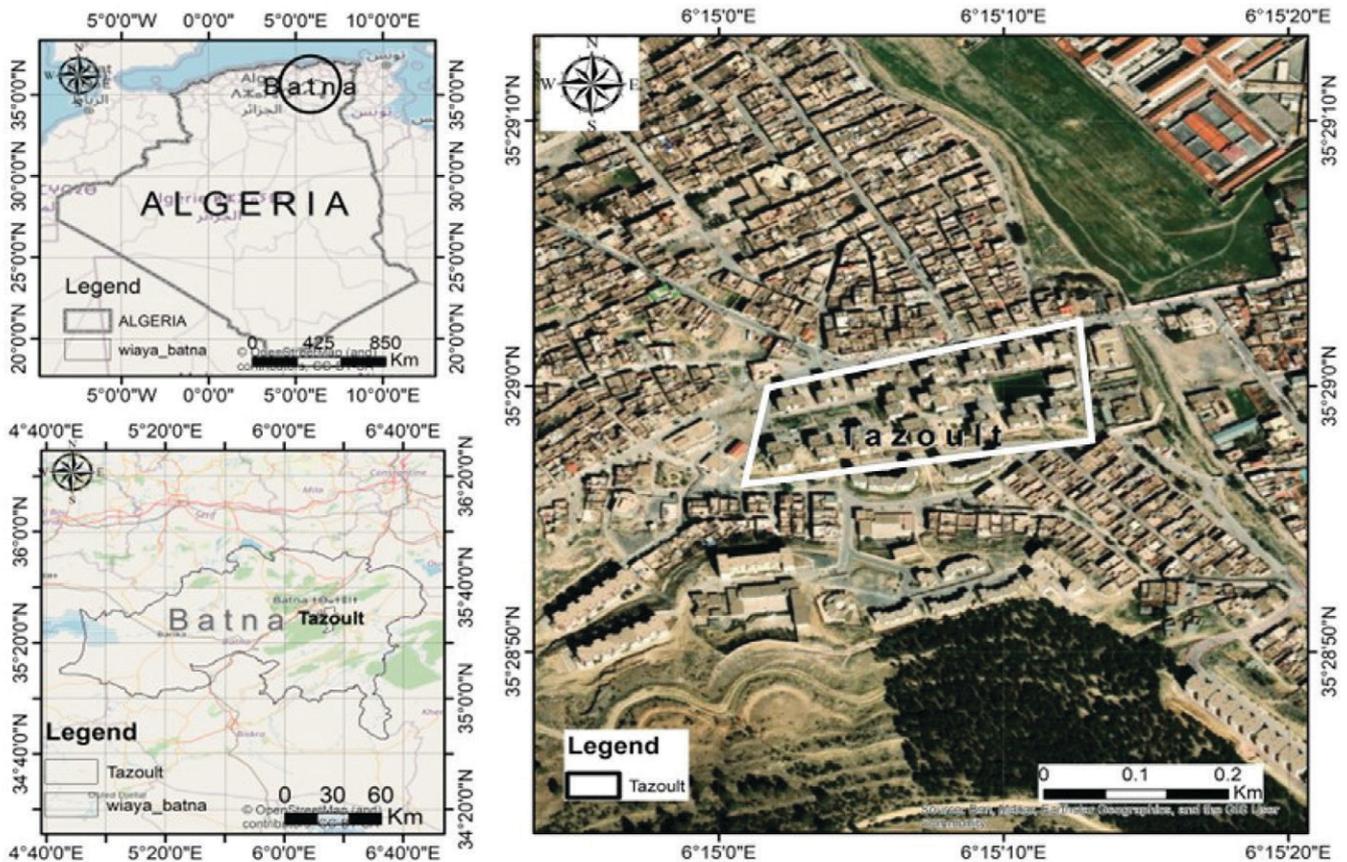


Figure 1. Geographic location of the study area
(Source: Authors, 2025)

1967), these data were distilled into 17 distinct lived phenotypes, which are synthetic models representing the most recurrent spatial transformations.

Benchmark phenotypes: To establish a cultural baseline, three traditional Aurès houses were included. This strategic inclusion made it possible to empirically test the hypothesis of convergence towards a vernacular genotype. Specifically, houses organized around the Ghorfat n'ilmas were selected.

Defining the vernacular model: The Ghorfat n'ilmas (or Hearth room)

The Ghorfat n'ilmas must be understood not merely as a specific room, but as a topological operator that forms the socio-spatial heart of the domestic genotype. Ethnographic studies define it as the symbolic and functional center of the house, which, through its composition, organizes the entire dwelling (Adjali, 2002). From a syntactic perspective, this space represents a unique configuration where convexity (occupation) and connectivity (movement) overlap. Unlike the standardized corridor-based layout typical of Algerian social housing, which serves purely for circulation, or the open courtyard found in other regions, the Ghorfat n'ilmas is an enclosed, highly integrated living space.

However, it is crucial to distinguish here between geometric centrality and functional centrality. As illustrated in the floor plans presented in Figure 2, the positioning of the Ghorfat n'ilmas varies: it may be located laterally adjacent to a courtyard or occupy a central position in dwellings without one. Yet, regardless of its location, it operates as the undisputed socio-

spatial core of the dwelling. Unlike the courtyard, which often acts merely as a light well or a transient space, the Ghorfat n'ilmas is the permanent hub for family gathering, dining, and social interaction, demonstrating that in the local genotype, centrality is defined by activity rather than geometry.

This variability in configuration is clearly observed in the appropriated dwelling plans. As demonstrated in Figure 2, two distinct variations of the Ghorfat n'ilmas layout are identified. In the first typology (a), found in dwellings with a central courtyard, the Ghorfat n'ilmas is located laterally to maintain privacy while opening onto the semi-private courtyard space. In the second typology (b), characteristic of dwellings without a courtyard, the Ghorfat n'ilmas shifts to occupy the central geometric position, acting directly as the primary distribution and gathering hub. In both cases, regardless of its specific geometric location, this room functions as the invariant socio-spatial core of the household.

A detailed analysis of the traditional Ghorfat n'ilmas further reveals that the adaptability of this local genotype relies on a sophisticated spatio-temporal logic. Functional divisions are not achieved through vertical walls, but through a subtle management of the floor plane using simple elevations or built-in benches that define specific zones without breaking visual integration. Unlike modern static rooms, the Ghorfat n'ilmas is defined not by a fixed function, but by the time of day. Its rhythms note the stages of daily life, shifting from periodic family gatherings around the hearth to women's cooking activities.

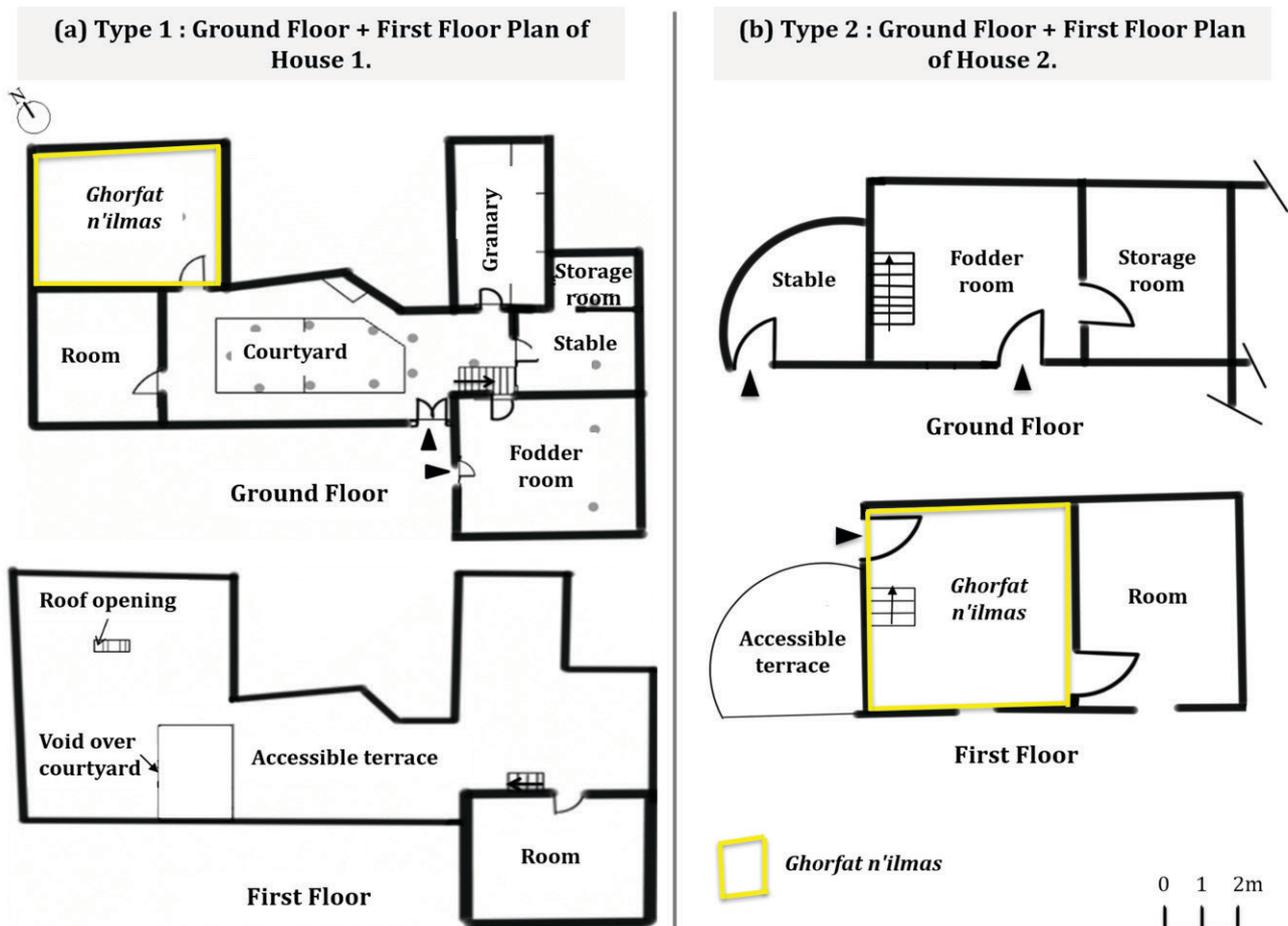


Figure 2. Appropriated dwelling floor plans showing two variations of the Ghorfat n'ilmas configuration (Source: Authors, 2025)

Based on this theoretical framework, this study hypothesizes that the spatial modifications observed in social housing represent a tacit attempt to retrieve this specific structure. Specifically, it argues that residents seek to re-establish a protected yet central social core within standardized plans that originally lacked one. This appropriation process can be visualized as a fundamental structural shift, as illustrated in Figure 3. The comparison highlights the transition from the initial designed genotype (a), characterized by a rigid, tree-like structure where a sterile corridor serves as the sole central integrator, to an emerging cultural genotype (b). In this appropriated configuration, a ring-like structure appears, and the central integrator shifts to a genuine living space (kitchen or living room), effectively mirroring the socio-spatial logic of the traditional Ghorfat n'ilmas.

Protocol synthesis

The proposed protocol applies space syntax tools across this entire corpus to systematically compare the configurational properties of each phenotype family. This comparative analysis is specifically designed to reveal the underlying logic of the "cultural rewriting" at play in the appropriation process.

RESULTS: A COMPARATIVE ANALYSIS OF CONFIGURATIONS

This section details the empirical findings of the comparative syntactic analysis, illustrating the transition from "designed" to "lived" layouts (Figure 4: (a) Designed Phenotype vs. (b) Lived Phenotype, showing the living room expansion). By systematically contrasting the configurational properties of "designed," "lived," and "traditional" phenotypes, this paper demonstrates the convergence of resident appropriations within the specific context of Batna towards an identifiable local genotype.

The analysis reveals a fundamental structural shift. While the designed models initially exhibit predominantly deep, hierarchical structures rooted in circulation spaces (even when minor rings exist), the lived phenotypes shift towards shallower systems through a rich diversity of strategies. These range from internal functional reorganization to create a central dining hub, to the creation of integrated open living cores, or the establishment of new connectivity loops linking the dwelling to its surroundings. This diversified connectivity strikingly mirrors the complex topological logic of the traditional reference.

Furthermore, the Visibility Graph Analysis maps the experiential qualities of the space and confirms a crucial shift: the potential for surveillance and social gathering

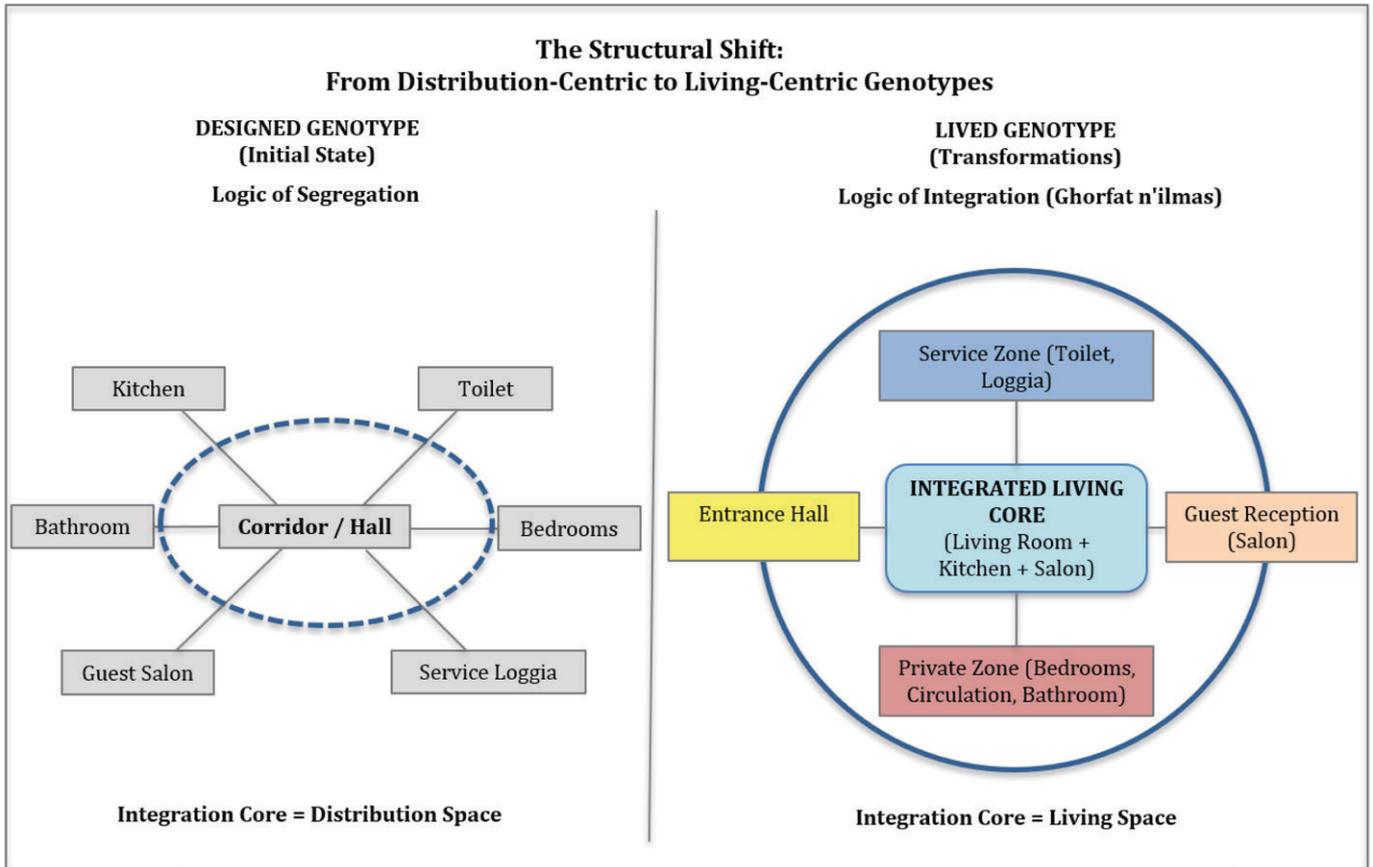


Figure 3. The Structural shift towards the Ghorfat n'ilmas logic
(Source: Authors, 2025)

migrates from the sterile circulation spaces of the initial design to the active living cores of the appropriated homes, effectively recreating the socio-spatial logic of the traditional Ghorfat n'ilmas.

Interpreting the shift: Introverted centrality

Crucially, the central living space emerging from these transformations represents a unique socio-spatial hybrid. Geometrically, it occupies the central position traditionally

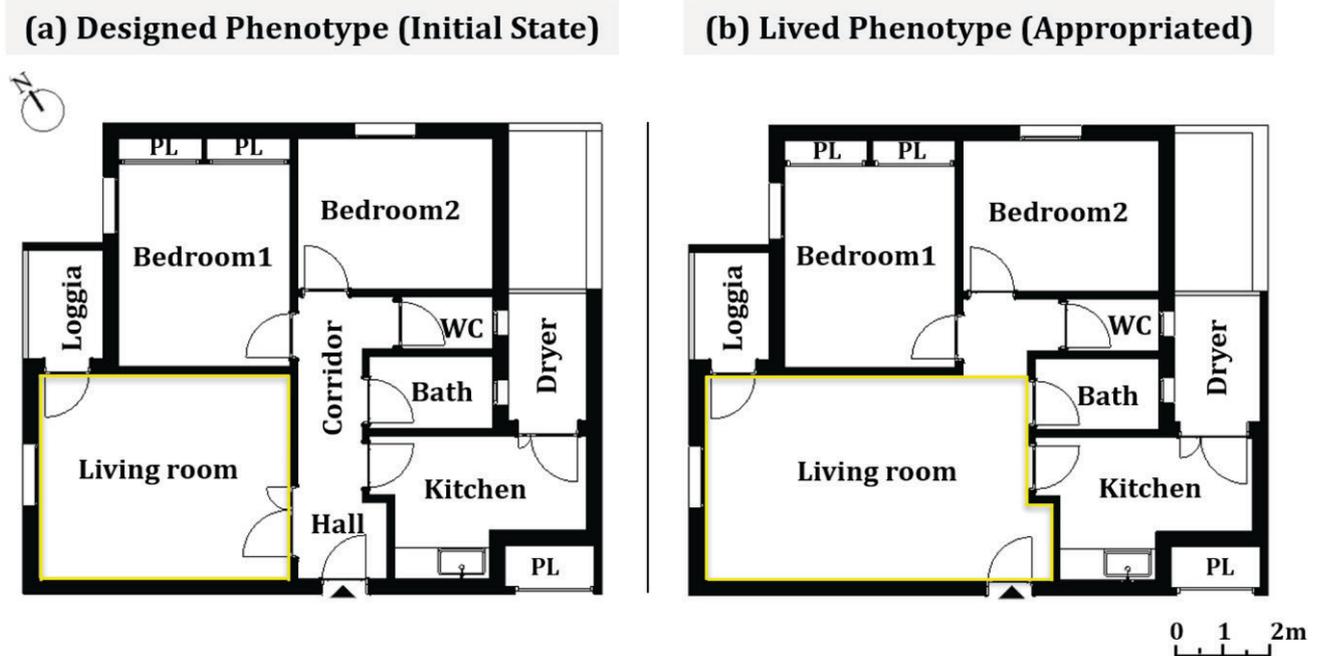


Figure 4. Floor plan comparison illustrating the configurational shift in the LSP model
(Source: Authors, 2025)

held by the courtyard, organizing circulation around it. However, functionally and climatically, it operates as a Ghorfat n'ilmās: an enclosed, protected, and polyvalent living core. This distinction is vital to separate it from the generic modern open plan. While both favor spatial integration, their syntactic logic differs. The modern open plan often seeks spatial continuity and transparency towards the exterior (extroverted). In contrast, this local genotype creates an *introverted centrality*: the living space is highly integrated to facilitate family gathering, yet it remains topologically deep or protected from the entrance to preserve the sanctity of private life. Residents do not seek unstructured openness; they construct a hierarchical openness that balances social interaction with strict privacy control.

Rejecting the tree: The systematic quest for ring-like structures

The primary investigation targeted the plan's most fundamental characteristic: its topology.

Spatial logic (empirical evidence)

The analysis of justified graphs reveals a pronounced and unambiguous trend (Table 2), highlighting a radical dichotomy between designed models and their lived or traditional counterparts. Precisely, the specific designed phenotypes analyzed in Batna encompassing both LSL and LSP typologies are consistently exhibited on a purely tree-like (arborescent) structure. In contrast, a substantial majority of lived LSL phenotypes (77%) disrupt this logic by introducing at least one ring structure (internal, external, or complex). This feature is not incidental; it is systematically present in 100% of the traditional phenotypes.

This structural shift is further corroborated at the level of elementary components. While designed plans rely exclusively on Type A (destinations) and Type B (obligatory passages), resident transformations foster the significant emergence of Type C (simple circuits) and Type D (complex circuits), which are the fundamental building blocks of ring topologies.

Social logic (interpretation)

This topological reconfiguration signifies more than a technical adjustment; it evidences a collective rejection

of the initial standardized layout. The tree-like structure, encoding a logic of control and segregation, is systematically deconstructed by residents. By introducing rings, they embed choice and fluidity into the spatial system. This is not mere sophistication but a response to specific social imperatives, such as segregating guest and family circulation paths, refining privacy management, or simply streamlining daily life. Residents effectively modify the spatial configuration to increase connectivity and integration values within the dwelling.

The case of LSP housing offers a critical counterpoint. Constrained by the absence of residential ground floors, LSP transformations failed to generate external rings, resulting in the persistence of tree-like structures. This confirms that the quest for flexibility is often contingent upon the capacity to renegotiate the dwelling's interface with its environment.

Synthesis

Consequently, this quantitative analysis demonstrates that resident modifications are neither random nor chaotic. They follow a clear trajectory towards greater integration, converging strikingly with the ring-based logic of traditional housing. The first indicator of the local genotype is thus established: the primacy of the ring.

Shifting the social core: the primacy of living space over distribution

Having examined the global topological structure, the second analysis interrogates the internal hierarchy of the dwelling. This phase compares indicators of centrality (Integration *i*) and dominance (Control *CV*) across each phenotype family to map the distribution of socio-spatial power.

Spatial logic (empirical evidence)

The analysis reveals a radical reconfiguration of the dwelling's "core". Table 3 synthesizes the mean indicators and, crucially, identifies the space type that consistently functions as the integration hub.

Two findings emerge from this data. First, lived phenotypes exhibit a higher degree of global integration (lower mean RA) compared to their designed counterparts. A granular analysis confirms that this improvement is primarily

Table 2. Comparison of topological structures by phenotype family
(Source: Authors, 2025)

Phenotype family	Tree-like topology (arborescent)	Ring-like topology (internal, external, or complex)
LSL (designed)	100%	0%
LSL (lived)	23%	77%
LSP (designed)	100%	0%
LSP (lived)	100%	0%
Traditional benchmark	0%	100%

Table 3. Comparison of mean syntactic indicators and the integration core by phenotype family
(Source: Authors, 2025)

Phenotype family	Mean relative asymmetry (RA)	Most integrated space (system core)
Designed phenotypes	0.30	Distribution space (corridor/hall)
Lived phenotypes	0.29	Active living space (living room/kitchen)
Traditional phenotypes	0.31	Central living core (courtyard/Ghorfat n'ilmās)

driven by LSL transformations where ring structures were successfully introduced. Second, and most significantly, the nature of the integration core undergoes a fundamental shift. In designed plans, the core is invariably a space of pure distribution (corridor/hall). In lived plans, this core migrates to a genuine living space (living room/kitchen), aligning perfectly with the logic of the traditional model where the courtyard or Ghorfat n'ilmas serves as the central hub.

Social logic (interpretation)

This structural shift constitutes a compelling indicator of the emergence of an alternative genotype. The standardized layout of the analyzed social housing units subordinates social life to circulation; its structural core effectively functions as an internal corridor. The observed transformations systematically reduce this dominance of transit. By reconfiguring their homes, they reposition living spaces at the center of the spatial configuration, creating a central hub for social interaction. This reconfiguration prioritizes spaces of social interaction over purely functional circulation areas. The detailed analysis uncovers two distinct strategies for this recentring: the elevation of the kitchen as the hub of informal daily life, and the promotion of the living room as the locus of formal reception.

However, this drive for integration does not compromise privacy. Analysis of Control (CV) values indicates that circulation spaces retain high control over access to private zones across all phenotypes.

Synthesis

Consequently, the second and third rules of the local genotype are established. Rule 2: The system's core must be a space for living and gathering, not merely distribution. Rule 3: This integrated core must articulate with a segregated, controlled private zone. Residents are thus engineering a sophisticated balance between social integration and the protection of intimacy.

Heterogeneity and perceptual experience: refining the genotype

To refine the modeling of the genotype, two complementary analyses were conducted focusing on spatial diversity and visual perception. Table 4 presents the synthesized mean indicators supporting this investigation.

The quest for structured heterogeneity (H* Analysis)

Spatial logic (empirical evidence)

As indicated in Table 4, H* values remain consistently low and stable across all LSL/LSP models, confirming the persistence of strong spatial heterogeneity. The traditional

model, with a significantly higher value (-0.22), exhibits greater configurational polyvalence.

Social logic (interpretation)

This persistence suggests that residents are not seeking undifferentiated or homogenized spaces. Conversely, they actively maintain a clear differentiation of social roles within the domestic environment. The fourth rule of the local genotype is thus defined: the system must be heterogeneous, offering a clear articulation of varying degrees of intimacy and functional distinction.

Synthesis

This specific finding is crucial for defining the complete social logic of the dwelling. While residents actively seek integration (Rules 1 and 2), they explicitly reject spatial confusion. By maintaining low H* values, they reaffirm Rule 4: the necessity of a structured heterogeneity. This validates the dialectic identified in Rule 3 (integration/segregation), demonstrating that the local genotype is a sophisticated system that balances the fluidity of the day-zone with a strict, readable hierarchy of privacy for the night-zone. Taken together, these analytical findings ranging from topological shifts to hierarchical inversions reveal the emergence of a coherent spatial logic that modern open plans often fail to capture.

The quest for visual co-presence (VGA analysis)

Spatial logic (Empirical evidence)

Table 3 reveals a clear convergence in visibility indicators. Quantitative data indicates that lived phenotypes (LSL CC=0.821; LSP CC=0.813) significantly enhance their performance in terms of Gathering Potential (CC), achieving levels nearly identical to the traditional benchmark (0.828). A parallel trend of improvement is observed for Strategic Visibility (PDE). Qualitative analysis of the visibility maps clarifies the mechanism behind this gain: it results from a systematic displacement of the most performant visual zones (low PDE and CC values) from the transit spaces of designed plans to the central living spaces of lived and traditional phenotypes.

Social logic (interpretation)

Residents reconfigure their dwellings to ensure that internal "public square" loci of gathering and informal social control coincide with primary living spaces. Consequently, the fifth rule of the genotype is established: the social and visual core of the dwelling must be a living space, facilitating both co-presence and a continuous awareness of domestic activity.

Table 4. Comparison of mean indicators of diversity and visual perception by phenotype family
(Source: Authors, 2025)

Phenotype family	Mean relative difference factor (H*)	Mean point depth entropy (PDE)	Mean clustering coefficient (CC)
LSL (designed)	-0.33	1.79	0.834
LSL (lived)	-0.36	1.69	0.821
LSP (designed)	-0.33	1.51	0.854
LSP (lived)	-0.32	1.59	0.813
Traditional benchmark	-0.22	1.41	0.828

Synthesis

These quantitative trends that drive for a more integrated system anchored by a central living space strongly suggest a convergence towards the properties inherent in traditional housing. To structurally confirm this hypothesis, a final visual analysis was performed using abstracted graphs, demonstrating the recreation of the Ghorfat n'ilmas logic.

Visualizing convergence: the Ghorfat n'ilmas as a genotypical model

To synthesize and visualize the convergence of social logics, a final comparative analysis was conducted using abstracted justified graphs. This method re-categorizes spaces based on their primary social function. To facilitate visual comparison, spaces were categorized by social activity following a coding schema adapted from housing analysis typologies (Heckman et al., 2018; Nishihara, 1968). The nodes were labeled as follows: Exterior space (E), Collective social space like the immediate vicinity (C), Semi-collective social

space like landings and stairwells (SC), Transition space like the entrance hall (T), Reception space like the guest salon (R), Service space including kitchen and bathrooms (S), Family space like the living room or Ghorfat n'ilmas (F), and Intimate space for bedrooms (I). This abstraction facilitates a direct comparison of the 'social syntax' across divergent phenotype families.

Spatial logic (empirical evidence)

Figure 5 represents a comparative analysis of abstracted justified graphs through a selection of representative cases. As can be observed, the matrix illustrates a distinct configurational shift from the rigid, tree-like structures of the designed models (left column) to the ring-like, integrated structures of the lived transformations (right column). In these graphs, the dotted line marks the threshold of the domestic sphere. Crucially, the emergence of rings in the lived phenotypes highlights a morphological convergence towards the vernacular model (bottom row).

Phenotype family	The "designed" phenotype (rigid model)	Representative "lived" phenotypes (adaptive solutions)			
Public rental housing (LSL)	<p>Rigid hierarchy</p>	<p>Constrained transformation</p>	<p>Creation of a simple ring</p>	<p>Creation of complex network</p>	
Participatory social housing (LSP)	<p>Linear depth sequence</p>	<p>Internal reorganization</p>	<p>Creation of a social filter</p>		
Traditional reference	n/a	<p>The "Ghorfat n'ilmas" model (central living core)</p>			

Figure 5. Comparative analysis of abstracted justified graphs by social function (Source: Authors, 2025)

Social logic (interpretation)

The visual evidence in Figure 5 corroborates the quantitative findings, revealing a process of spatial reconfiguration driven by cultural patterns (Rapoport, 1969) unfolding in three distinct phases:

- **Designed logic:** Designed phenotypes consistently exhibit a linear, hierarchical, tree-like structure. The underlying social syntax is characterized by linear distribution and functional separation.
- **Lived logic:** Lived phenotypes demonstrate a systematic rupture from this model. Residents explore diverse solutions, ranging from constrained adaptations that merely complicate the tree structure to the creation of simple or complex ring topologies. The social syntax shifts towards flexibility and enhanced social integration; and
- **Convergence with the traditional model:** The logic of the most successful lived phenotypes converges remarkably with the traditional benchmark. Crucially, this benchmark was strategically selected: it is organized not around an open courtyard, but around a large, polyvalent central living space the Ghorfat n'ilmas (polyvalent central hearth). This space functions as an interior hearth, a spatial form directly comparable to the integrated living room/kitchen of a modern dwelling.

Synthesis: The Ghorfat n'ilmas as the archetype of the local genotype

The Ghorfat n'ilmas embodies the precise social logic of centrality manifest in residents' transformations, where the living room or kitchen assumes the role of the dwelling's core. This finding is pivotal: it demonstrates that the fundamental principle of the local genotype is not merely a courtyard, but rather a large, covered, and integrated interior living space. The Ghorfat n'ilmas thus serves as the historical and cultural validation of the contemporary resident's spatial quest.

Ultimately, this visual analysis provides definitive proof of the central argument. Residents are not merely displacing or moving walls; they are rewriting the syntax of relations between social functions. They are transitioning from a model of hierarchical segregation to one of networked integration, attempting to recreate the logic of the Ghorfat n'ilmas as the heart of social life within the constraints of the imposed standardized phenotype.

DISCUSSION

Modeling the social and spatial genotype

The findings from the comparative analysis demonstrate that the transformations undertaken by residents in Batna are not random disorder, but a coherent cultural pattern. This discussion synthesizes these findings to extract their primary significance: they constitute empirical evidence of a deliberate cultural rewriting of space.

The convergence of phenotypes: Transitioning from standardized layouts to culturally adapted configurations

Analysis has revealed three convergent trends of striking clarity:

- **Topological rupture:** Residents systematically reject the tree-like structure of designed plans in favor of circulation rings, thereby prioritizing flexibility of movement;
- **Shift in the social core:** The dwelling's center of gravity migrates from spaces of distribution (corridors) to genuine living spaces (living room or kitchen), subordinating circulation to social life; and
- **Dialectic of balance:** While integrating spaces, the transformations maintain a high degree of functional differentiation and a clear protection of the private sphere, consistent with the logic of traditional housing.

In sum, residents are rewriting their dwellings according to a spatial grammar that is radically distinct from the designed genotype. A significant finding of this analysis is that this new grammar is not a novel invention, but a cultural retrieval.

This comparative analysis with traditional housing reveals that the residents' quest for a large, central, and integrated living space is a contemporary recreation of the socio-spatial logic of the Ghorfat n'ilmas the polyvalent central hearth of the traditional Aurès home. This vernacular model, much like the transformed living room, acts as the integrated pivot organizing all domestic life. Therefore, the observed convergence is not merely a trend towards generic open layouts; it suggests the persistence of a spatial preference for centralized living configurations. This process goes beyond simple renovation; it represents a reconfiguration of the spatial syntax, shifting from a model of hierarchical segregation to one of networked integration, in an attempt to recreate the logic of the Ghorfat n'ilmas within the imposed standardized phenotype.

Modeling the local genotype: Five principles for a relevant design framework

The convergence of empirical trends towards the logic of the Ghorfat n'ilmas enables the modeling of the sought-after social and spatial genotype. This model is not a rigid standard plan, but a set of five configurational principles that constitute its grammar. This modeling represents the central contribution of this paper; it gives an objective voice to the resident's cry for adaptability and transforms qualitative needs into an evidence-based design framework:

Primacy of the ring (Flexibility of paths)

- **Theory:** The systematic shift from tree-like to ring-like graphs in lived phenotypes indicates a critical need for multiple circulation routes and spatial fluidity.
- **Architectural application:** Architects must move away from rigid, corridor-based distribution. Instead, floor plans must offer potential connections between adjacent living spaces (e.g., via knock-out panels or double doors connecting the kitchen to the living room). This enables residents to activate circular circulation

rings when needed, mimicking the fluid flow of the traditional courtyard house.

The centrality of the living space (Social hierarchy)

- **Theory:** The lived graphs reveal that the living area consistently becomes the most integrated node, replacing the corridor.
- **Architectural application:** Future layouts should reposition the main living area as the gravitational center of the home, to be a high-integration hub rather than a segregated room. This space must act as the primary distributor, directly controlling access to peripheral zones to minimize spatial depth and maximize social interaction.

The dialectic of integration and segregation (Control of intimacy)

- **Theory:** The local genotype demands a paradox: high integration in the day zone for social fluidity, but strict structural segregation for the night zone to preserve privacy.
- **Architectural application:** Designs must incorporate a dynamic management of privacy. The boundary between the semi-public reception zone and the private family sanctuary must not be static. Partitions should be designed for adaptability, allowing this cultural buffer zone to expand or contract. This enables gendered privacy to be activated temporarily during visits without permanently fragmenting the home's unity.

Structured heterogeneity (Differentiation of roles)

- **Theory:** Spaces must not be generic; the depth of the layout must clearly reflect distinct social roles.
- **Architectural application:** The depth of the layout should unambiguously differentiate between guest spaces (shallow, accessible) and family spaces (deep). This can be achieved by creating a transitional vestibule that allows direct access to a guest reception area without penetrating the family core.

Visual co-presence (Social control through visibility)

- **Theory:** Low entropy values in transformed plans indicate a strong desire for visual mastery and passive awareness of the domestic space.
- **Architectural application:** Layouts should prioritize diagonal sightlines and wide openings between day-spaces (kitchen/living/hall). This facilitates passive surveillance and social connection, favoring visual continuity rather than compartmentalizing functions behind solid walls.

Summary of the model

This model provides quantitative evidence that the appropriation of social housing is not a chaotic process, but a coherent pattern of spatial adaptation. The analysis shows that residents modify the initial standardized configuration to increase spatial integration and connectivity, aligning the layout with specific local usage patterns. This adaptation process reflects a dynamic reinterpretation of tradition rather than mere nostalgia (Rapoport, 1969); as the Ghorfat n'ilmas model demonstrates, it is the recreation of an enduring socio-spatial logic that prioritizes the integrated living core as the heart of domestic life. This research thus

transforms a cultural intuition into a verifiable, evidence-based framework for design.

Contribution to the literature and global implications

These findings resonate with, and substantially enrich, the existing literature on housing appropriation and adaptable architecture, extending the debate within the context of Algerian social housing.

First, this study quantitatively substantiates the qualitative observations of local scholars such as Tebib (2008), Mezrag (2015), and Mouaziz-Bouchentouf (2014) regarding the transformative nature of Algerian social housing. However, by employing Space Syntax, this research moves beyond mere documentation to reveal the underlying structural logic of these alterations. This responds directly to long-standing calls for more analytical approaches in post-occupancy evaluation (Vischer, 2002). Furthermore, the results provide strong empirical support for the phenomenon of genotype retrieval as a widespread mechanism of the informalization of the formal. The structural conflict observed in Batna mirrors resident-led modifications documented in diverse mass housing contexts, from Cairo (Shehayeb, 2009) to Latin America (Kellett and Napier, 1995). In all these cases, residents are not merely adding space; they are fundamentally re-wiring the topological logic of the home, transforming the imposed tree-like structure of the initial plan into a ring-like structure that mirrors traditional spatial continuity. This confirms Rapoport's (1972) foundational hypothesis: residents practices aim to reintroduce the configurational principles of a deep-seated cultural model into the standardized dwelling.

Second, these findings engage critically with contemporary theories of adaptability, particularly the framework established by Schmidt and Austin (2016). While these authors argue that adaptability should be an inherent design characteristic deliberately embedded within the building's layers, the Algerian case presents an inverted scenario. Here, although the structural system (column-beam) allows for potential flexibility, the initial spatial layout was designed with high rigidity and minimal adaptability options. Yet, the sheer scale of transformations demonstrates that the cultural genotype acts as a driver far more powerful than the physical constraints of the built form. In the absence of what Schmidt and Austin define as planned adaptability, residents resort to forced adaptation, modifying the standardized layout to accommodate evolving household needs and usage patterns. This leads to a pivotal conclusion: in many developing contexts, adaptability is not a technical luxury, but a survival strategy imposed by users to reconcile the acute mismatch between a static built environment and their evolving socio-cultural needs.

Finally, the implications for policy and future design are significant. The resilience of the Ghorfat n'ilmas logic confirms a phenomenon of cultural persistence (Kent, 1990; Oliver, 1987) that must be integrated into architectural practice. The goal should no longer be to design the perfect finished phenotype, but rather an open genotype. This approach resonates with Habraken's (1972) Open Building principles, but with a crucial nuance: the support

must not be culturally neutral. It must be informed by the specific topological deep structures such as the ring-like circulation that users inevitably seek to recreate. Consequently, the modeling of this local genotype becomes a vital tool for designing a new generation of sustainable housing. By linking cultural relevance directly to long-term environmental and economic sustainability (Mlote *et al.*, 2024), this research offers a concrete path towards housing that is resilient precisely because it is culturally grounded.

CONCLUSIONS

This research began with the premise that the apparent disorder of transformations in Algerian social housing concealed a deep order, a cultural logic striving to assert itself against a rigid built form. The objective of this paper was to decode this logic through rigorous quantitative analysis. At the conclusion of this investigation, the hypothesis has been unequivocally validated.

This study demonstrates that residents' appropriations are not random interventions but systematic convergences towards an identifiable configurational model. The primary contribution of the study is, therefore, the first quantitative modeling of a socio-spatial genotype for housing in this context. The analysis proves that residents do not merely correct their dwellings; they rewrite them according to a spatial grammar of their own, transitioning the home from a standardized system for segregation to a vernacular system for connection. The most illuminating discovery is the identification of this genotype as a contemporary recreation of the socio-spatial logic of the Ghorfat n'ilmas the polyvalent central hearth of the traditional Aurès home. By rejecting the dominance of corridors in favor of a large, integrated living core, residents intuitively reintroduce the principle of centrality that lies at the heart of their housing culture.

The implications of this discovery are profound. First, it demands a paradigm shift for designers and policymakers: the focus must shift from designing the perfect, finished phenotype to designing open genotypes spatial systems that integrate, from the outset, the principles of flexibility and centrality that residents inevitably seek to recreate. Second, the proposed model provides an objective, evidence-based foundation to inform these new designs, transforming cultural intuition into a verifiable framework.

While the specific findings are local to Batna, the methodological framework developed here is transferable. Future research could fruitfully apply this syntactic analysis to other contexts of social housing appropriation, allowing for a comparative understanding of how residents adapt standardized spaces to diverse cultural needs.

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QUANTUM URBANISM AND THE NFT NEXUS: REDEFINING VIRTUAL LAND VALUE IN DECENTRALIZED CITIES

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The intersection of quantum urbanism and non-fungible tokens (NFTs) offers a new paradigm for remapping urban futures, wherein digital and physical realms merge into dynamic, decentralized ecosystems. This article examines how quantum computing, by applying principles such as superposition and probabilistic optimization, can simulate extremely intricate urban systems, from energy networks to traffic patterns, with unprecedented efficiency. Meanwhile, NFTs are transforming the notion of virtual land ownership, allowing decentralized control and hybrid economies that bypass geographical constraints. By integrating these domains, cities can become vibrant spaces where quantum algorithms optimize virtual land value, and NFT-based platforms democratize urban development. However, this transformation poses fundamental challenges: the energy consumption of quantum-blockchain infrastructures risks compromising sustainability goals, while algorithmic opacity and digital divides risk reproducing historical inequalities in virtual realms. Ethical governance policy and principles must concentrate on renewable energy integration, algorithmic transparency, and fair access to prevent exploitation. Drawing from emergent metaverse economy trials and quantum urban simulations, the paper argues that such a nexus would be capable of driving Sustainable Development Goals (SDGs), namely SDG 9 (innovation), SDG 11 (sustainable cities), and SDG 17 (partnerships) if they are premised on participatory design and cross-sectoral collaboration.

Key words: quantum urbanism, NFT, virtual, land, decentralized cities.

INTRODUCTION

Urban planning's history has long been inextricably linked to the material, physical world, where infrastructure, zoning laws, and socio-economic pressures shape cities in the traditional sense. The 21st century has heralded a paradigm shift, however, driven by the rapid digitization of human existence and the rise of decentralized technologies. This has dissolved the boundary between the physical and virtual worlds, creating unparalleled opportunities and dilemmas for the rethinking of urbanism. At the confluence of this revolution are two innovative ideas: quantum urbanism, which uses quantum computing to streamline intricate urban systems, and non-fungible tokens (NFTs) (unique

digital certificates of ownership stored on a blockchain), which are transforming ownership and value creation in virtual worlds. In combination, these technologies disrupt traditional ideas of land use, governance, and economic fairness, providing a template for cities that transcend the limitations of physical geography.

Alvarez León and Rosen (2024) discuss the evolving understanding of land in line with virtual worlds such as the Metaverse, pointing out that virtual land is now a critical element in contemporary economies and social orders. The emergence of virtual worlds from blockchain metaverses like Decentraland to AI-emulated cityscapes has made "virtual land" a scarce, exchangeable commodity. Non-fungible tokens (NFTs), as digital certificates of ownership that are one-of-a-kind, have opened up a speculative but revolutionary market for such assets, allowing individuals and institutions to monetize creativity, governance rights,

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and even algorithmic decision-making in decentralized urban settings. This is reflected in contemporary discussions on the potential of decentralized digital assets to enhance new governance frameworks in urban planning (Alvarez León and Rosen, 2024).

Meanwhile, quantum urbanism promotes a revolutionary rethinking of urban planning through the use of quantum algorithms that can efficiently model hyper-complex systems such as energy networks and traffic flows, displaying an unparalleled degree of efficiency (Marchesin *et al.*, 2023). Such applications greatly enhance the capacity of urban planners to address complex urban issues and enhance the allocation of resources, underscoring the urgency for creative solutions in rapidly evolving urban settings (Giraldo-Quintero *et al.*, 2022). Current discourse around digital urbanism has a tendency to separate technological innovation from environmental management or socio-political equity. This work bridges the gap by proposing an interdisciplinary framework that combines the computational power of quantum urbanism with NFT-driven economic models to enable inclusive, sustainable, and resilient cities. Through case studies of nascent metaverse economies and quantum computing initiatives in urban planning, we contend that the intersection of these domains can democratize access to urban development, speed up achievement of the Sustainable Development Goals (SDGs), especially SDG 9 (Industry, Innovation), SDG 11 (Sustainable Cities), and SDG 17 (Partnerships), and reinvent wealth creation in a post-physical economy.

Nevertheless, this perspective necessitates immediate examination of the deficiencies in governance, energy usage, and disparities in digital access, in order to prevent the reproduction of past injustices in novel, algorithmically influenced manifestations. By critically analyzing these conflicts, this viewpoint seeks to stimulate an international conversation about reconciling technological aspirations with the fair and ecological necessities of future urban environments.

The research design for this study is classified as exploratory and integrative. Rather, the research will integrate understandings gleaned from a critical review of emergent literature at the nexus of Quantum Computing, Urban Studies, and Blockchain Economics. A cursory bibliometric survey of Scopus and Web of Science databases for the last decade reveals a rapidly growing but still niche body of literature, with sharp increases in publications on ‘smart cities’ and ‘blockchain’, and nascent but rising interest in ‘quantum computing’ applications for urban systems. The research is structured by way of conceptual triangulation, leveraging peer-reviewed scholarly literature, case studies of emergent economies within the Metaverse (Decentraland) and Quantum Computing pilot projects focused on urban planning. The research design and intentions do not seek to test a particular hypothesis but instead to develop a cohesive framework for multiple disciplines and to discern emergent opportunities and challenges for future urban development.

QUANTUM URBANISM: PRINCIPLES AND APPLICATIONS

Quantum urbanism is a radical break with conventional urban planning models, incorporating principles of quantum computing superposition, entanglement, and probabilistic optimization to envision and organize cities as adaptive, dynamic systems. Departing from classical models based on linear frameworks, quantum urbanism acknowledges and embraces uncertainty and complexity and views urban space as web-like networks of energy, information, and human activity. Quantum computing has the ability to simulate scenarios that are computationally expensive for classical systems, allowing, for example, the optimization of energy usage across a city in real time with changing demand or the prediction of traffic flows based on numerous interconnected variables. Quantum annealing has been proposed as a method of optimizing land-use priority blending housing density, parks, and commercial zones by testing numerous permutations more efficiently than classical models (Krantz *et al.*, 2019; Hassija *et al.*, 2020). Quantum urbanism applications extend beyond efficiency; they revolutionize the way cities learn and evolve. Urban infrastructure might autonomously respond to crises, such as climate disasters or pandemics, through quantum machine learning. For example, a self-reconfiguring power grid in the face of a heatwave in a matter of milliseconds can redistribute energy to impacted neighborhoods and remain stable; or a public transportation system can anticipate alterations in commuter patterns amidst a flood based on weather sensor information, social media, and IoT devices. These systems should not be viewed as static infrastructures but as dynamic ecosystems that reflect the probabilistic nature of quantum states (Helbing *et al.*, 2024; Preskill, 2018; Gonçalves *et al.*, 2024).

Secondly, the new paradigm favors democratic decision-making. Quantum technology platforms have the ability to merge vast amounts of citizen feedback in real time, building consensus-based urban policies that align with various community agendas instead of merely following the majority rule doctrine (Thompson and Lorne, 2023; Jiang *et al.*, 2022a). The aspirations of quantum urbanism are confronted by serious practical and ethical hurdles that must be addressed to reach their complete potential. The technology for quantum computing is in its early stages, with poor qubit stability and scalability, which provokes essential questions regarding the potential implementation of such systems in resource-scarce urban settings (Xu *et al.*, 2023). This points to a wider problem in the urban governance structures regarding whether cities are able to implement advanced technologies in an effective way, particularly where infrastructure is absent or non-existent (Criqui, 2015).

Furthermore, fears about the lack of transparency of quantum algorithms refer to the risk of “black box urbanism”, in which decision-making is not transparent and accountable (Robins and Baumgardt, 2024). This kind of transparency deficiency may result in skewed outcomes, especially if the data used at the core of model development are not adequately verified for fairness and representativeness. For example, a quantum model for maximizing economic efficiency may overlook the requirements of marginalized

groups and exacerbate differences in the urban resource distribution that already exist (Voskamp *et al.*, 2017). This relates back to arguments in the literature concerning the nexus between socioeconomic factors and urban planning decisions, which are employed to reproduce or resist urban inequalities (Liang *et al.*, 2023).

VIRTUAL LAND AND NFTS: A NEW ECONOMIC PARADIGM

The concept of land ownership has been significantly altered due to advances in virtual worlds and blockchain. Virtual land, represented by digital parcels on metaverse platforms, is a new asset class that leverages non-fungible tokens (NFTs) to verify ownership and facilitate global transactions. In contrast to physical real estate, which is limited by geographical physicality, virtual land exists in a world of code where value is derived from algorithmic proximity, platform compatibility, and the possibility of rich experiences, such as digital shopping spaces and participatory cultural activities (Alvarez León and Rosen, 2024). NFTs provide transparent and immutable ownership records, allowing open access to this emerging market. They enable a range of actors ranging from individuals, businesses, and decentralized autonomous organizations (DAOs) to speculate, create, and monetize virtual assets. This is attested to by the rise of virtual art museums within blockchain-based metaverse platforms, which serve as places for NFT artwork exhibition, the hosting of global conferences, and experimentation with user-driven economies that merge entertainment and commerce (Nurjaman *et al.*, 2022).

Yet the boom in NFT virtual real estate raises pressing questions about equity and sustainability. As open as the metaverse is touted to be, access is organized around technological literacy, cryptocurrency, and energy grid capacity. The energy cost of blockchain transactions, particularly proof-of-work protocols, contradicts the sustainability goals many virtual environments commit to. Furthermore, the lack of regulatory frameworks for virtual land has generated speculative bubbles, where prices become detached from utility, a phenomenon dating back to earlier land rushes, but driven by global, 24/7 markets. However, experimental projects are closing these gaps. Solar-powered blockchain networks, for example, are reducing carbon footprints, while DAOs are experimenting with redistributive models, such as setting aside land NFTs for public goods or subsidizing access for marginalized communities. These developments suggest a future in which virtual land economies may play a role in achieving Sustainable Development Goals (SDGs) 9 (infrastructure development of the digital kind) and SDG 11 (making communities inclusive), depending on whether they prioritize ethical design over profit-making extraction. Finally, the relationship between NFTs and virtual land is more than a simple financial innovation; it is a model for remapping ownership, governance, and value creation in an increasingly digitized urban space in an age when the lines between physical objects and digital copies blur, allowing every person to shape the cities of tomorrow, pixel by pixel.

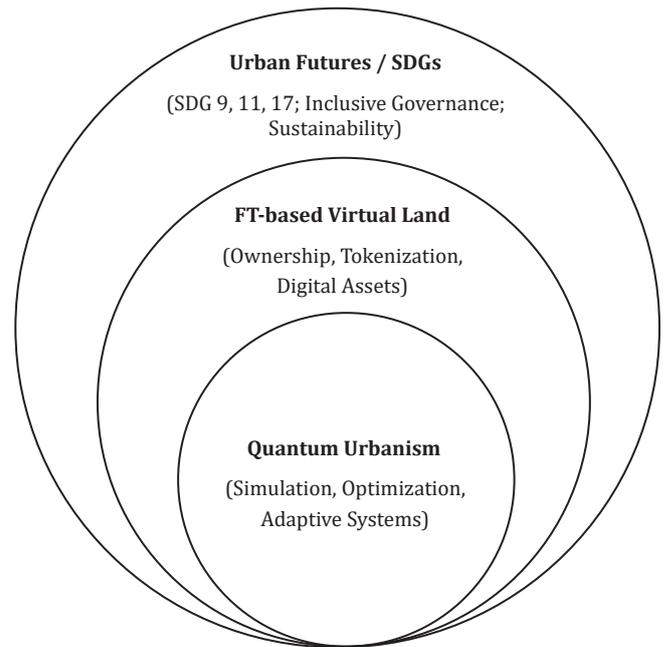


Figure 1. Conceptual framework: Intersection of quantum urbanism and NFTs in shaping urban futures

Figure 1 shows a conceptual visualization of the synergistic integration between quantum urbanism's computational power and NFT-based ownership models, driving towards sustainable and inclusive urban futures aligned with key Sustainable Development Goals.

SYNTHESIS: BRIDGING QUANTUM URBANISM AND NFTS

As visualized in the conceptual framework (Figure 1), the intersection of quantum urbanism and NFTs is a revolutionary synthesis, wherein the computational power of quantum systems meets the decentralized ownership frameworks of blockchain to reshape urban futures. At this intersection, quantum algorithms operating on large, networked datasets enable dynamic simulations of virtual spaces, and NFTs validate and commodify digital properties. This creates a two-way interaction between predictive analytics and the market's real-time behavior (Balcerzak *et al.*, 2022). Imagine a virtual city where land plots, as non-fungible tokens (NFTs), are being constantly appraised not just on the basis of user demand, but also guided by quantum models simulating traffic flow, energy consumption, and social interaction under different scenarios. These systems might automatically adapt zoning regulations or infrastructure plans, with every algorithmic choice immutably documented on the blockchain, building transparency and confidence in decentralized governance (Bai *et al.*, 2022; Treiblmaier *et al.*, 2020).

This synthesis allows urban spaces to arise as adaptive ecological systems. For instance, a quantum-enabled system may optimize the placement of virtual schools, parks, or shopping malls based on analyzing real-time streams of IoT sensor data and user activities, and then mint NFTs representing ownership of the optimally located digital assets (Sifah *et al.*, 2020; Khan *et al.*, 2020). These NFT owners could influence city policies through decentralized autonomous

organizations (DAOs), where quantum-processed consensus protocols balance stakeholder contributions without centralized authority. This is democratizing city planning so that various stakeholders, regardless of geographic and socio-economic divides, can shape virtual neighborhoods through tokenized voting rights (Crandall, 2023; Wong *et al.*, 2022). Blockchain technology effectively enhances the engagement of citizens and enables smooth governance in such smart environments (Jiang *et al.*, 2022b; Gloerich *et al.*, 2020).

However, this convergence is not without friction. Quantum processing and blockchain network energy density have a paradox: technologies designed to enhance sustainability would entrench carbon emissions unless they are founded upon renewable energy foundations. Moreover, the “black box” legacy of quantum algorithms risks concealing decision-making processes and disenfranchising communities that lack technical expertise. In response, hybrid governance models are emerging, blending quantum-enabled efficiency and AI explainability platforms that translate complex simulations into actionable intelligence for NFT holders. Some of the initial pilots, like decentralized metaverses with quantum annealing used for land-use disputes, promise the potential for equitable distribution of resources, and NFT-backed carbon credits catalyze green infrastructure investment in both virtual and real environments.

Finally, the convergence of quantum and NFT is also more than technological advancement. It envisions cities as living laboratories wherein computational intelligence and decentralized ownership spawn resilience, inclusivity, and creativity. By combining quantum urbanism’s predictive capacity with NFTs’ potential for tokenizing engagement, this framework drives Sustainable Development Goals SDG 9 via digital infrastructure innovation, SDG 11 by building resilient urban systems, and SDG 17 via cross-domain collaboration. The challenge is in having these technologies put human-centered design, ethical transparency, and environmental balance at their center, or else they will merely reproduce old injustices in hyper-digitized versions. At this juncture, the task is not only to build wiser cities, but to reimagine citizenship as such, where every individual, with a quantum-enabled NFT, is a co-architect of the space where they reside, be it physical or virtual.

CHALLENGES AND ETHICAL CONSIDERATIONS

The marriage of quantum urbanism and NFTs, as exciting as it is, reveals a maze of technical, social, and ethical challenges that require immediate attention. Top among them is the energy paradox: quantum computing and blockchain technologies, both celebrated as game-changing, come at a tremendous environmental price tag. Quantum processors demand extreme cooling infrastructure, and numerous blockchain networks, especially those using proof-of-work consensus, consume energy at levels rivaling small countries. This imbalance imperils the potential to promote Sustainable Development Goals (SDGs) like affordable and clean energy (SDG 7) and climate action (SDG 13), unless emerging innovations in the form of carbon-neutral quantum data centers or proof-of-stake blockchains become mainstream.

Indeed, the sheer pace of obsolescence of the hardware combined with the extractive mining of rare earth minerals that go into quantum chips imperils exacerbating global inequalities further, where the poorly endowed regions suffer most from environmental degradation. Just as pressing is the digital divide that such technologies perpetuate. Quantum-empowered government and virtual property ownership presume equal access to broadband internet, smart devices, and crypto literacy a situation far from becoming real for underprivileged groups. For instance, while a DAO in a metaverse can decentralize decision-making among NFT owners, it excludes those who are unable to purchase or interact with digital wallets, effectively replicating historical patterns of spatial exclusion in virtual space. This raises ethical concerns about who benefits from “decentralized” urban futures and who is rendered invisible in algorithmic governance.

Furthermore, the opacity of quantum systems also renders accountability more challenging. The formulation of urban policies through quantum simulations, which often confound even specialists, may lead to a diminishment of citizen agency concerning the environments they occupy. Should a quantum model emphasize energy efficiency, it could inadvertently marginalize low-income communities if biased training data is not properly regulated, thereby integrating systemic inequalities into the foundational programming of smart cities. The speculative character of NFT-based virtual land markets adds another dimension of peril. Prices tend to mirror hype, not usefulness, forming bubbles similar to the 2008 housing bubble, but with even less regulatory protection. Unprotected investors who are enticed by visions of “decentralized wealth” could experience disastrous losses when markets adjust. Further, the immutability of blockchain transactions makes error correction more difficult: a misplaced decimal in a smart contract or an erroneous prediction by a quantum algorithm could irrevocably reshape urban environments without remedy. Privacy issues also lurk on the horizon. Quantum computers’ potential to decrypt current encryption techniques threatens the safety of sensitive city information, from citizen biometrics to infrastructure blueprints, and NFTs relating to virtual land can expose users to surveillance or exploitation by corporations harvesting behavioral data. Ethically, the merging of quantum urbanism and NFTs questions fundamental concepts of human agency and cultural sovereignty.

With cities becoming more dependent on AI-quantum hybrids for system optimization, there is a risk of boiling urban existence down to measurable terms, with efficiency over spontaneity, creativity, or shared traditions. Virtual land markets also threaten to homogenize cultural landscapes as global speculators remodel digital territories into profit-driven designs rather than being driven by local identities. Indigenous communities, for instance, may experience the commercialization of their digital representations as NFT art without prior consent or financial remuneration, reflecting longstanding trends of cultural appropriation. Addressing these difficulties requires a multi-disciplinary approach. Policymakers must collaborate with technologists to develop architectures that impose energy

transparency on quantum-blockchain environments, apply antidiscrimination policies on algorithmic management, and protect vulnerable populations within virtual land markets. In addition, ethicists and urban planners must prioritize participatory design to ensure that excluded communities are given a direct hand in shaping the tools that drive their digital-physical spaces. It is only through such watchfulness that the quantum-NFT relationship can avoid being a new frontier of exploitation and instead fulfill its promise as a driver of equitable, sustainable urban change.

POLICY AND FUTURE DIRECTIONS

The future-making promise of quantum urbanism and NFT-based virtual land economies depends on forward-thinking, adaptive policymaking that weighs innovation against ethical guardrails. To unlock these technologies for equitable and sustainable urban futures, governments, multilateral organizations, and communities need to work together in developing frameworks that manage technical risks while promoting inclusive growth. An essential place to start is the creation of dynamic regulatory sandboxes where cities can experiment with quantum-NFT integrations in controlled environments. For example, local governments may collaborate with blockchain consortia to pilot decentralized land registries based on quantum-resistant cryptography, providing protection against future cyberattacks while optimizing property rights management.

At the same time, global organizations such as the UN-Habitat or the OECD need to develop standards for cross-border virtual land transactions, avoiding tax evasion, speculative exploitation, or the loss of local cultural identities in virtual environments. Energy sustainability must be embedded within these policies. Legislation must mandate carbon auditing of blockchain networks and quantum computing facilities and tie operating permits to auditable renewable energy use a theme adapted from the EU's Carbon Border Adjustment Mechanism. Tax incentives for solar-run quantum data centers or NFT platforms using proof-of-stake consensus may accelerate green technology transitions. Equally essential are policies to bridge the digital divide. Public-private partnerships could underwrite participation in quantum literacy education and decentralized identity wallets to ensure that marginalized communities are not left out of virtual land economies. Barcelona's "Digital Sovereignty Plan", with its focus on citizen-driven data cooperatives, offers a template for constructing equity into technology-driven urbanization.

Going forward, research must emphasize interdisciplinary innovation. Universities and technology centers must create quantum-urbanism labs in which physicists, planners, and ethicists work together to co-design algorithms that encode fairness into city simulations, for example, by auditing training data for bias against informal settlements or by prioritizing climate resilience in virtual land valuation models. Meanwhile, decentralized autonomous organizations (DAOs) that oversee metaverse platforms must adopt hybrid governance structures, merging AI-powered efficiency with human oversight to prevent algorithmic tyranny. Pilot initiatives, such as Nairobi's "Quantum Slum Redevelopment Project", which utilizes NFT-based

crowdfunding to develop informal settlements without disempowering the community, illustrate the potential for grassroots innovation. International cooperation is imperative. Just as cities come together under the C40 Climate Network to fight emissions, a "Decentralized Cities Coalition" might exchange best practices in NFT zoning regulations, quantum infrastructure standards, and digital rights to citizenship. Such coalitions would further SDG 17 (Partnerships) while preventing fragmentation in virtual urban environments. Artists, activists, and Indigenous leaders, meanwhile, need to be empowered to inform metaverse cultural policy to make virtual land represent humanity's diversity instead of corporate monocultures. Lastly, the future demands humility. Policymakers must acknowledge that quantum and blockchain technologies are not silver bullets but tools to be wielded with prudence. By placing human dignity, ecological balance, and participatory design at the forefront, cities can evolve into cohesive, adaptive networks where physical and virtual spaces exist as equal, sustainable, and creative expressions of collective desire.

CONCLUSIONS

The intersection of quantum urbanism and NFTs heralds a revolutionary era in city design, one where cities transcend physical boundaries to evolve into adaptive, inclusive, and creative ecosystems. By integrating quantum computing's unparalleled capacity to simulate hyper-complex systems with blockchain's decentralized ownership models, this intersection reconfigures how cities are designed, governed, and lived. Virtual land, represented in NFT token form, presents itself not only as a digital commodity but as an inclusive platform of engagement for global citizens enabling grassroots innovation in commerce, governance, and culture. Meanwhile, quantum urbanism's probabilistic frameworks beckon planners to embrace uncertainty, optimizing cities as living systems that learn from failure, privilege equity, and evolve in synchronization with ecological limits. Yet, this vision remains fraught with paradoxes. The same technologies that offer the hope of democratized access to urban development risk amplifying energy consumption, algorithmic opacity, and digital divides if employed without ethical oversight. The virtual land markets' speculative allure, if left unchecked, can further solidify socioeconomic divides rather than transcend them. Similarly, quantum systems' capacity to outpace human accountability needs to be safeguarded against the erosion of civic agency.

Yet, these obstacles are not inevitable. They call for collaborative efforts across disciplines bringing technologists, policymakers, and communities together to incorporate transparency, sustainability, and justice into the very architecture of next-generation cities. Standing at this crossroads, history's lessons are clear: urbanization's worst failures have been spawned by placing efficiency over humanity, growth over resilience. The quantum-NFT paradigm offers a chance to re-write this narrative, but only if its tools are wielded with foresight and humility. By tying innovation to the Sustainable Development Goals promoting sustainable infrastructure, inclusive communities, and global partnerships cities can leverage

these technologies to widen access to opportunity, enhance cultural diversity, and restore the broken connections between urban habitats and natural ecosystems. The way forward is bold experimentation constrained by rigorous ethical considerations, so that the cities of the future are not just smarter but more wise cities where every person, with a quantum-aware NFT or a contributory stake in a DAO, is included in the stewardship of the commons. It is in this intersection of digital information and physical space, computation and creative culture, that we can imagine urban futures that are both fair and phenomenal.

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LEGAL PATHWAYS FOR BOTTOM-UP PROJECT DEVELOPMENT IN SERBIA

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In the context of increasing calls for participatory and community-led development, understanding the extent to which legal frameworks enable bottom-up approaches is crucial. This paper examines the legislative framework governing spatial development in Serbia in order to identify legal possibilities for initiatives coming from non-governmental actors. The research employs a content analysis of relevant legislative acts, followed by a second layer of analysis that focuses on the planning documents these laws prescribe and their interrelations at the operational level. The findings reveal that, while the legal framework formally allows the engagement of licensed professionals and legal entities, the initiation, financing, and control of development processes remain largely in the hands of state and local authorities. The only significant space for bottom-up development is found within the Law on Agriculture and Rural Development, through the LEADER program, which explicitly encourages community-led initiatives. In contrast, other legal provisions offer limited room for meaningful participation by non-governmental actors, highlighting a top-down orientation in Serbia's development planning system.

Key words: development, bottom-up initiative, legislation, operationalization, Serbia.

INTRODUCTION

The essence of spatial planning implies a comprehensive and thoughtful approach to the development of all sectors within a given area, with a focus on the spatial aspect but without neglecting others. Such an approach requires careful harmonization of various interests and activities in the most rational, fair, and responsible manner, with the ultimate goal of improving the quality of life of the population, preserving nature, enhancing aesthetic values, and promoting sustainable development as a whole (Maksin-Mičić *et al.*, 2009).

One of the central challenges of spatial planning in Serbia is that, despite an extensive legal and strategic framework, formal planning instruments rarely translate into operational pathways for bottom-up project development (Lukić, 2021). Instead of driving positive change, planners often passively conform to the existing system by producing plans that, although formally correct, frequently lack operationalization (Nikolić *et al.*, 2021).

Additionally, communication among stakeholders in the planning process is increasingly reduced to formal meetings, where more attention is paid to administrative procedures than to a genuine understanding of the actual conditions on the ground, including environmental, social, and economic aspects. Field research, familiarity with local specificities, and in-depth analysis are often marginalized due to a lack of time, the absence of legal obligations, or limited jurisdiction (Marković, 2022).

The consequences of this situation are reflected in the fact that development documents, although formally present, have not had the expected impact on spatial development in Serbia for decades (Stefanović *et al.*, 2015; Nikolić *et al.*, 2021). Since the implementation of planning documents can be affected by limited awareness, the disagreement of non-governmental actors with governmental plans, or by the inability of authorities to execute all planned measures due to capacity constraints, challenges arise in the operationalization of planning solutions. This highlights the importance of exploring mechanisms for involving local communities and non-governmental actors as a potential means to address these implementation gaps.

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Contemporary planning theories and concepts, as well as EU practices, increasingly emphasize the importance of involving a broad range of actors in development processes, moving beyond traditional top-down decision-making models. In the face of growing social, economic, and environmental challenges, there is a growing recognition of the need for approaches that acknowledge the specificities of places and local communities, as well as for decisions that reflect the interests of citizens, civil society, and other non-state stakeholders. European institutions and initiatives are progressively supporting principles of territorial cohesion, integrated development, and multi-level governance, which are reflected in key EU spatial planning documents.

This article examines the legal framework for bottom-up spatial development in Serbia, highlighting the opportunities and constraints for participation by non-governmental actors. The main research question is: What are the possibilities for applying a bottom-up approach to spatial development in Serbia within the existing legislative framework, and how can this framework be improved to empower involvement of non-governmental actors?

The following section presents perspectives on the bottom-up approach and highlights the importance of involving non-governmental actors in development. For the contextualization of Serbia as an EU accession country, it also outlines the main guidelines of European spatial planning documents, as well as their directions and principles for spatial development.

THEORETICAL BACKGROUND

In recent decades, the bottom-up approach in development planning has gained increasing support in both academic and practical circles, as a response to the limitations of traditional, hierarchically oriented top-down models. In the theory and practice of spatial development, this approach is recognized as a key instrument for fostering local sustainability, social justice, and the long-term relevance of development policies (Chambers, 1997; Healey, 1997; Forester, 1999). Involving citizens, local organizations, and other relevant actors at early stages of the planning process enables a better understanding of local needs and contexts, contributing to more realistic and legitimate planning outcomes (Innes and Booher, 2004; Fung, 2006; Čolić and Dželebdžić, 2018).

Researchers such as Arnstein (1969), who formulated the well-known "ladder of participation", argue that forms of participation initiated from below that involve the transfer of power to communities are essential for democratizing planning. Support for the bottom-up approach also stems from the argument that local populations possess specific knowledge about their environment – so-called tacit knowledge (Spinuzzi, 2005; Polanyi, 2009) – which often remains invisible in formal technocratic processes. For this reason, many authors advocate for methods of co-creation by local communities and various stakeholders, such as working panels, community mapping, and participatory budgeting (Huxley and Yiftachel, 2000; Fung and Wright, 2003; Albrechts, 2010; Bennett, 2025).

In addition, recent research explores the role of digital technologies and hybrid modes of participation as a way to strengthen bottom-up engagement, especially in post-COVID planning contexts (Kleinhans *et al.*, 2022). New forms of participation, including online platforms and place-based citizen assemblies, have extended the reach of potential participants in the bottom-up approach, while raising new questions of accessibility and legitimacy (Pantić *et al.*, 2021).

Furthermore, research has shown that bottom-up approaches can lead to greater sustainability and success of development projects, as they increase the level of local ownership over both the process and its outcomes (Pretty, 1995; Cornwall, 2008). Local actors are often better positioned to identify real problems and formulate adaptable solutions (Scott, 1998), while citizen participation in planning also contributes to building social capital and trust (Putnam, 2000). Likewise, several comparative studies have confirmed that programs incorporating bottom-up elements tend to have higher legitimacy in the eyes of citizens and better performance in practice (Evans, 2002; Gaventa, 2004; Natan-Krup and Mizrahi, 2025).

At the EU level, participatory and bottom-up approaches to spatial development are strongly promoted through strategic frameworks and implementation instruments. The New Leipzig Charter (EU, 2020) emphasizes the use of local knowledge and identities in spatial and urban policy, while EU Cohesion Policy (EC, 2021a) mandates stakeholder involvement through the partnership principle. Co-creation and inclusive governance are further advanced by the Urban Agenda for the EU (EC, 2016) and the New European Bauhaus (EC, 2021b). These principles are most concretely operationalized through LEADER and Community-Led Local Development, which institutionalize bottom-up approaches at the local level, and are increasingly supported by digital tools promoted through EU digitalization and smart governance initiatives.

In the Serbian context, several authors have critically examined the limits of participatory and bottom-up approaches within a highly centralized and institutionally constrained planning system. Research shows that although public participation is formally guaranteed through planning legislation, it is predominantly reduced to late-stage consultations with limited influence on decision-making, resulting in low levels of trust and engagement among citizens (Maričić *et al.*, 2018; Lukić, 2021). Furthermore, studies emphasize that post-socialist legacies, strong state control, and procedural formalism continue to hinder genuine co-creation and the initiation of development processes by non-governmental actors, despite normative alignment with contemporary European planning principles (Vujić *et al.*, 2024; Maričić *et al.*, 2018; Lukić, 2021).

An effective spatial planning system supports the **integrated planning of public policies**, ensuring that various sectoral strategies, such as those related to transportation, the environment, energy, or economic development, are aligned to achieve broader societal goals (Nadin *et al.*, 2021). Spatial planning serves not only as a coordinating platform, but also as a tool to assess the **territorial impacts** of sectoral policies. By doing so, it fosters inter-institutional

cooperation and promotes coherent action across policy domains. As emphasized in the Territorial Agenda 2030 (EU MRSPTD, 2020), spatial planning plays a crucial role in guiding sectoral policies to better address the specific needs of places and people, particularly when informed by strategic and evidence-based territorial considerations.

Closely tied to this is the principle of **territorial cohesion and cooperation**, which calls for a more balanced and harmonious territorial development across and within countries, regions, and local communities (ESPON, 2021). Territorial cohesion involves the reduction of regional disparities and the promotion of equal access to opportunities, while embracing **the subsidiarity principle**. This concept strengthens the case for planning that is responsive to territorial specificities regardless of their size or geographic position (EU MRSPTD, 2020).

The importance of **decentralized and sectoral planning** is also recognized within the framework of modern governance. While decentralization allows local and regional authorities to tailor decisions to their development contexts, sectoral planning ensures that specific domains receive the focused attention they require (OECD, 2021). However, such sectoral efforts must not occur in isolation.

METHODOLOGY

Intending to explore the possibilities for bottom-up initiatives in spatial development, a two-step content analysis was conducted. The first step was an analysis of the legal acts regulating spatial planning in Serbia: *Law on the Planning System of the Republic of Serbia* (Službeni glasnik RS, br. 30/2018), *Law on Planning and Construction* (br. 72/2009, 81/2009 - ispr., 64/2010 - odluka US, 24/2011, 121/2012, 42/2013 - odluka US, 50/2013 - odluka US, 98/2013 - odluka US, 132/2014, 145/2014, 83/2018, 31/2019, 37/2019 - dr. zakon, 9/2020, 52/2021, 62/2023 i 91/2025), *Law on Regional Development* (Službeni glasnik RS, br. 51/2009-3, 30/2010-7, 89/2015-3 (dr. zakon)), *Law on Agriculture and Rural Development* (Službeni glasnik RS, br. 41/2009-71, 10/2013-3 (dr. zakon), 101/2016-3, 67/2021-10 (dr. zakon), 114/2021-186, 19/2025-52).

The second step was an analysis of the development documents prescribed by each of the listed laws, examining the opportunities these documents provide for the involvement of non-governmental actors and bottom-up approaches in spatial development. The examination was narrowed to a case study of the local self-government unit (LSGU) of Sokobanja in eastern Serbia, as, to the authors' knowledge, no municipality has adopted the full set of prescribed documents and Sokobanja is among those with nearly complete coverage. Documents of a predominantly strategic or sectoral nature, although mentioned in the legislation, were not analyzed, as the focus was on the operational dimension of the documents.

Sokobanja was selected as a case study as a municipality with typical challenges, strong development potential, and a broad set of relevant planning documents. Although case study findings are not fully generalizable, they highlight systemic gaps in Serbia's planning framework. Given the uniform legal context, similar results would likely be observed in other municipalities.

The purpose of this content analysis was to identify potential legal gaps and opportunities within Serbia's legislative framework that would allow non-governmental actors – such as researchers, urbanists, planners, local entrepreneurs, communities or activists – to contribute to spatial development.

ANALYSIS

Legislative acts regulating spatial development

An analysis of the four laws (Figure 1) reveals varying levels of integration and comprehensiveness in their development approaches in the following way:

- *Law on the Planning System of the Republic of Serbia* (Službeni glasnik RS, br. 30/2018) provides a framework for the coordination of public policies, encompassing the widest range of documents and emphasizing hierarchy and alignment;
- *Law on Regional Development* (Službeni glasnik RS, br. 51/2009-3, 30/2010-7, 89/2015-3 (dr. zakon)) focuses on territorial cohesion and cooperation among different levels of government and agencies;
- *Law on Agriculture and Rural Development* (Službeni glasnik RS, br. 41/2009-71, 10/2013-3 (dr. zakon), 101/2016-3, 67/2021-10 (dr. zakon), 114/2021-186, 19/2025-52) is the first to seriously include local action groups (LAGs), promoting decentralization;
- In contrast to all others, the *Law on Planning and Construction* (Službeni glasnik RS, br. 72/2009, 81/2009 - ispr., 64/2010 - odluka US, 24/2011, 121/2012, 42/2013 - odluka US, 50/2013 - odluka US, 98/2013 - odluka US, 132/2014, 145/2014, 83/2018, 31/2019, 37/2019 - dr. zakon, 9/2020, 52/2021, 62/2023 i 91/2025) mainly addresses the physical aspects of space and regulates the preparation of technical and urban plans – it does not integrate development objectives but assumes them through predefined rules for land use.

The legislative review reveals that Serbia's development planning system remains predominantly **state-driven** (Table 1), despite the contemporary planning discourse that increasingly promotes broader participation, territorial sensitivity, and the involvement of diverse societal actors. Across all four laws examined, the authority to initiate, prepare, finance, and supervise planning documents largely lies with **state institutions**, whether at the national, provincial, or local level.

In terms of **initiating planning processes**, the laws consistently assign this responsibility to formal governmental bodies – ministries, public authorities, regional agencies, and local self-governments. None of the analyzed acts provides a mechanism through which an individual, civil society group, or informal community initiative can formally trigger the development or revision of a planning document. This reinforces a hierarchical model in which change in space is expected to originate from within the institutional apparatus.

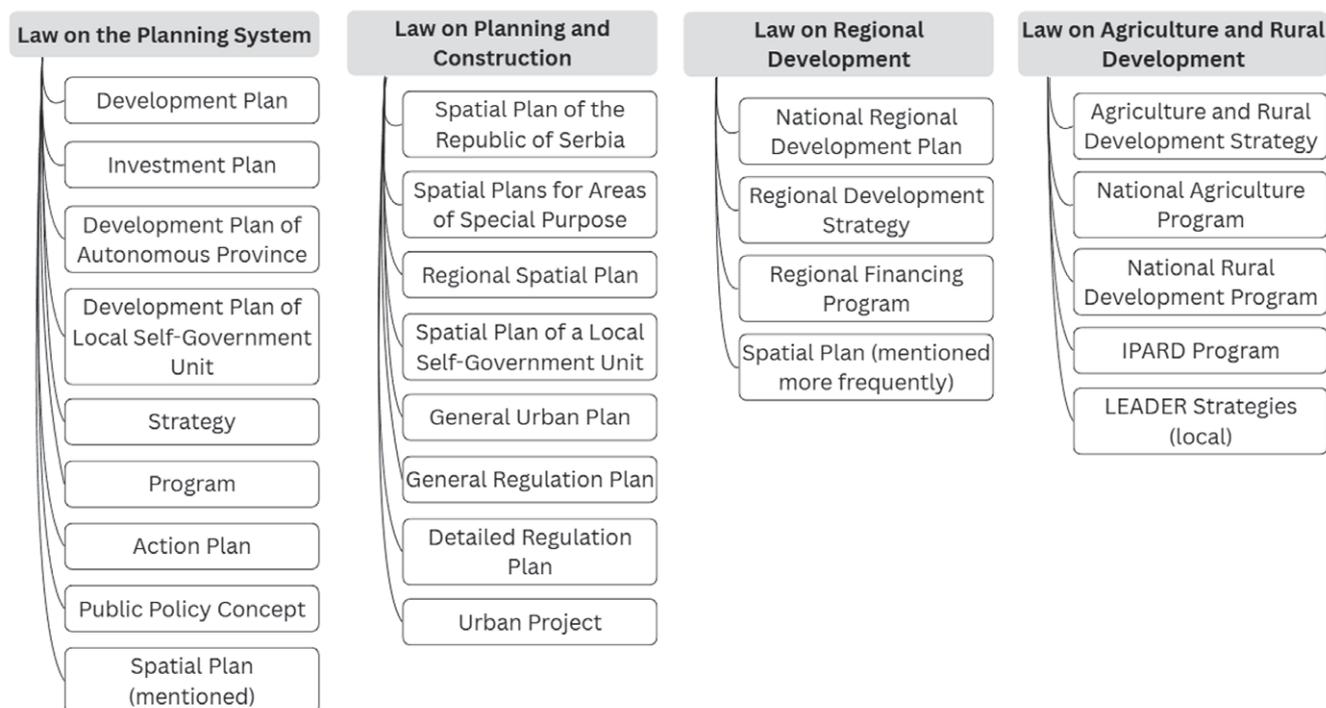


Figure 1. Legislative framework for development documents

(Source: Authors, based on the Law on regional development (Službeni glasnik RS, br. 51/2009-3, 30/2010-7, 89/2015-3 (dr. zakon)), Law on the planning system of the Republic of Serbia (Službeni glasnik RS, br. 30/2018), Law on planning and construction (Službeni glasnik RS, br. 72/2009, 81/2009 - ispr., 64/2010 - odluka US, 24/2011, 121/2012, 42/2013 - odluka US, 50/2013 - odluka US, 98/2013 - odluka US, 132/2014, 145/2014, 83/2018, 31/2019, 37/2019 - dr. zakon, 9/2020, 52/2021, 62/2023 i 91/2025), and Law on agriculture and rural development (Službeni glasnik RS, br. 41/2009-71, 10/2013-3 (dr. zakon), 101/2016-3, 67/2021-10 (dr. zakon), 114/2021-186, 19/2025-52)

Table 1. Overview of key legal provisions relevant to the development planning in Serbia

(Source: Službeni glasnik RS, br. 51/2009-3, 30/2010-7, 89/2015-3 (dr. zakon); Službeni glasnik RS, br. 30/2018; Službeni glasnik RS, br. 72/2009, 81/2009 - ispr., 64/2010 - odluka US, 24/2011, 121/2012, 42/2013 - odluka US, 50/2013 - odluka US, 98/2013 - odluka US, 132/2014, 145/2014, 83/2018, 31/2019, 37/2019 - dr. zakon, 9/2020, 52/2021, 62/2023 i 91/2025; Službeni glasnik RS, br. 41/2009-71, 10/2013-3 (dr. zakon), 101/2016-3, 67/2021-10 (dr. zakon), 114/2021-186, 19/2025-52)

Aspect	Law on the planning system	Law on planning and construction	Law on regional development	Law on agriculture and rural development
Initiators of the document preparation	The state administration body responsible for the coordination of public policies (the National Assembly, the Government, and local government authorities) submits the proposal to the Government for adoption (Article 6, Paragraphs 3 and 13).	The competent authority - the Government, the ministry in charge of urban and spatial planning, the autonomous province, or LSGU - in accordance with the planning hierarchy (Articles 39, 40, 41, 43).	The preparation of the National Regional Development Plan is initiated by the Ministry responsible for regional development. The Ministry initiates the Regional Development Strategy in cooperation with regional agencies and local self-government units (LSGUs) (Articles 14-16). Spatial plans are prepared in accordance with a separate law, but they are linked to development documents within the broader framework of regional development.	The preparation of the Strategy for Agriculture and Rural Development, the National Agriculture Program, the National Rural Development Program, and the Instrument for Pre-Accession in Rural Development (IPARD) program is initiated by the Ministry in charge of agriculture (Articles 4, 5, 6, 7a).
Required baseline data	Analysis of development potential, trends, and existing plans. This analysis is an integral part of the development Plan. It is not specified who conducts the analysis (Article 6, Paragraph 6).	The Study of Spatial Foundations, Feasibility Study, Study of Cultural Heritage Protection, and similar technical, demographic, ecological, and spatial analyses (Articles 42, 45, 46, 55).	Analyses of the current state, spatial and socio-economic needs, in accordance with planning and spatial documents. Public hearings and public inspections are also mandatory. Spatial plans serve as the foundational basis (Article 14).	Measures, activities, objectives, results, and incentives derived from higher-level documents; the IPARD program contains both general and specific objectives. The FADN system and other registries are also input data (Articles 4, 5, 6, 7a, 32, 33).

Aspect	Law on the planning system	Law on planning and construction	Law on regional development	Law on agriculture and rural development
Responsible drafting authority	Competent authority at the state level, the Autonomous Province, or the LSGU (Article 6, Paragraph 3; Articles 8-9).	Qualified legal entities (licensed urban planning institutes, research institutes, companies), while authorized designers are responsible for the technical documentation (Articles 36, 38, 122).	The Ministry in charge of regional development, regional development agencies, autonomous provinces, the City of Belgrade, and local self-governments act within their respective competences. Agencies often serve as executors of the technical preparation (Articles 15-16, 18-19 and 34).	The Ministry in charge of agriculture and its organizational units are responsible for preparation and monitoring, while LAGs are responsible for LEADER strategies (Articles 6, 7a, 7b).
Funding for the document development	The Budget of the Republic of Serbia, in the case of the national development plan, and from the budget of the LSGU in the case of a municipal/city development plan, along with the possibility of utilizing EU funds or other forms of international assistance (Article 6, Paragraphs 5-6).	The budgets of the Republic of Serbia, autonomous provinces, LSGU, as well as donations, loans, and public-private partnerships (Articles 47, 136).	The budgets of the Republic of Serbia, autonomous provinces, LSGU, EU funds, donations, loans from international institutions, and other sources (Article 48).	The budget of the Republic of Serbia and through IPARD and other EU instruments (Articles 7a, 9-12).
Implementation documents	Strategies, programs, investment plans, and action plans (Articles 6-7, 11-14, 18).	Urban planning projects, location conditions, building permits, and the implementation of investments and relevant projects (Articles 135, 144-145).	Regional development programs, project execution, regional strategies, and other development documents aligned with the National Plan. Spatial plans are the basis for defining locations and activities (Articles 14, 17-18).	Programs and strategies are implemented by the Ministry in charge of agriculture, its units, and LAGs (Articles 6, 7a-7b).
Monitoring and supervision	The state administration body responsible for coordinating public policies submits a report to the Government and the National Assembly every three years (Article 6, Paragraphs 7-10).	Ministry in charge of spatial planning, competent provincial and local authorities, inspection bodies, and the Chief Urbanist (Articles 129, 133, 134).	Ministry in charge of regional development, with reports submitted by the National Council, regional councils, and regional agencies. Evaluation of measures and projects is conducted according to a specific methodology (Articles 26, 33, 40, 47).	The Ministry in charge of agriculture and the Agricultural Payments Agency; there is also inspection supervision (Articles 6, 7a, 8, 35-38).

Regarding **baseline data requirements**, all laws acknowledge the importance of analytical foundations, such as studies, assessments, and evaluations. However, the responsibility for conducting or commissioning these analyses is either unspecified or assigned to institutional actors. While this ensures a certain level of technical and administrative control, it also implicitly restricts the opportunity for independent actors to generate alternative knowledge that could be formally recognized within planning processes.

The examination of **responsible drafting authorities** shows a similar pattern. The preparation of planning documents is reserved for licensed professional organizations, ministries, regional development bodies, or local administrations. Although this ensures professional quality and compliance with technical standards, it further narrows the entry points for individual engagement.

Funding mechanisms are likewise rooted in public budgets and institutional sources, including EU funds and international assistance. While these channels provide

stability, they also reinforce state control over project agendas. The lack of provisions for independent or citizen-led funding streams, even as complementary inputs, suggests that grassroots initiatives must rely on informal channels if they seek to generate planning-relevant studies or development proposals.

The analysis of **implementation and monitoring provisions** confirms the dominance of public institutions throughout the policy cycle. Ministries, agencies, and inspection bodies supervise implementation and reporting, while the involvement of non-state actors is limited to participatory processes defined by public authorities. Monitoring frameworks do not explicitly recognize independent initiatives or community-led projects as part of the planning system.

Planning and strategic documents regulating spatial development

The following sections present an analysis of development documents prescribed by the selected laws, focusing on the case of the LSGU of Sokobanja (Figure 2). Rather than examining each document in isolation, the analysis explores opportunities for bottom-up planning and the involvement of non-governmental actors that these documents enable.

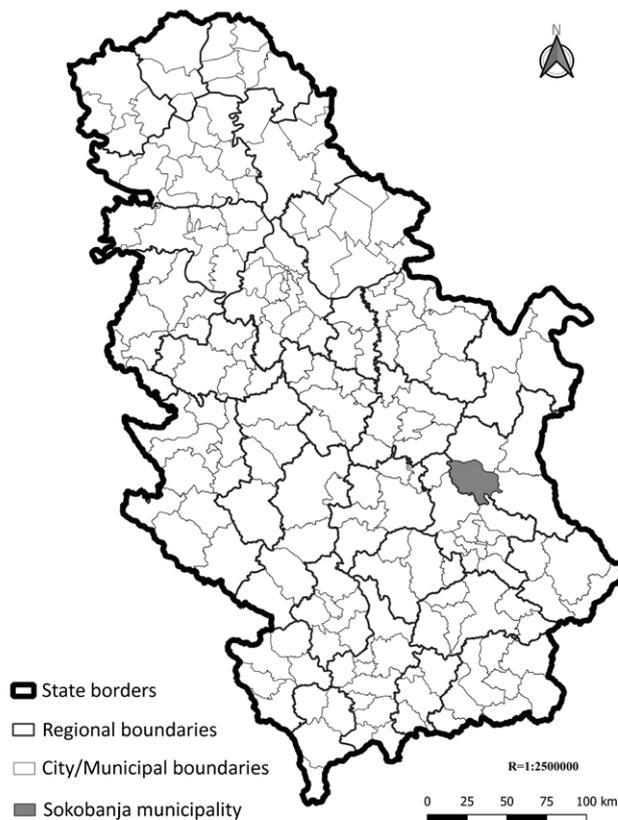


Figure 2. Geographical position of Sokobanja municipality (Source: Authors, 2025)

Mid-term development planning

The *Development plan of the municipality of Sokobanja for 2023–2027* (Development Plan) (Službeni list opštine Sokobanja, br. 02-104/22) and the *Mid-term plan of the municipality of Sokobanja for 2024–2026* (Program) (Službeni list opštine Sokobanja, br. 02-6/23) form a vertically aligned but institutionally closed planning framework. Although both documents are grounded in the *Law on the planning system of the Republic of Serbia* (Službeni glasnik RS, br. 30/2018), they operate at different levels of abstraction and operationalization, which has important implications for bottom-up project development.

The **Development plan** (Službeni list opštine Sokobanja, br. 02-104/22) is the highest strategic document at the local level, defining long-term objectives, priorities, and measures. While it identifies development needs and potential intervention areas, it does not provide mechanisms for the direct implementation or legally secured participation of non-governmental actors. In this sense, it establishes a strategic reference framework rather than a legal pathway for initiating projects from the bottom up.

The **Program** (Službeni list opštine Sokobanja, br. 02-6/23) is a three-year technical-operational document. It translates selected Development Plan (Službeni list opštine Sokobanja, br. 02-104/22) objectives into concrete measures, activities, funding allocations, and responsible institutions. As such, it constitutes the only document within this framework that enables operationalization and financing of projects. However, its preparation remains fully within the institutional domain of the local administration, in coordination with central authorities, leaving no formal procedural role for external actors in defining project content.

Although the Law on the Planning System requires Development Plans to be based on analyses of development potentials and opportunities, it does not regulate the role of third parties in preparing such analyses, nor does it provide any guarantee of financial compensation. Consequently, while non-governmental actors may theoretically propose studies or project ideas aligned with Development Plan objectives, this possibility remains economically and legally unviable in practice.

The only functional legal pathway for bottom-up initiatives within this framework is indirect: the local government must formally recognize the initiative and include the preparation of the relevant study or project within the Program. Only then does the process become legally structured, financially compensated, and eligible for public procurement. Bottom-up project development is therefore not institutionally prohibited, but it is entirely dependent on discretionary top-down inclusion.

Bottom-up opportunities in rural development planning

Within Serbia's rural development framework, a clear vertical hierarchy can be observed: the **Strategy for Agriculture and Rural Development 2014–2024 (SARD)** (Službeni glasnik RS, br. 85/2014-30) establishes overarching goals; the **National Agriculture Program (NAP)** (MPŠV, 2022a) and the **National Rural Development Program 2022–2024 (NRDP)** (MPŠV, 2022b) function as national programmatic instruments for their implementation; and the **Local Rural Development Strategy (LRDS)** (LAG "Rtanj", 2020) represents their territorial application within the Sokobanja area.

In contrast to the general development planning framework, documents defined by the Law on Agriculture and Rural Development (Službeni glasnik RS, br. 41/2009-71, 10/2013-3 (dr. zakon), 101/2016-3, 67/2021-10 (dr. zakon), 114/2021-186, 19/2025-52) demonstrate a more articulated structure for territorially embedded initiatives. A clear vertical alignment exists between the SARD (Službeni glasnik RS, br. 85/2014-30), the National Agriculture Program (NAP) (Ministarstvo poljoprivrede, šumarstva i vodoprivrede (MPŠV, 2022a), the National Rural Development Program (NRDP) (MPŠV, 2022b), and the Local Rural Development Strategy (LRDS) (LAG "Rtanj", 2020).

This alignment creates a legally recognizable space for local-level initiatives, particularly through the application of the LEADER methodology within the LRDS (LAG "Rtanj", 2020). The LRDS (LAG "Rtanj", 2020) translates national objectives into territorially specific project ideas and measures, thereby offering a structured framework in which

local actors may articulate development needs and propose concrete interventions.

However, this bottom-up orientation remains procedurally bounded. Project ideas must conform to predefined national measures, funding schemes, and monitoring requirements established at higher governance levels. While the LRDS (LAG "Rtanj", 2020) allows local communities and partnerships to participate in shaping development priorities, their initiatives are legally valid only insofar as they align with programmatic frameworks defined at the national level.

In practice, the operationalization of this pathway is further constrained by the absence of stable financial support for LAGs (Paraušić *et al.*, 2011). Although the LEADER approach is formally recognized, the IPARD measure dedicated to LAGs has not yet been implemented in Serbia, nor has support for the preparation and implementation of Local Rural Development Strategies been consistently programmed within the national budget. As a result, LAGs operate in a context where participatory structures exist legally but lack the financial instruments necessary to translate locally defined priorities into implemented projects (Paraušić *et al.*, 2011; Paraušić and Kljajić, 2024).

Thus, rural development planning provides a conditional legal pathway for bottom-up project development: participation is formally acknowledged, but tightly embedded within standardized procedures, funding rules, and eligibility criteria.

Bottom-up initiatives in spatial planning

This section analyzes the *Regional Spatial Plan of the Timok Krajina* (RSPTK) (Službeni glasnik RS, br. 51/2011-3) with its Implementation Program (Službeni glasnik RS, br. 17/2015), the *Spatial Plan of the Sokobanja Municipality* (SPSM) (Službeni list opštine Sokobanja, br. 3/18), and the Regulatory Framework for the Village of Vrmdža (part of the SPSM, Službeni list opštine Sokobanja, br. 3/18).

Spatial planning documents prepared under the Law on Planning and Construction (Službeni glasnik RS, br. 72/2009, 81/2009 - ispr., 64/2010 - odluka US, 24/2011, 121/2012, 42/2013 - odluka US, 50/2013 - odluka US, 98/2013 - odluka US, 132/2014, 145/2014, 83/2018, 31/2019, 37/2019 - dr. zakon, 9/2020, 52/2021, 62/2023 i 91/2025) reveal a high degree of hierarchical coherence but limited operational capacity for bottom-up project initiation. The Regional Spatial Plan of the Timok Krajina (Službeni glasnik RS, br. 51/2011-3), the SPSM and its Regulatory Framework for the Village of Vrmdža (Službeni list opštine Sokobanja, br. 3/18) demonstrate thematic alignment with development and rural strategies, particularly in tourism, infrastructure, and environmental protection.

Despite this alignment, these documents primarily function as regulatory and descriptive instruments. The lowest planning tier, represented by the Regulatory Framework for the Village of Vrmdža (Službeni list opštine Sokobanja, br. 3/18), identifies spatial potentials but does not provide concrete implementation mechanisms, feasibility assessments, or legally defined procedures for project completion.

As a result, spatial planning documents do not constitute effective legal pathways for bottom-up project development. They acknowledge local resources and development directions, but lack procedural tools that would enable local actors to initiate, formalize, and implement projects independently of institutional decision-making.

RESULTS AND DISCUSSION

The analysis of Serbia's legal and planning framework reveals a highly centralized and hierarchical system, consistent with critiques of top-down approaches (Wolf, 1993; Shohet Radom *et al.*, 2025). Centralization is associated with reduced democratic quality (Tranvik and Selle, 2022), and in Serbia, it constrains meaningful citizen participation. Although a formal hierarchy of planning documents exists, its operational effectiveness is limited. Only a few plans successfully translate general objectives into actionable measures (Svetikas, 2014), while local-level instruments, such as the Regulatory Framework for the Village of Vrmdža, fail to provide mechanisms for implementation.

Regional and municipal spatial plans primarily set broad objectives and zoning guidelines, whereas local regulatory documents are expected to guide practical application. In practice, these lower-level plans often remain descriptive, highlighting a structural gap: even documents intended to bridge planning and practice function largely as administrative tools (Escobedo Garcia and Ulibarri, 2022). This rigidity undermines both democratic engagement and the sustainability of development projects, as bottom-up involvement is widely recognized to enhance legitimacy and effectiveness (Pretty, 1995; Cornwall, 2008). Non-governmental actors can participate only after visions and frameworks are predefined, leaving local knowledge largely invisible in the formal planning process (Scott, 1998; Rossi *et al.*, 2024). Inclusive, co-creative processes are associated with increased public acceptance and project legitimacy (Innes and Booher, 2004). Yet, within Serbia's framework, those best acquainted with local contexts have no formal opportunity to initiate planning. Integrated planning, promoted by ESPON (2021), remains largely aspirational: the Law on the Planning System of the Republic of Serbia (Službeni glasnik RS, br. 30/2018) establishes vertical and horizontal alignment, but the integration of spatial, economic and social dimensions is limited. Coordination across sectors and territories – a precondition for coherent development policies (Nadin *et al.*, 2021) – is often reduced to formal document alignment without genuine intersectoral cooperation.

The absence of certain planning documents reflects broader structural weaknesses within Serbia's planning system, including limited administrative and professional capacities at the local level (Pantić *et al.*, 2026). This situation directly affects the implementation and operationalization of planning policies. Importantly, the same capacity constraints that hinder the preparation of planning documents also might limit the organization of participatory processes and the involvement of non-governmental actors.

Territorial cohesion, also emphasized in European policy (ESPON, 2021), is insufficiently operationalized nationally. Initiatives such as LEADER show potential for balanced

development and local capacity building but remain marginal relative to centralized state control, limiting the equal distribution of opportunities and adaptation to local needs.

The institutional centrality of the system constrains bottom-up initiatives. Citizens can participate indirectly, as stakeholders or commenters, but cannot initiate or produce a planning content. Baseline data requirements do not accommodate citizen-generated or community-sourced evidence, and implementation frameworks do not recognize independent or community-led projects.

Collectively, these findings reveal a significant gap between contemporary planning ideals – which emphasize local specificity, multi-actor involvement, and bottom-up innovation – and Serbia's centralized, institutionally driven legal architecture. While the system structurally limits individual initiatives, opportunities exist outside formal procedures. Informal, project-based, or experimental approaches – such as analytical studies, pilot interventions, or development projects – can enable individuals to influence spatial development. Such initiatives align with the EU principles of territorial cohesion, integrated development, and multi-level partnerships, even when not embedded in national legislation.

This analysis establishes a foundation for understanding the constraints, potential leverage points, and conditions under which bottom-up, individual spatial interventions may gain visibility and impact within a predominantly centralized planning system.

CONCLUSIONS

The research demonstrates that Serbia's legal and strategic framework formally recognizes a multi-level planning system and a variety of actors, yet the opportunities for genuine bottom-up engagement remain extremely limited. Although different types of planning documents exist, the authority to initiate, prepare, and fund them is concentrated within public institutions, leaving non-state actors with only consultative or implementation roles rather than any real influence over planning content or direction.

While certain sectoral mechanisms symbolically open space for local participation, these remain tightly regulated and procedurally constrained, preventing citizens, associations, and independent experts from meaningfully initiating or shaping development processes. Even where partial openness exists, methodological requirements and state-defined priorities significantly narrow the room for autonomous action.

The case study confirms that, despite formal vertical and horizontal alignment, planning documents rarely provide operational guidance for local development. Local knowledge, analytical inputs, and community initiative tend to be overshadowed by administrative procedures, resulting in plans that remain largely declarative and disconnected from practice.

Strengthening bottom-up planning would require a more coherent and flexible legal framework – one that allows expert or community-led initiatives, supports evidence-based proposals, and encourages planning documents to evolve from prescriptive templates into tools that activate local potential. Creating a legal pathway for bottom-up development in Serbia requires fostering genuine

partnerships between governmental and non-governmental actors, enabling communities and NGOs to co-design projects, receive institutional support, and see local plans become flexible, operational, and responsive to their inputs. A shift toward such a system would not diminish the regulatory role of the state but would enable a more balanced, participatory, and context-responsive approach to development.

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MODELLING A SUSTAINABILITY THRESHOLD-BASED ASSESSMENT AND ITS EXPERIMENTATION IN SUBURBAN ALGIERS

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This article examines the impact of growing urbanisation, with particular attention given to identifying thresholds that mark the onset of irreversible change and the associated risks when these thresholds are exceeded. The research presents a threshold-based tool for assessing sustainability – the Suburban Sustainability Systemic Thresholds Index (S³-TI) – which uses a systemic approach with threshold modelling to evaluate urban sustainability. It identifies trigger factors and their development thresholds within the socio-ecological system. This tool was applied to the Bordj-El-Kiffan municipality in Algiers, where data was collected through indicators spanning five systems: social, managerial, economic, environmental, and the built environment. The results from these indicators were then benchmarked against a reference area: the central urban system area. The assessment categorises the development thresholds as acceptable, critical, or unacceptable, reflecting the system's proximity to sustainable or at-risk states. The results indicate that Bordj-El-Kiffan has surpassed critical to unacceptable thresholds in several domains, highlighting persistent deficiencies in essential services, limited citizen participation, difficulties in managing urban services and natural resources, unsustainable demographic patterns, and inadequate mobility infrastructure. The S³-TI tool serves as an alert system and awareness-raising instrument, emphasizing the importance of defining and respecting development thresholds to support adaptive and sustainable territorial governance. By integrating the S³-TI tool into future urban planning practices, sustainability in Algerian cities – and potentially in other Global South contexts – can be strengthened. The study emphasises qualitative aspects such as urban well-being and environmental equilibrium rather than solely focusing on quantitative indicators of growth, promoting a more holistic approach to urban sustainability.

Key words: sustainability, assessment, thresholds, modelling, Algiers.

INTRODUCTION AND THEORETICAL FRAMEWORK

In 2018, cities housed 55% of the world's population, and projections suggest this will rise to 68% by 2050 (UN, 2018). However, rapid urbanisation in the Global South, particularly in Africa, has led to the proliferation of slums due to demographic pressures, poverty, infrastructure gaps, and limited resources (Agyemang *et al.*, 2022). For the Sustainable Development Goals, especially Goal 11, addressing these challenges is the central target, which

aims to foster inclusive, safe, resilient, and sustainable urban environments by tackling social, economic, and environmental aspects of urban life (UN, 2017).

In Algerian cities such as Algiers, rural migration and continuing housing shortages drive unsustainable urbanisation, as evidenced by Riadh and Osman (2021). This phenomenon is characterised by a demographic and spatial dynamic. Here, the centripetal movement from rural to urban areas intensifies the scarcity of adequate housing in the receiving urban centers.

Rapid urbanisation frequently surpasses the capacity of urban planning, thereby undermining sustainable

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development efforts. The use of dedicated management tools allows for monitoring, controlling, and benchmarking urban growth. Ultimately, it leads to improved planning and greater awareness of growth limits. In crisis contexts, territorial management provides a flexible, adaptive framework for negotiation and planning, and for integrating managerial techniques to foster resilient, equitable, and sustainable local governance (Repetti and Desthieux, 2006; Zhang *et al.*, 2016).

The integration of structured frameworks and advanced quantitative tools in benchmarking methods significantly advances sustainable suburban development. The use of robust and reliable indicators allows the effective comparison, evaluation, and prioritization of urban strategies, while also encouraging participatory governance and facilitating the adaptation of best practices to specific local contexts. This approach mitigates the negative impacts associated with traditional patterns of suburban growth and supports inclusive and resilient urban environments (Sáez *et al.*, 2020).

A threshold is the point at which actions produce irreversible effects and result in permanent changes to the system (Randolph, 2004; Zhang *et al.*, 2016). Within a spatio-temporal continuum, a threshold is the maximum or minimum value permitted before an event or process becomes irrevocable, after which it is no longer possible to reverse a decision (Hocine, 2021). Exceeding this limit signifies danger or the onset of significant transformation, marking the system's transition into a fundamentally altered state (Berezowska-Azzag, 2005).

This article investigates the effects of growing urbanisation, focusing on thresholds that go beyond conventional sustainability analyses. It proposes a threshold index as a problem-solving tool, particularly for suburban municipalities such as Bordj-El-Kiffan in the wilaya of Algiers, which frequently encounter eco-sociological challenges linked to urban development (Perrin and Nougaredes, 2022). Within Algeria's administrative structure, Algiers is one of 58 wilayas and constitutes a first-order administrative territorial division.

Although sustainability evaluation tools vary, those focused on identifying and governing thresholds in suburban areas are limited. Notable examples include Malisz (1972), Hughes and Kozlowski (1968), Kennett (2006), Stossel *et al.* (2015), and Hocine (2021). The tool was implemented in the Bordj-El-Kiffan municipality to examine sustainability challenges and to determine threshold conditions for transformative growth in social-ecological systems.

Urbanisation crisis and challenges in assessing sustainability

Davis (1965) noted that North American and European cities adopt sustainability assessments during crises. They have pioneered sustainable land use, containment, and growth boundary strategies (Valencia Torres *et al.*, 2021), setting normative thresholds for economic output, resource use, and social accessibility. The Mediterranean, Middle Eastern, and North African regions are experiencing crises in their own cities, and the rapid growth in southern Mediterranean

cities intensifies issues due to socioeconomic and management challenges (PLAN BLEU – Centre d'activités régionales du PNUE/PAM, 2013). These encompass limit thresholds, vulnerability to threats, resource availability, socioeconomic development, and territorial management.

Various theoretical frameworks address unsustainable environmental and urban development. These include the unsustainability related to the IPAT equation (Alcott, 2012; Ehrlich and Ehrlich, 2009); 'biophysical carrying capacity' and 'social carrying capacity' (Arrow *et al.*, 1996); and the 'acceptable threshold' and 'limits of development' (Randolph, 2004; Hocine 2021).

Information on how to reach certain thresholds is intended to guide stakeholders through an open decision-making process. The tool is then formalised as a 'codified indicators system for thresholds', addressed to a forum of participatory members, which allows them to set up a dashboard, without the framework of an observatory (Martin *et al.*, 2009). Acceptance will have to come from the community because any action of planning, developing, or preserving the various capitals, including natural capital and its carrying capacity, will depend on the consensus (Hegarty and Maubrey, 2020).

Benchmarking locally, and then in a broader context to experiment on evaluation made it possible to later consolidate the acceptable limit values and their threshold character. Theoretical methods for identifying thresholds between evolutionary states were compared. The methodology in this study involved bibliographic research to synthesize theoretical knowledge about sustainability assessment, impacts, factors, capacities, limitations, and thresholds.

The findings suggest that causality loops involving triggers and amplifying factors contribute to sustainability assessment issues and crises. As urban systems exceed their limits and their carrying capacities decline, they reach a critical state that could lead to collapse if not given prompt attention (Gudlaugsson *et al.*, 2021; Hocine, 2021).

To assess sustainability, 'carrying capacity' is a central key, as it sets the limit beyond which environmental pressure becomes unsustainable. However, while this concept suits ecological systems, socio-spatial contexts require more nuanced, judgment-based approaches (Becker *et al.*, 1984). The use of development thresholds, linked to drivers of imbalance and social-ecological systems, is advocated. These dynamic thresholds more effectively capture stabilising or destabilising changes, especially within holistic social-ecological frameworks in suburban areas. Carrying capacity is important for assessing sustainability because it marks the threshold where human pressure on natural resources becomes unsustainable. However, this concept fits ecological systems better than socio-spatial contexts, which need more judgment-based approaches (Becker *et al.*, 1984).

The use of development thresholds, connected to drivers of imbalance and to social-ecological systems, is proposed to characterise stabilising or destabilising trends, particularly in holistic suburban environments, i.e.:

- Factors of imbalance: according to the IPAT model, it is the multiplicative combination of factors – population, per capita consumption and technology – that determines human pressure on the environment, creating the main factors of imbalances that society must manage to achieve sustainability (Alcott, 2012; Ehrlich and Ehrlich, 2009);
- Social-ecological system: These hybrid systems, which combine artificial infrastructure and ecological processes, redefine the traditional boundaries between the city and nature. The socio-ecosystem emerges from the integration of human activities as a major ecological force, modifying energy flows and biogeochemical cycles (Barles, 2020); and
- Development threshold: In social-ecological systems, accelerated and amplified processes within a vicious cycle can generate a snowball effect and ultimately destabilise the system. The perception of a threshold or a floor/ceiling level limit, and the intervention of a decision processor, can lead to a negative loop of reflex regulation. (Berezowska-Azzag, 2005; Hocine, 2021).

Systemic approach to extract trigger factors and their thresholds

Following the establishment of these fundamental concepts, the ‘general system paradigm’, ‘systemic causality’, and ‘tree representation’ are employed to depict the critical progression of a metropolitan social-ecological system. The methodology developed in earlier research was used as the basis for this study (Hocine, 2021). Three methodologies and tools related to thresholds in engineering design and land-use planning are also examined to deepen the understanding of limits in sustainability assessment.

As in the previous study (Hocine, 2021), the thresholds and limits of development in territorial sustainable suburban planning will be examined, with particular emphasis on the role of indicators, observatories, and threshold dashboards as essential components of strategic and intelligent planning for enhanced dynamic territorial management. Insights were drawn from systems developed by Repetti and Desthieux (2006), Berezowska-Azzag (2013), and Hocine (2021). The methodology is built on the general framework established in an earlier publication (Hocine, 2021) to model positive feedback mechanisms and threshold crossings within circular causal frameworks as defined by de Rosnay (1975), Morin (1981), and Le Moigne (1994).

In his book *Le Macroscopie*, de Rosnay (1975, p.79) contrasts circular causality with linear causality, asking: “Does the cause precede the effect, or is it the opposite?” He argues that the question cannot be answered definitively, noting that cause and effect appear to be intertwined. They cannot be dissociated in time. Causality circulates throughout the loop and leads to vicissitudes. For systems scientists, the vicious circle can be transformed into a virtuous one through balancing. The most illustrative examples are: (1) the flow of

materials and the explosion of waste quantities; balancing by recycling reverses the trend towards a new balance; and (2) the explosion of CO₂ emissions and the pursuit of balance by their mitigation at source or increasing carbon sinks.

Morin (1981) further develops this by emphasising feedback in closed systems, which create their own causality and autonomy. Le Moigne (1994) ranked the complexity of evolving system models from 1 to 9, with level 4 involving the information system and level 5 involving the decision-making system. The threshold then allows the emergence of level 6; the decision processor will have to plan actions for compensation and stabilisation, drawing on the reserves of its memory. Memory is important for decision-making systems, and can notably give rise to dashboards and urban observatories. As previously stated by Hocine (2021), this approach has been applied in medical science research (Falissard, 2005) and developmental psychology (Vernon *et al.*, 2015). This study identifies strategies to address unstable conditions in territorial, urban and social-ecological systems resulting from threshold exceedance within these circular causalities.

Unsustainable urban development causes a crisis when the socio-ecological system reaches its limits. A virtuous negative feedback loop counteracts a vicious positive feedback loop to restore system integrity. A heuristic mapping method was used to identify stabilising and destabilising elements, as well as threshold indicators, representing multiple factors in arborescent shapes (Kumar *et al.*, 2013).

METHODOLOGICAL FRAMEWORKS FOR ASSESSMENT

To perform urban sustainability, it is necessary to merge theoretical constructs, practical methodologies, and three crucial elements: modelling the threshold system, selecting an experimental territory, and creating the S³-TI assessment tool.

Modelling threshold systems

A tree model of threshold systems is developed on the basis of previously identified driving factors and threshold indicators. Five auxiliary systems are incorporated into the model: social, managerial, economic, environmental, and built environment. Systems theory is employed to construct a modelling tool capable of representing complex interdependent thresholds and variables that contribute to system stabilisation.

Selection of experimental terrain

Algiers, the capital and largest metropolitan region of Algeria is administratively divided into 57 municipalities. The Master Plan for 2035 or PDAU-2035 (*Plan Directeur d'Aménagement et d'Urbanisme*) outlines a CUSA – Central Urban System Area composed of 27 municipalities and nine additional urban systems (PDAU, 2015). This study focuses on the municipality of Bordj-El-Kiffan (Figure 1), which is part of the suburban areas due to recent population growth and housing constructions that require a rapid sustainability assessment.

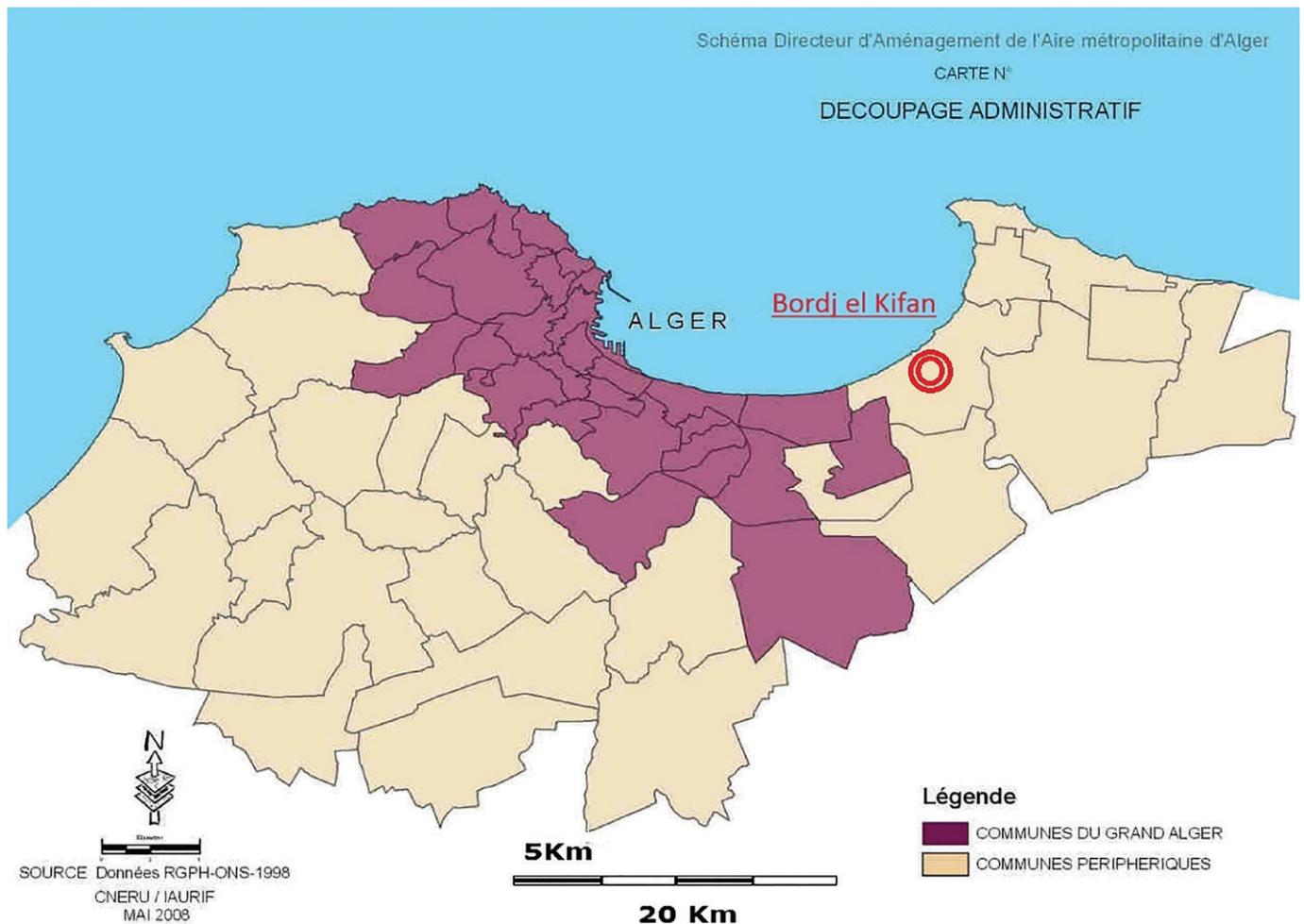


Figure 1. Bordj-El-Kiffan municipality in suburban Algiers, East side of CUSA-central urban area system (Source: CNERU/IAURIF, 2008)

According to numerous studies, the development of the Algiers metropolis and its municipalities does not seem sustainable, demonstrated by:

- Ben-Hamouche and Medjitna (2020, p. 353) showed that “Algiers offers a striking example of the urbanisation trend and primacy observed in many African and Arab countries”. From its origins, the city has been deeply shaped by the colonial era and by a capitalist economy largely rooted in rural–urban disparities.
- Tabti-Talamali and Baouni (2018) and Hocine (2021) have emphasised the redeployment of the population towards suburban areas in their research on residential mobility in Algiers. Within 50 km of the CUSA central urban system, an array of secondary cities has subsequently developed at a rapid pace.
- Semmoud (2003; 2015) examined how social inequality and mobility had contributed to maintaining the Bordj-El-Kiffan and other Algiers fringe municipalities in a state of uncontrolled development.

Bordj-El-Kiffan was also examined as part of the Algiers Bay development project study (Nouri-Boudiba *et al.*, 2022). Bordj-El-Kiffan, originally a rural area containing 21.5 km², is located entirely on the fertile Mitidja plain, and bordered to the south by the hills of the Blida Atlas and to the north by the Mediterranean Sea. It features 8 km of beaches

and tourist facilities. Because of the proximity to Algiers’ industrial belt built in the 1970s, workers have taken over some abandoned fields and farmland to meet their need for affordable housing.

The 1990s, marked by terrorism, prevented the establishment of a sustainability assessment framework. The municipalities and the PDAU-2010 urban plan (approved in 1995) lack coherent development projects, and the rush to provide housing and facilities for residents and war refugees had a detrimental effect on the municipality’s sustainability assessment (Baouni, 2016). Migration to the Algiers wilaya and its territory took on intensity during a period of anti-terrorism operations. Many inhabitants felt compelled, because of security threats in their regions, to move to denser, safer areas, hence Algiers. This situation affected a few poorly prepared municipalities in the Algiers wilaya, particularly Bordj-El-Kiffan. The resignations of the urban administration, the war on terrorism, and the expansion of uncontrolled urbanisation have worsened these problems (Hocine, 2021).

Bordj-El-Kiffan experienced major socioeconomic changes, urbanisation, and demographic increases between 1989 and 2015. Its population increased from 61,035 in 1987 to 147,715 in 2008. According to the prospective diagnosis of the PDAU-2035 urban plan, which includes a section on

socio-economic aspects and scenarios projected a further rise to 191,144 inhabitants by 2015 (PDAU, 2015). The PDAU-2035 aims to analyse sustainability through 2035, integrating fringe territories into metropolitan dynamics. Semmoud (2015) highlighted the efforts made by the wilaya's administration to reduce disparities between central and suburban communities.

This resulted in infrastructure upgrades across three main categories: (1) local facilities and services (schools, health, post offices, etc.); (2) basic infrastructure (sanitation, water supply, and electricity); and (3) significant infrastructure developments, such as the east-west tramway line and coastal protection measures along an 8 km of BEK (Bordj-El-Kiffan) shoreline. Notable disparities between the BEK municipality and the CUSA underscore the importance of enhanced local sustainability assessments in the future (Figure 2).

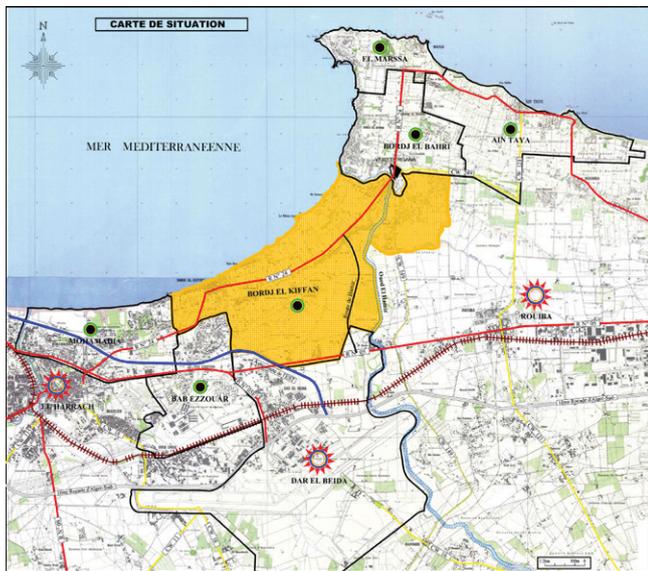


Figure 2. Bordj-El-Kiffan municipality along the Mediterranean coast and the national road n°24 (Source: PDAU, 2015, modified by Authors)

Proposing the S³-TI assessment tool

The threshold system was first modelled and subsequently tested in the suburban municipalities of Algiers, with Bordj-El-Kiffan selected as the case study. Before proceeding with the analysis, the municipality and its planning and management context are introduced, with emphasis on three key elements:

- Gathering data on indicators and their accessibility in Bordj-El-Kiffan and Algiers wilaya and classifying them within preset subsystems;
- Hypothetically assigning average points, referencing PDAU-2035 and the central urban system area (CUSA), composed of 27 Algiers municipalities; and
- Providing comments on the findings and calculating and verifying achievement threshold levels.

This experimental method explains the reduction in urban quality in Algiers' fringes. The benchmark establishes a shared norm based on target indicators that preserves local urban system stability and prevents destabilisation.

Internal, temporal, and spatial comparisons are employed by integrating territorial units; this is achieved by contrasting a suburban municipality with the central urban area of Algiers. The development of threshold indicators can be further refined by considering additional urban entities. Alternative benchmarking methods remain possible. The benchmark's 'acceptable' values align with the average values observed in the reference territory. Data is sourced mainly from PDAU-2035 (PDAU, 2015), governmental sources (DPAT, 2005; DPAT, 2015; ONS, 2011; ONS, 2012), and other researchers' data (Berezowska-Azzag *et al.*, 2015; Hocine, 2021).

RESULTS AND DISCUSSION

The benchmark was applied to a reference territory: the CUS (Central Urban System) area comprising (27 municipalities) as defined in PDAU-2035. It is an experimental assessment, based on the threshold values (floor and ceiling) derived from the CUS area by an aggregation procedure. The values and their weights were hypothesised to be acceptable. A participatory judgment of experts and/or citizens within the framework of an observatory or a dashboard could retain the threshold values.

As in the previous publication (Hocine, 2021), hypothetical average weights, a point-based weight scale, and a five-level colour code (1-acceptable, 2-critical low, 3-critical high, 4-unacceptable low and 5-unacceptable high) were set. Based on the average calculation formula (1) below, an acceptable threshold weight and a reasonable ideal constant were obtained, denoted as 'What' (hypothetical acceptable threshold weight):

$$What = \frac{1}{27} * \sum Wlci(i = 1, 2, 3, \dots, 27) \quad (1)$$

What: hypothetical acceptable threshold Weight
Wlc: locally collected Weight
i: central urban area 27 municipalities

The socio-ecological system is organised into five auxiliary systems. It is then followed by an experimental evaluation using 65 relevant and feasible threshold indicators specific to the township and municipal territory of Bordj-El-Kiffan. The assessment matrix is structured around the three core subsystems of sustainable development: economic, social, and environmental, with governance incorporated as a key enhancement to both the social and economic subsystems. Given its significance, the ecological aspect is divided into two subsystems: the natural environment and the built environment. The selection of the 65 indicators was guided by both their pressure attributes and data availability. The administration of the wilaya of Algiers validated all the data used. Tables 1-5 present the results:

- AS1: Social, 17 indicators (Table 1)
- AS2: Managerial, seven (7) indicators (Table 2)
- AS3: Economic, 16 indicators (Table 3)
- AS4: Environmental, 12 indicators (Table 4)
- AS5: Built-Environment, 13 indicators (Table 5)

The use of ratios and aggregation allows for the comparison between the BEK municipality and the CUS area without the results being skewed by their differences in size. Furthermore, as a suburban municipality, BEK is justified in seeking to evaluate the sustainability of its urban development. In the absence of an established system of indicators, internal benchmarking presents a viable approach. This method can use the central urban area as a reference for sustainable development and extend the analysis to suburban zones, enabling assessment even when standardised frameworks are lacking.

This represents an important milestone toward developing and refining a methodological framework for appraising urban sustainability at the local scale. The development of context-sensitive tools is part of this framework.

The calculated weight in the Bordj-El-Kiffan municipality is assigned a score, expressed in points according to formula (2) below (Hocine, 2021). The Acceptable Threshold weight – or the reference threshold for optimality – is set at a score of 100 points, fixed by the reference region.

$$Sl = \frac{Wlc}{What} \times 100 \text{ points} \quad (2)$$

Sl: Local score In Bordj-El-Kiffan
Wlc: Locally Collected Weight
What = hypothetical acceptable threshold Weight
The optimal Score, in 27 CUSA municipalities is fixed at: 100 points

Assessment results

Thresholds indicators

The indicator’s weight is always 100 points (Hocine, 2021), nevertheless, the weight of the threshold indicator can be expressed as follows:

- More (>) 100, the threshold is then called ‘high’ or,
- Less (<) 100, the threshold is then called ‘low’

Aggregate threshold indicators

Aggregations are essential to represent threshold indicators for each auxiliary system and the entire social ecological system. The Weighted Sum Method (WSM) is employed to aggregate the various trigger factors (causes and effects) arising from the multi-component and auxiliary systems. This method is renowned for its mathematical simplicity and is common to mathematical multi-criteria analysis. Employing a top-down method following a thematic approach, numerous criteria were combined, assuming transitive judgments (e.g., a > b, b > c, then a > c) (Hocine 2021). The total weight score is expressed in points and is obtained using the formula (3), below:

$$Slag = \left[\frac{\sum Sli}{\sum Shat} \right] * 100 (i = 1, 2, \dots, n) \quad (3)$$

Slag: Local aggregated weight score In Bordj-El-Kiffan, i: indicators and/or aggregated indicator
Sli: Local scores In Bordj-El-Kiffan (i=1,2,...,n)
Shat = hypothetical acceptable threshold Score, in 27 CUSA municipalities, fixed at 100 points

Table 1. Test assessment ‘social’ auxiliary system, acceptable threshold indicators (Source: Authors, according to: DPAT (2005), DPAT (2015), ONS (2011), ONS (2012), Berezowska Azzag et al. (2015), PDAU, (2015), Hocine, (2021))

Threshold Indicator (code & unit)	W _{lc}	W _{hat}	S _i (point)	S _{hat}	High/low
AS1.1: number of students by pedagogical division in primary education (No. /Div.)	35.0	29.5	118.7	100	(↑)
AS1.3: number of pupils per pedagogical division in secondary education (No. /Div.)	38.4	29.3	131.0		
AS1.14: public health care facilities capacity (U/10, 000 inhb.)	0.9	0.8	112.5		
AS1.16: capacity of hospitality facilities (U/10, 000 inhb.)	46.0	44.2	103.3		(↓)
AS1.2: availability educational places in high schools (No. /10,000 inhb.)	324.6	436.6	74.3		
AS1.4: vocational training centre density (U/10, 000 inhb.)	0.08	0.2	40		
AS1.5: ratio of trainees in vocational training centre (No. /10,000 inhb.)	17.5	31.0	56.5		
AS1.6: density of post office (U/10, 000 inhb.)	0.2	0.6	33.3		
AS1.7: telephone connection density (Con. No. /10,000 inhb.)	807	1781	45.3		
AS1.8: internet connection density (Con. No. /10,000 inhb.)	72.2	359.3	20		
AS1.9: publishing house density (U/10, 000 inhb.)	0.1	0.9	11.1		
AS1.10: density of listed heritage buildings (U/10, 000 inhb.)	0.1	0.4	25		
AS1.11: density of cultural facilities: public libraries, youth and cultural centres (U/10,000 inhb.)	0.2	0.6	33		
AS1.12: capacity in preschool places (No. /10,000 inhb.)	12.8	25.2	50.8		
AS1.13: capacity of sport facilities (U/10,000 inhb.)	0.6	1.1	54.5		
AS1.15: pharmacy capacity (U/10, 000 inhb.)	1.9	3.2	59.3		
AS1.17: Travel agency capacity (U /10,000 inhb.)	0.5	1.2	41.6		

Table 2. Test assessment 'Governance' auxiliary system, acceptable threshold indicators (Source: Authors, according to: DPAT (2005), DPAT (2015), ONS (2011), ONS (2012), Berezowska Azzag et al. (2015), PDAU (2015), Hocine, (2021))

Threshold Indicator (code & unit)	W _{lc}	W _{hat}	S _i (point)	S _{hat}	High/low
AS2.1: Municipality (local government) provision (U /10,000 inhb.)	0.15	0.2	75	100	(↓)
AS2.2: Capacity of local government officer (No. /10,000 inhb.)	74.4	92.2	80.7		
AS2.3: Operating expenses per inhabitant (Dzd. / Inhabit)	3835	5141	74.6		
AS2.4: Capacity in neighbourhood association (No. /10,000 inhb.)	2.9	7.1	40.8		
AS2.5: Subsidy for local associations per inhabitant (Dzd. / Inhabit.)	158.4	473.4	33.4		
AS2.6: Civil defence station provision (U /10,000 inhb.)	0.10	0.11	90.9		
AS2.7: Capacity in sanitation worker (No. /10,000 inhb.)	8.9	21.2	42.0		

Table 3. Test assessment 'economic' auxiliary system, acceptable threshold indicators (Source: Authors, according to: DPAT (2005), DPAT (2015), ONS (2011), ONS (2012), Berezowska Azzag et al. (2015), PDAU (2015), Hocine, (2021))

Threshold Indicator (code & unit)	W _{lc}	W _{hat}	S _i (point)	S _{hat}	High/low
AS3.1: annual population increase, 2008-2015 (%/ year)	5.2	1.2	433.3	100	(↑)
AS3.3: level of uneducated women in the total female population (%)	17.9	15.8	113.3		
AS3.16: number of industry economic entities (U /10,000 inhb.)	30.1	28.3	106.3		
AS3.2: level of the population over 65 (%)	6.5	10	65		(↓)
AS3.4: level of women with university education (%)	8.1	14.5	55.9		
AS3.5: level of working women in the female population (%)	16.2	25.1	64.5		
AS3.6: level of active male population in the male population (%)	72.9	74.5	97.9		
AS3.7: level of uneducated male population (in global male population) (%)	9.7	13.1	74		
AS3.8: inhabitants receiving social assistance (U /10,000 inhb.)	62.3	91.3	68.2		
AS3.9: household rate with a second home (%)	2.8	4.6	60.9		
AS3.10: households equipped with washing machines (%)	39.2	50.3	77.9		
AS3.11: households equipped with computers (%)	17.3	25.8	67		
AS3.12: level of household energy consumption (103 Kwh/annum)	33	60	55		
AS3.13: total economic entities (U /10,000 inhb.)	284.8	351.3	81.1		
AS3.14: number of service economic entities (U /10,000 inhb.)	78.7	115.3	68.3		
AS3.15: number of business economic entities (U /10,000 inhb.)	112.3	191.8	58.6		

Table 4. Test assessment 'environmental' auxiliary system, acceptable threshold indicators (Source: Authors, according to: DPAT (2005), DPAT (2015), ONS (2011), ONS (2012), Berezowska Azzag et al. (2015), PDAU (2015), Hocine, (2021))

Threshold Indicator (code & unit)	W _{lc}	W _{hat}	S _i (point)	S _{hat}	High/low
AS4.1: Land area subject to landslide hazard (Ha)	4000	1400	285.7	100	(↑)
AS4.2: Land area subject to flood hazard (ha)	2500	1000	250		
AS4.3: Urban protected land against Urb. Dev. (ha /10,000 inhab.)	120	40	300		
AS4.7: Availability of LPG (liquefied petroleum gas) filling station (U /10,000 inhb.)	0.2	0.1	200		
AS4.10: Number of chronic respiratory patients (No. /10,000 inhb.)	2.7	2.6	103.8		
AS4.11: Number of water drilling sites per km ² (No. /km ²)	1.5	0.4	375		(↓)
AS4.4: Availability of wooded (forest) land (ha /10,000 inhab.)	4.9	8.5	57.6		
AS4.5: Public parks and gardens (U /10,000 inhb.)	0.3	1.4	21.4		
AS4.6: Availability of urban green areas (m ² / inhab.)	0.1	10.2	1		
AS4.8: Share of housing connected to gas (%)	41.8	69.9	59.8		
AS4.9: Number of households with a private car (%)	35.7	41.1	86.9		
AS4.12: Level of housing connection to the sewerage network (%)	75.7	88.8	85.2		

Table 5. Test assessment 'built-environment' auxiliary system, acceptable threshold indicators (Source: Authors, according to: DPAT (2005), DPAT (2015), ONS (2011), ONS (2012), Berezowska Azzag et al. (2015), PDAU (2015), Hocine, (2021))

Threshold Indicator (code & unit)	W_{lc}	W_{hat}	S_i (point)	S_{hat}	High/low
AS5.1: Sustainability assessment area per inhabitant (m ² / inhab.)	102	92.9	109.8	100	(↑)
AS5.3: Evolution rate of sustainability assessment area from 2011 to 2035 (% / year)	1.05	0.8	131.3		
AS5.4: Annual evolution rate of the housing stock, 1987- 2015 (% / year)	15.1	6.4	235.9		
AS5.7: Annual evolution of new housing program for 2015-2035 period (% / year)	1.8	1.6	112.5		
AS5.2: Population density in sustainability assessment area (Inhab. / ha)	102	108	94.4		
AS5.5: collective housing rate in housing stock (%)	20.1	43.2	46.5		(↓)
AS5.6: Housing density in sustainability assessment area in 2015 (Houses / Ha)	18.2	23.1	78.8		
AS5.8: Business park surface area per inhabitant in 2015 (m ² / inhab.)	1.3	4.5	28.9		
AS5.9: Number of households with a private vehicle (%)	35.7	41.1	86.9		
AS5.10: Availability in 1st and/or 2nd order street linear (Km/ 10,000 inhab.)	1.0	3.5	28.6		
AS5.11: Availability of public transport (bus, tramway) lines (U. / 10,000 inhab.)	0.1	1.4	7.1		
AS5.12: Availability of public transport (bus, tramway) seats (U. / 10,000 inhab.)	340	550	61.8		
AS5.13: Availability of public transport stations: bus, train, metro, tramway (U. / 10,000 inhab.)	0.2	0.5	40		

Next, threshold indicators were aggregate from the five auxiliary systems, distinguishing between default values (low) and excess values (high) in Table 6.

Table 6. Threshold indicators aggregated by auxiliary system and global (Source: Authors)

Auxiliary systems	S_i (point)	S_{hat}	S_{lag}
AS1: Social	116.3 (↑)	100	183.4 (↑)
AS3: Economic	217.6 (↑)		
AS4: Environmental	252.4 (↑)		
AS5: Built-Environment	147.4 (↑)		
AS1: Social	41.9 (↓)		
AS2: Management	62.5 (↓)		
AS3: Economic	67 (↓)		
AS4: Environmental	52 (↓)		
AS5: Built-Environment	47.4 (↓)		

Threshold representations

The assessment objective is to inform a broad audience about the attainment of at least five threshold levels: acceptable, critical (low, high), and unacceptable (low, high). A result meter was created, based on the work of Stossel et al. (2015) and Hocine (2021), to display the score points for each threshold indicator and for the aggregated threshold indicator. The result meter shows both the measured (local) value and the optimal (threshold) value, along with the indicator weight (score in points) and the optimal weight (100 points). The three main situations of reaching threshold values, their points score, and cursor colour code are as follows:

- Acceptable: 75 < P.S. < 125 - ☺
- Critical, (2.1) Low value: 50 ≤ P.S. ≤ 75- ☹, (2.1) High value: 125 ≤ P.S. ≤ 150- ☹
- Unacceptable, (2.1) Low value: 0 ≤ P.S. ≤ 50- ☹, (2.1) High value: P.S. > 150- ☹

In the Result meter, the point index highlights three situations when thresholds exceed the floor or ceiling values. Hypothetically the levels were fixed. The colour code comprises three complementary colours: green, orange, and purple, representing the five states: acceptable, critical (low, high), and unacceptable (low, high), as defined earlier.

Threshold indicators can be depicted in the result meter (Figure 3), showing both high and low values, aggregated by the auxiliary system and globally for the entire social ecological system.

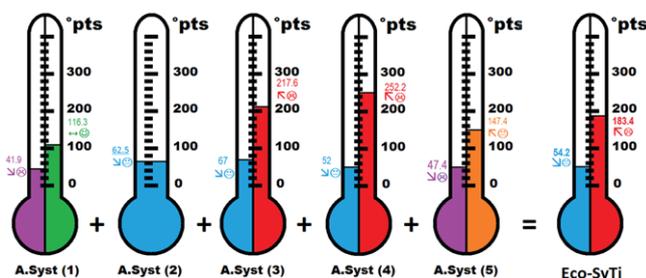


Figure 3. Systemic threshold index result meter aggregated by auxiliary system and globally for all the social ecological-system (Source: Authors)

Discussion of results

Urban development, particularly in major cities and metropolitan areas, should prioritise environmental sustainability. When urban growth exceeds critical or unacceptable thresholds, municipal management must assess and notify residents groups. Considering this assessment and the definition of critical or unacceptable thresholds, some strategies are presented for the sustainable and balanced development of Bordj-El-Kiffan.

Social auxiliary system

Multiple threshold indicators (AS1.3, AS1.6, AS1.7, AS1.8, AS1.11, AS1.12, and AS1.13) highlight substantial limitations in providing essential urban services at the neighbourhood level, including secondary education, sports, culture, youth,

early childhood services, a postal service, and ICT services across social, physiological, and operational aspects.

For instance, the UN's Sustainable Development Goal 4 advocates for inclusive and equitable quality education throughout all primary and secondary schools. However, should secondary education be limited only to those in central districts? It is argued that the population of Bordj-El-Kiffan, as in other suburban municipalities, should have adequate access to educational opportunities. The educational facilities considered here are limited to the secondary level. Higher education institutions (universities, research centers) serving broader metropolitan and regional networks beyond municipal boundaries were not included in this evaluation.

This assessment highlights substantial shortfalls in the facilities and equipment available within Bordj-El-Kiffan's urban context, particularly evident in indicators AS1.9, AS1.10, and AS1.7, which point to a pronounced lack of cultural infrastructure.

To revitalise certain regions and reduce over-tourism in central areas, there is a greater focus placed on developing heritage initiatives, focusing more on rural, archaeological, and intangible resources. These approaches are labelling and developing new alternatives to traditional tourism by utilising local specialties, agricultural products, and landscapes.

Management auxiliary system

The assessment identifies states with threshold excesses as follows:

- Citizen involvement tends to be weak, especially when local organisations receive extra support from local authorities. (See threshold indicators AS2.4 and AS2.5);
- Weak management services, particularly in the collection of waste, as evidenced by the threshold indicator AS2.7.

Bordj-El-Kiffan residents and the local government must recognise the importance of smarter urban management. This involves the implementation of threshold dashboards, observatories, and indicators, followed by dynamic territorial management techniques such as monitoring, tracking, and benchmarking (Repetti and Desthieux, 2006; Hocine, 2021). Modern urban planning, as described by Berezowska-Azzag (2013), has evolved into a project with three key components: encompassing social justice, economic performance, and environmental sustainability (Hocine, 2021). Through participatory and collaborative means, these components have evolved into a local government. The responsible, efficient, and strategic shaping of the future of urban development necessitates engineering, innovation, and a vision of urban intelligence (Berezowska-Azzag, 2013). Intelligence and intelligent system control represent advanced levels of system complexity (Le Moigne, 1994).

Economic auxiliary system

The evaluation of this system has revealed unacceptable threshold crossings in terms of both the rate and magnitude of population growth, as indicated by AS3.1. Economic development inadequately engages women and the elderly,

as reflected in indicators AS3.2, AS3.4, and AS3.5. Additionally, access to economic opportunities that would bring life on par with CUSA's 27 municipalities remains significantly challenging, as indicated by threshold indicators AS3.11 and AS3.12.

This unsustainable development scenario runs counter to the United Nations Sustainable Development Goals and 2030 Sustainable Development Goals. This specifically contradicts the definition of sustainable development in the Commission's 2017 report, which abolishes all forms of poverty internationally (UN, 2017).

Environmental auxiliary system

This assessment highlights the municipality of Bordj-El-Kiffan's challenges in protecting and upgrading its freshwater, groundwater, and green agricultural soil resources. Key components of the water cycle and territorial hydrogeology (such as watercourses and aquifers) face management limitations, as indicated by threshold indicators AS4.1, AS4.2, and AS4.11.

Threshold indicators AS4.4, AS4.5, and AS4.6 regarding population access to urban green spaces and wooded areas reveal critical circumstances. Although unused soil resources have potential for urban use, they are primarily employed in agriculture. Conversion of large-scale agricultural land is a widespread tendency in suburban areas, posing a danger to the stability of the eco-social system.

To fulfil the land requirements of the Bordj-El-Kiffan municipality, the PDAU-2035 established a 169 ha urban land reserve as one of its components. Additionally, a 533 ha restricted construction area was designated into three primary categories (PDAU, 2015; Hocine, 2021):

- Agri-park: a perimeter aimed at stopping urbanisation, a kind of city-scale green belt (373 ha);
- More major agricultural land is being protected and added to the Algiers wilaya's Agricultural Land Reserve: 73 ha; and
- Natural area related to the wetland of the El Hamiz River (87 ha) and shoreline facing the Mediterranean Sea (41 ha)

Initiatives for natural areas, agri-parks and agricultural reserves have yet to begin, although urbanisation programs have generated considerable areas for housing operations. Long-term urbanisation schemes would divert prime agricultural soils from their intended use for urbanisation.

Built-environment auxiliary system

From a built-environment perspective, the threshold indicators signal high urban growth expected by 2035 within the new urban perimeter (PDAU, 2015; Hocine, 2021), with indicators AS5.3 and AS5.4 having already been at critical levels since 1987. Mobility conditions in the area have seen little improvement, largely due to the absence of an integrated multimodal transport network to accommodate urban growth that is primarily housing-focused. Threshold indicators AS5.10, AS5.11, AS5.12, and AS5.13 underscore deficiencies in the road system, particularly regarding the development of first- and second-order roads, which signals a suboptimal transport network.

Urban sprawl and design constraints drive people to rely on private vehicles despite growing congestion (Newman and Kenworthy, 2006). The Bordj-El-Kiffan municipality has had a tramway in place since 2010. Given its population and urban growth, it stands to gain even more from this type of transportation. A densification process, as well as functional diversification and urban intensification along the corridor in line with Transit-Oriented Development (TOD) theory (Wood, 2021), can enhance the municipality's urbanisation model. This assessment highlights Bordj-El-Kiffan's challenges in establishing an independent sustainability model. Although PDAU-2035 aims to limit farmland conversion, it has still allocated a 169 ha land reserve for housing and amenities in the municipality (PDAU, 2015).

To preserve the natural urban growth potential and safeguard natural resources, especially land, the Bordj-El-Kiffan municipality must consider two key strategies: (1) densifying its urban fabric and (2) postponing urbanisation to other sites within the regional urban network where potential exists (Hocine, 2021).

The 'Systemic Thresholds Index' suburban sustainability assessment tool can be used to efficiently mobilise human, financial, and managerial resources, while also being an early warning system. Communities worldwide are continuously developing innovative approaches to sustainable development and resilience building. The Bordj-El-Kiffan municipality appears capable of implementing this strategy.

The S³-TI assessment tool raises awareness of the importance of establishing and adhering to thresholds and facilitating arbitration and compromises. It enables effective management of climate change impacts, resource scarcity, and fulfillment of human and community development needs. As in the previous publication (Hocine, 2021), its integration is envisioned as part of an assessment and monitoring tool in future municipal land use and development plans, enhancing the quality of the planning process and promoting local sustainable development.

CONCLUSIONS

After conducting this study, the threshold-based assessment modelling revealed several limitations:

- The database used mainly reflects past conditions, which may not fully reflect the evolution over time of threshold exceeding processes.
- The evaluation model needs to be made stronger by performing sensitivity analyses and replacing the current list of sixty-five (65) indicators with equally relevant ones.
- The third limitation relates to the relationship between the five (5) threshold levels: acceptable, critical (low, high), and unacceptable (low, high), as well as their weight (expressed in points), which represents an average value. Typically, these elements can be generated through focus groups and brainstorming sessions in an urban decision-makers' workshop or an urban/metropolitan observatory (Hocine, 2021). However, due to unavailability, an empirical simulation study was substituted.

- Internal benchmarking was selected to construct the evaluation database indicators. Specifically, this means spatial comparison by aggregating territorial entities (municipalities, wilaya averages, etc.). Further refining this comparison by incorporating sub-municipal urban organisations – such as homogeneous or structural units – could yield more detailed and nuanced findings.

Our development approach prioritises qualitative aspects, such as urban comfort, social well-being, and environmental balance, over quantitative growth alone. Sustainability assessment allows for effective decision-making and adaptability to stress and crises. Addressing negative human impacts is emphasised through impact assessment, which is essential for averting environmental crises while preserving resource availability. The impact magnitude depends on the factors exceeding the thresholds. The system's carrying capacity is directly linked to its acceptability. Evaluating thresholds by participatory members establishes acceptance, often via observations integrated into master plans (Ohnuma *et al.*, 2022; Repetti and Desthieux, 2006).

The essential concept here is the threshold for sustainability and other social-ecological system components. At critical levels, their overruns can cause irreparable damage. Considering this, sustainability assessment planning tools should include a monitoring mechanism, informed by diagnoses and assessments, and a dashboard, to communicate potential development crises. The S³-TI tool's development leads to sustainable and intelligent planning for suburban areas. The objective is to integrate the S³-TI assessment tool into urban planning practice in Algerian cities. With the ongoing revision of the Algerian Act, university researchers are tasked with contributing to its enhancement. This addresses challenges in Algiers, potentially, other Algerian, African, and global south cities. Careful attention is essential, given the issue's sensitivity and limited human skills in planning suburban municipalities.

By the end of the 21st century, the global surface will cross the 1.5°C and 2°C warming thresholds. There are potential future developments of the S³-TI assessment tool for mitigation and attenuation strategies. They are fundamental components of urban planning practice, helping to create more sustainable and resilient cities, in reference to the UN SDG Goal 13 "Climate Action" (UN, 2017).

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TOURISM POTENTIAL OF THE WESTERN SERBIAN LAKES

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Western Serbia boasts a hilly landscape and rich natural and cultural heritage, enriched by its hydrographic network of rivers and artificial lakes. While the lakes are mainly used as water management facilities, recently their coastal areas have been improved to promote tourism, turning the lakes into tourist attractions. Their tourist valorisation is therefore essential for water-based tourism development and its integration with other forms of tourism. This paper analyzes the current state, development opportunities, and preservation of the observed area through planning documents and legislation. Spatial Plans in Serbia have a key role as the mechanism for the improvement and protection of the lakes. They contribute to the preservation of natural resources while creating added value through tourism. The emphasis of this paper is on a detailed review of the spatial plans aimed at preserving and protecting the lakes' potential, identifying, and minimizing negative impacts on aquatic ecosystems, as well as encouraging the development of activities compatible with natural resources and goods. The biggest challenge is planning and developing tourism within protected areas. While stimulating the economy and benefiting the local communities, dense tourism could also harm ecosystems and the spatial balance. Improving the coastal areas of lakes and developing tourist infrastructure can significantly increase attractiveness, but it is vital to simultaneously preserve natural resources. Balancing economic development with the protection of natural values to ensure their long-term sustainability is both a challenge and a necessity. Planning tourism development and involving the local population in it can be important steps in that direction.

Key words: lakes, tourism potentials, development, improvement, preservation.

INTRODUCTION

In recent decades, tourism has become one of the main drivers of economic development in many countries, including Serbia. Its importance stems from several key aspects. From an economic perspective, tourism generates significant financial income, creating new jobs in various sectors (hospitality, transport, services, etc.). The growing interest in tourism stimulates investments in infrastructure, including hotels, restaurants, and transportation networks, thereby enhancing the living standards of the local population. When it comes to culture and identity, tourism helps preserve and promote local culture, traditions, and both natural and cultural heritage, thus strengthening the community identity. In terms of sustainable development, with proper management, tourism can be sustainable, allowing the use of natural resources without overexploitation, thus preserving

ecosystems and biodiversity. Tourism development can contribute to the growth of less-developed areas by stirring economic activity and attracting more visitors to rural and less urbanised regions. Nevertheless, tourism can also give rise to challenges, e.g. overcrowding, pollution and a decline in the authenticity of local communities. Therefore, it is crucial to develop strategies that will enable the sustainable development of tourism, balancing economic benefits with the preservation of local culture and the environment.

Western Serbia, the case study in this research, is a region with exceptional potential for tourism development thanks to its rich natural resources, cultural and historical heritage, and traditions. It is one of the four main tourism clusters in Serbia (Službeni glasnik RS, 98/2016). Parts of the case study area also belong to the destinations Drina-Tara-Zlatibor and Zlatibor-Pešter, which are a primary tourist destination with a significant share of the year-round offer (Službeni glasnik RS, 88/2010).

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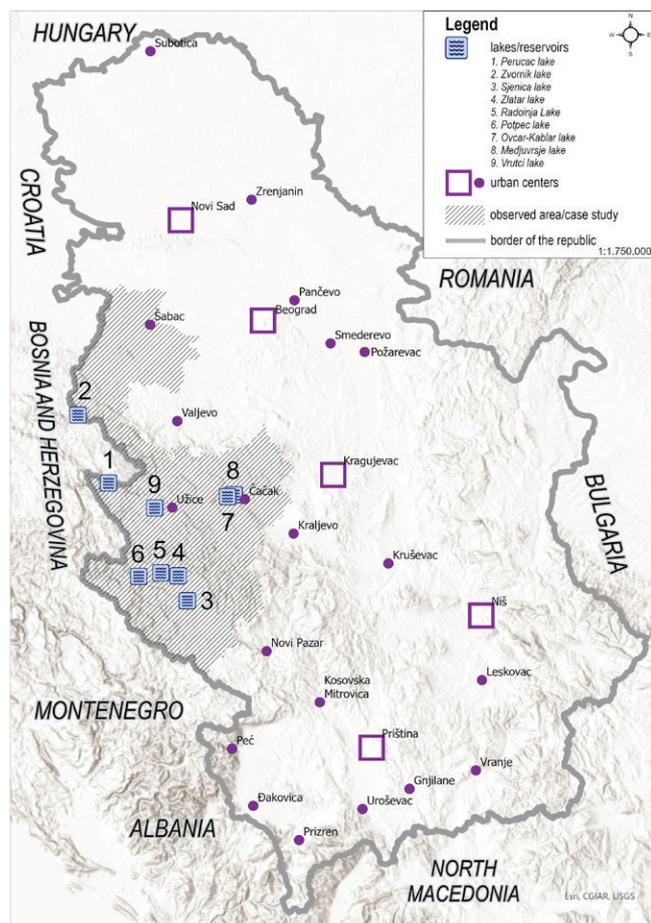


Figure 1. Position of the observed area (parts of the Mačvanska, Moravička and Zlatiborska oblast)
(Source: Authors, ESRI, CGIAR, USGS)

This paper will present the opportunities and challenges for enhancing tourism development in relation to artificial lakes, focusing on planning documents, strategies, and legislature that could contribute to attracting more visitors. By analysing the current state of geographic and socio-economic characteristics, key elements of tourism development at artificial lakes include: **natural assets** (artificial lakes are surrounded by mountains and greenery, and such landscapes are especially attractive and interesting to tourists); **water-based activities** (tourists can enjoy boating, sailing, fishing, swimming, and water sports, which increase the appeal of these locations); **hospitality and infrastructure** (the development of accommodation facilities, restaurants, and other tourist services is essential for attracting visitors, as are investments in infrastructure such as roads, parking areas, recreational facilities, etc.); **ecology and sustainability** (it is important to develop tourism in a way that does not harm natural resources, but preserves the environment and promotes eco-tourism, which attracts many visitors); **cultural and local content** (in addition to natural attractions, it is important to promote local culture, traditions, and gastronomy, which enrich the tourist experience); and **marketing and promotion** (effective marketing, including social media and travel agencies, which can help attract visitors).

In terms of utilisation, artificial lakes are currently underused compared to other forms of tourism in Serbia.

This is particularly significant given that some lakes are located near major urban areas, roads, and cultural and historical sites. Although they differ in size, climate and hydrographic features, location, and accessibility, artificial lakes can support transit, event-based, recreational, excursion, weekend, eco-, and ethno-tourism. In addition to their primary functions (such as power production, water supply, irrigation, etc.), artificial lakes enhance not only the coastal zones but also significantly larger areas in their hinterlands. As such, they can be considered to have priority tourism potential, especially given that Serbia has no access to the sea. Lake complexes, together with other natural and cultural values in their surroundings, are of importance in the development and improvement of tourism at both local and regional levels.

Tourism could significantly influence the local communities through economic development with new employment and a local economy boost (Đurašević, 2014), cultural heritage preservation, infrastructure development caused by increased interest in tourism, ecology and sustainability, education and awareness.

Several studies have shown that local communities are the main drivers and stakeholders of tourism development, and that local populations mostly have a positive attitude towards tourism development (Demirović *et al.*, 2019; Surla *et al.*, 2024; Surla *et al.*, 2025).

DESCRIPTION OF THE CASE STUDY

The Drina lakes

The dam of the Perućac Lake in Bajina Bašta, which is 461 m long and 93 m high, is located near the strong karst spring of Perućac. The artificial lake formed here is 50 km long, and a maximum of 70 m deep, with a width that ranges from 80 m to 500 m, and an area of 12.4 km². The lake accumulates 340x10⁶ m³ of water. Monthly water temperatures go up to 22°C, indicating that swimming is possible during the summer months. The lake has a greenish colour, with visibility that extends to a depth of up to 5 m (Stanković, 2005; RZS, 2025b).

Zvornik Lake was established in the mid-1950s. The dam is 166 m long and 42 m high. The lake can hold 89x10⁶ m³ of water. It is 25 km long, with a maximum width of 5.7 km, an area of 8.1 km² and a maximum water depth of 28 m. The average monthly water temperature in July and August exceeds 18°C, enabling water sports. Zvornik Lake has a dark green colour, with maximum water clarity reaching 4.5 m (Stanković, 2005; RZS, 2025b).

The Uvac and the Lim lakes

Sjenica Lake was formed on the river Uvac. It is 25 km long. The reservoir accumulates 212x10⁶ m³ of water, and the dam is 160 m long. The area of the lake is 5 km², with a maximum depth of 35 m. The lake's water is green in colour, with visibility reaching depths of up to 7 m (Stanković, 2005; RZS, 2025b).

Zlatar Lake is located about 50 km upstream from the confluence of the Uvac and Lim rivers. The dam is 83 m high and 1,264 m long with an area of 7.2 km² and a depth

of up to 75 m. The lake holds $250 \times 10^6 \text{ m}^3$ of water. During July and August, water temperatures (around 21°C) and air temperatures are the most suitable for swimming and water sports (Stanković, 2005; RZS, 2025b).

At the lowest point of the Uvac River, Radoinja Lake was formed. The dam of the lake is 40 m high and 150 m long. It is one of the smaller artificial lakes in Serbia, with an area of 1.8 km^2 , a capacity of $4 \times 10^6 \text{ m}^3$ of water, and a maximum depth of 30 m. Due to the inflow of large amounts of water from Zlatar Lake, which does not stay in its reservoir for long, the lower water temperature limits bathing tourism (Stanković, 2005; Rezervat Uvac d.o.o., 2025).

Potpeć Lake is located on the Lim. The Potpeć reservoir dam is 215 m long and 46 m high. The area of the artificial lake is 7 km^2 . It has an elongated shape due to the gorge-like structure of the Lim valley. The lake's maximum depth does not exceed 40 m, and the reservoir holds around $44 \times 10^6 \text{ m}^3$ of water (Stanković, 2005; RZS, 2025b).

The Zapadna Morava lakes

Ovčar–Kabljar Lake is located upstream from the railway bridge on the Čačak–Užice line. The dam is 45 m long and 12 m high. Nowadays the lake is 2 km long and 30–60 m wide, with an area of 0.72 km^2 while the reservoir has a capacity of approximately $3 \times 10^6 \text{ m}^3$ of water (usable $1.1 \times 10^6 \text{ m}^3$). The lake is subject to heavy sedimentation due to transported deposits, so the maximum depth is reduced to 2 m instead of 7 m. Because of these characteristics, Ovčar–Kabljar Lake is limited in terms of water-based tourism and sport fishing (Stanković, 2005; Službeni glasnik RS, br. 46/2019).

Međuvršje Lake is the largest reservoir on the Zapadna Morava River. The lake is 11 km long and 30–60 m wide, with an area of 1.7 km^2 , a capacity of $18.5 \times 10^6 \text{ m}^3$ of water (usable $11.1 \times 10^6 \text{ m}^3$) and a maximum depth reduced to 12–15 m instead of 23 m. The lake is located in the Ovčar–Kabljar gorge, whose shoreline is home to numerous protected monasteries, as well as Ovčar Spa, known for its thermal mineral water (Stanković, 2005).

Vrutci Lake, along with its dam, located on the Đetinja River, is a source branch of the Zapadna Morava, near the city of Užice. The dam is 77 m high and 241 m long, allowing the accumulation of $54 \times 10^6 \text{ m}^3$ of water. The lake extends along the Đetinja river valley for a length of about 7.3 km while the area of the reservoir at the normal backwater level is about 1.9 km^2 . Annual water level fluctuations range mainly up to 10 m, rarely 15 m or more, with a minimum water level during winter (Stanković, 2005; Službeni glasnik RS, br. 91/2018).

OVERVIEW OF TOURIST TRENDS

The reservoirs belong to the municipalities of Bajina Bašta, Mali Zvornik, Sjenica, Nova Varoš, and Priboj, and the cities of Čačak and Užice.

In 2022 and 2023, Bajina Bašta recorded the highest number of visitors among the listed municipalities, with about 2% of both domestic and foreign visitors' arrivals and an equivalent share of the total overnight stays in Serbia.

Table 1. Tourist visits and overnight stays in 2021–2024
(Source: RZS, 2023; 2024; 2025a)

Reservoir	City/municipality	Year: 2022					
		2021	2022	2023	2024	2025a	Total
Bajina Bašta	Bajina Bašta	85,018	77,592	7,426	312,804	294,096	18,708
Zvornik	Mali Zvornik	2,059	1,702	357	6,075	5,216	859
Sjenica	Sjenica	2,927	1,627	1,300	7,490	4,184	3,306
Zlatar	Nova Varoš	22,176	20,694	1,482	89,431	86,762	2,669
Radoinja							
Potpeć	Priboj	7,886	6,344	1,542	46,857	40,892	5,965
Ovčar–Kabljar	Čačak	54,716	39,054	15,662	217,471	177,887	39,584
Međuvršje							
Vrutci	Užice	38,658	23,558	15,100	80,495	56,380	24,115
The Republic of Serbia		3,869,235	2,096,472	1,772,763	12,245,613	7,306,219	4,939,394
Reservoir	City/municipality	Year: 2023					
		2021	2022	2023	2024	2025a	Total
Bajina Bašta	Bajina Bašta	76,217	67,881	8,336	281,362	261,823	19,539
Zvornik	Mali Zvornik	2,431	1,900	531	5,942	5,164	778
Sjenica	Sjenica	8,109	4,373	3,736	17,830	10,852	6,978
Zlatar	Nova Varoš	23,314	20,809	2,505	88,628	83,801	4,827
Radoinja							
Potpeć	Priboj	8,948	6,390	2,558	40,141	31,002	9,139
Ovčar–Kabljar	Čačak	53,298	34,482	18,816	185,344	139,393	45,951
Međuvršje							
Vrutci	Užice	47,259	29,190	18,069	101,374	73,041	28,333
The Republic of Serbia		4,192,797	2,058,492	2,134,305	12,440,935	6,858,331	5,582,604

Reservoir	City/municipality	Year: 2024					
Bajina Bašta	Bajina Bašta	55,321	49,157	6,164	200,406	182,639	17,767
Zvornik	Mali Zvornik	2,149	1,715	434	5,291	4,410	881
Sjenica	Sjenica	10,450	5,330	5,120	19,671	11,627	8,044
Zlatar	Nova Varoš	17,981	16,227	1,754	65,819	61,913	3,906
Radoinja							
Potpeć	Priboj	8,782	5,285	3,497	38,842	27,294	11,548
Ovčar–Kablar	Čačak	48,569	30,934	22,045	295,557	235,372	60,185
Međuvršje							
Vrutci	Užice	67,614	46,064	21,550	159,038	123,840	35,198
The Republic of Serbia		4,432,751	2,048,016	2,384,735	12,662,151	6,564,402	6,097,749

Regarding the average length of stay per tourist in 2024, the highest result is recorded in Priboj, with 5.2 nights for domestic and 3.3 for foreign tourists, followed by Čačak and Nova Varoš, with an average of 3.9 and 3.8 nights for domestic and 2.5 and 2.2 overnight stays for foreign tourists, respectively. The lowest value is recorded in Sjenica, amounting to 2.2 nights for domestic and 1.6 nights for foreign visitors (RZS, 2025a) (Table 1). Based on the presented data, it can be concluded that these local self-governments show an exceptionally low level of visitation, although conditions exist to significantly increase the number of tourists and visits.

In the observed area in October 2025, according to tourism sector data, 23 tourist accommodation facilities are categorised, with a total of 2,016 beds (Ministarstvo turizma i omladine, Sektor za turizam, 2025):

- Bajina Bašta has five hotels (two rated 2* and 3*, and one rated 4*, with a total of 458 beds);
- Mali Zvornik has one 2* hotel and 52 beds;
- Nova Varoš has one motel (rated 1*) and one hotel (rated 3*), with a total of 70 beds);
- Priboj has one 4* hotel with 108 beds;
- Sjenica has two hotels (one rated 3* and one rated 4*, with a total of 319 beds);
- Užice has four hotels and one tourist settlement (one rated 2*, two rated 3*, and one rated 4*, with a total of 645 beds); and
- Čačak has seven hotels (three rated 3* and four rated 4*, with a total of 364 beds).

Tourism products are not sufficiently commercialised on the domestic, or especially on the international market. Adequate marketing, stimulated commercial tourism and recreational demand, as well as an increase in the competitiveness of different tourism types could influence tourism development. Domestic tourists are mostly oriented towards mountain, spa, excursion, cultural-event, and rural tourism. Foreign visitors are mostly individual guests whose primary motives for their arrival are events, specialised types of tourism, and business trips. They cannot be attracted only by promoting the potential of natural resources, mountains, rural surroundings, spa areas, rivers, and lakes, but rather primarily by improving the quality of the accommodation and year-round tourist and recreational offer in an area, combined with preserved nature, ethno- and cultural heritage, and organic food.

EXCERPTS FROM PLANNING DOCUMENTS

The spatial plan of the special purpose area (SPSPA) for the mentioned accumulations, aimed at the development, improvement, and protection of such areas was adopted. Each planning document analysed, elaborated, and prioritised further development and preservation from a particular aspect. The accumulation areas in the planning documents are recognised as tourism values with numerous contents and possibilities for the local and broader environment.

SPSPA Uvac Special Nature Reserve (Službeni glasnik RS, br. 83/2010)

The natural and anthropogenic resources analysed by this spatial plan are the basic development potentials for a specific tourist offer. Based on the valorisation of available tourism resources, the possibilities for the development of winter-ski tourism, transit, excursion, rural, and ecological tourism are recognised.

The development of tourism, as a significant economic branch in the future, should be based on the preservation of nature and respect for the local communities' interests. Ensuring the traffic accessibility and integration of the area's tourist offer with the offer of the surrounding areas (mountains Zlatibor, Tara, Golija and Kopaonik) is a necessity. With the aim of developing tourism in the area, the priority is to complete the public utility, tourist infrastructure, tourist offers and programs, to raise the service standards of tourist capacities, and to activate the local population in rural areas (Šećerov *et al.*, 2018).

The dominant tourist products and the mentioned types of tourism will be based on rich natural and anthropogenic resources and spatial values such as lakes and rivers. Accordingly, fishing, sports, recreational, and other types of water tourism will be improved on three lakes within the Special Nature Reserve, the planned accumulation on Ljudska River, the Uvac and Vapa rivers, and other hydrological features. The unique meanders of Uvac, Đalovića Gorge, and other gorges (of the River Mileševka etc.) contribute to the attractiveness of aquatic areas and the development of specific tourist activities (panoramic sightseeing, photography, observation of protected endangered species, study of geomorphological phenomena, etc.). The development of all tourist products will be adapted to the needs of tourists, enabling the combination

of multiple types of tourism. The integration of the area's tourist offer with those of neighbouring municipalities and tourist regions provides a basis for the development of diversified thematic itineraries.

SPSPA Bistrica reversible hydroelectric power plant and Potpeć hydroelectric power plant (HPP) system (Službeni glasnik RS, br. 86/2024)

According to the spatial plan, the tourism offer will be integrated, in particular regarding the development and equipping of villages, and the use of tourism amenities in connection with the immediate surroundings. Tourism will be an alternative activity and a form of compensation for the local population for various development restrictions imposed by the operating regimes of the Bistrica Reversible HPP and the Potpeć HPP system, as well as by nature protection measures. The areas around Potpeć and Radoinja reservoirs are planned as excursion and transit-oriented sports and recreational destinations, near the infrastructure corridors of main roads and the railway line.

The planned picnic area will cater to transit tourists, as well as local day-trippers from Priboj, Nova Varoš, Prijepolje, etc. In the wider mountain region, excursion and hiking trails for pedestrians and mountain bikers are planned, featuring viewpoints, rest areas, pavilions, and more.

The tourism development potential in the planning area will be based on a healthy environment, under the condition of more intensive and organised protection, presentation, and controlled use of natural values (mountain peaks, ridges and slopes with habitats in forests and pastures, river flows and canyons, etc.), providing the prerequisites for the development of eco, ethno, and hunting tourism, as well as organic food production, ethno-handicrafts, forest fruit gathering, and more.

There are opportunities to organise tourism content in rural zones aiming to enhance the overall quality of life in villages. The tourism offer will also be based on cultural and historical landmarks (cultural monuments, ethno-values of traditional villages, and numerous events supporting tourism), with more intensive and organised presentation and use, including the revival of neglected traditional crafts and more.

The characteristics of the Lim and Uvac rivers, in the most attractive parts of their courses, provide favourable conditions for the development of a wide range of tourism products and activities (rafting, hiking, extreme sports, and more).

SPSPA Ovčar-Kablar Gorge outstanding features landscape (Službeni glasnik RS, br. 46/2019)

The development of tourism and outdoor recreation will be based on organised tours and specialised tourist guides focused on biodiversity and geodiversity, as well as nature schools and the values of geo-heritage. A Nature and Geo-heritage Route will be established along existing marked hiking and cycling trails and viewpoints, which will need to be equipped with tourist signage, informational boards, and accompanying amenities. Tours of the protected area will be organised on foot, by bicycle, or by controlled off-road vehicles, with rest areas and accommodation provided in Ovčar Banja, mountain lodges, private family-run guesthouses, and rural lodgings in tourist villages.

Spa and wellness tourism will be developed in Ovčar Banja, with planned hotel and spa capacities, as well as recreational amenities. The kayak trail downstream from the Ovčar Banja HPP will be implemented exclusively in the so-called Old Riverbed, based on local planning documents. A prerequisite for its formation is the construction of a bridge in Ovčar Banja.

The aquatic zone will consist of lakes with all hydro-technical and hydro-energy structures, water sports and recreation areas, docks for boats supporting cultural and nature routes, birdwatching, and more. For local users, beaches and pontoons for mooring small boats are planned on Lake Međuvršje.

SPSPA Vrutci Reservoir catchment area (Službeni glasnik RS, br. 91/2018)

The tourism and recreational offer of the area is currently underdeveloped, disorganised, and not functionally connected with the surrounding areas. However, the area's diverse natural potential and favourable transportation and geographical position are development factors for tourism and recreation. It is part of a primary tourist destination where year-round tourism can be achieved.

The main tourist offer of the area will develop around Lake Vrutci and the Đetinja River, along with the tourism offer of the City of Užice. This will be connected to numerous tourism resources and natural and cultural assets within the basin and surrounding areas, including ethno-villages, Tara National Park, Mokra Gora Nature Park, the tourist attractions of Zlatibor, and others. The development of tourism will require the completion of tourist and recreational content and accommodation capacities, improved protection of the water source basin, better presentation and tourist interpretation of natural and cultural values, and improved transportation access to villages where rural tourism is emerging – combined with the recreational and tourism offer in the wider area.

The development of water-based, mountain, hunting, fishing, sports and recreational, ecological, and rural tourism is envisioned. The integrated tourism offer will be based on ethno-tradition, by means of authentic accommodation and the organisation of individual sports and recreational tourism activities, as well as the production and placement of traditional and ecologically high-quality food, traditional crafts, and more.

The Vrutci reservoir area is planned as an excursion and transit sports and recreational destination, located in immediate proximity to infrastructure corridors of main roads and railway lines. In the wider area excursion and hiking trails are planned for walkers, riders, and mountain bikers, featuring viewpoints, rest areas, and shelters.

Management plan for the Uvac Special Nature Reserve 2025-2034 (Rezervat Uvac d.o.o., 2025)

Within the protected natural area, there are a significant number of tourist sites that can attract a large number of visitors and keep them in the region or its individual parts. The accessibility of locations near the protected area is also important for planning the stay of tourists who wish to spend more time in the region.

Tourism, along with science and education, is considered one of the most important functions of the protected area and should be, from the perspective of economic objectives, a respectable or even primary activity for the local population. The need and opportunity for the construction of facilities, infrastructure and land arrangement, for the purposes of ecotourism and the presentation of speleological features for recreational and tourism purposes, is confirmed in the plan. Tourism in protected areas should be oriented toward sustainability in order to achieve the fundamental characteristics of ecotourism. Also, strengthening business connections between agriculture and complementary sectors aiming to enable the direct placement of agricultural products within the tourism offer (Bezbradica and Basarić, 2021), and encouraging the diversification of the rural economy through the development of supplementary activities, would improve both tourism development and the quality of life for the local population.

Spatial plan of the Mali Zvornik municipality (Službeni list opštine Mali Zvornik, br. 8/2012)

In the above spatial plan, tourism is defined as a sector to be encouraged, which would ensure an improved tourist offer (accommodation, hospitality services, etc.) that aligns with the concept of the future development of the Mali Zvornik area as a modern, small business and administrative local centre, with primarily local influence. At the same time, watercourses, the reservoir, villages, and agriculture can serve as motifs for tourism development, including transit tourism in areas along the transportation corridor.

For the development of tourism in this area, natural and anthropogenic values are of great importance, and the planned activities must be original and attractive, without negative impacts on natural resources. In accordance with the principles of sustainable development, the plan outlines strategic priorities for the development of rural, excursion-based, recreational, and educational tourism with research programs, as well as hunting, fishing, cultural-event, nautical, and spa tourism. Future development plans must consider tourists with a high level of environmental awareness, as the preservation of the natural environment is the dominant factor guiding and shaping tourism demand. Sustainable tourism relies on the responsibility of all participants in the tourism industry toward the natural environment.

Water management strategy for the territory of the Republic of Serbia until 2034 (Službeni glasnik RS, br. 3/2017)

In the first half of the 20th century, dams were primarily constructed for energy purposes, and later also for water supply needs. In the second half of the 20th century, during the phase of accelerated electrification, high dams were built and the first large reservoirs were created, with volumes exceeding $10 \times 10^6 \text{ m}^3$ (such as those on Lake Međuvršje and Lake Zvornik) (Table 2). Currently, there are 28 reservoirs in Serbia, each with a volume exceeding $10 \times 10^6 \text{ m}^3$. In parallel to the development of large reservoirs, some smaller reservoirs have also been built, serving various functions.

The construction of dams and the formation of reservoirs aim to regulate the water regime in each area, ensuring an adequate water supply for users, as well as to protect them from the threat of high floods, serving at the same time for environmental protection.

The multipurpose nature of reservoirs includes meeting other needs as well (sport, recreation, other tourism offers, etc.). As previously stated, a particularly important function of reservoirs has to be active flood protection, provision of additional usable water quantities, etc. One such benefit is sediment retention which, although detrimental due to the loss of reservoir capacity, is beneficial for the protection of downstream areas.

During the 20th century, water-based tourism and recreation expanded significantly in Serbia, with 57 public bathing and recreational sites on lakes, rivers, and reservoirs. Spa tourism became particularly prominent due to favorable natural conditions and established tradition, reaching its peak development in the second half of the century. In 1960, spas were legally recognized as natural health resorts, stimulating the development of accommodation facilities and modern spa and rehabilitation centers.

Serbia is rich in rivers where numerous water sports are practiced: sailing, kayaking, rowing, water skiing, and more. On the Drina, Uvac, and Lim, rafting is also available, and the Drina hosts an annual regatta.

Table 2. High dams on reservoirs exceeding ten million cubic metres
(Source: Službeni glasnik RS, br. 3/2017)

	Reservoir	Water course	Year of building	Dam type	Dam height (m)	Length (m)	Dam body volume (10^3 m^3)	Total reservoir volume (10^6 m^3)	Purpose
1	Međuvršje	Zapadna Morava	1953	G	31	190	38	18	E
2	Zvornik	Drina	1955	G	42	269	316	89	E
3	Bajina Bašta	Drina	1966	SG	90	461	995	340	E
4	Potpeć	Lim	1967	G	46	212	116	44	E
5	Uvac	Uvac	1979	R	110	307	2.500	213	E
6	Vrutci	Đetinja	1984	A	77	241	83	54	W

Primary purpose of the dam: W – drinking water supply; E – energy production

Dam type: R – rockfill dam; G – gravity dam; SG – semi-gravity (lightened gravity) dam; A – arch dam

TOURISM SIGNIFICANCE OF LAKES

Coastal areas are the most popular among tourists (Gladstone *et al.*, 2013). In the tourism literature, different concepts have been discussed, such as river, marine, coastal and more recently lake tourism (Hall and Härkönen, 2006a; Rodrigues *et al.*, 2015). According to Ramazanova *et al.* (2019), lakes are the major attraction for many tourist destinations like Balaton in Hungary, the Great Lakes in the USA, Lombardy's lakes in Northern Italy, the Finnish Lakeland, and the Lake District in the UK.

Natural and artificial lakes represent a significant tourist value that encourages the development of various tourism offers: sports, recreation, excursions and events, nautical tourism, fishing and so on. They are more attractive during the summer, and their value stems from their recreational function, the beauty of the landscape, interesting phenomena on the water and in the surroundings, as well as their recognition in the tourist market and the arrangement of the tourist and catering infrastructure (Šmelcerović, 2021).

Water-based or nautical tourism, provides a variety of organised, boats as well as sports and recreational facilities on the coast (Martínez Vázquez *et al.*, 2021; Spinelli and Benevolo, 2022; Baldassarre *et al.*, 2017; Wheaton, 2000).

Regardless of their size, lakes play a significant role in human activities, for example, as a water-supply, or for energy production, aquaculture, transportation or irrigation. The majority of human activities on lakes are directed towards development. Also, Brillo (2025) highlights 'lake tourism' as the key term in his work, mentioning its occasional appearance in the literature from the early 2000s onwards, but without proper definition of the concept itself. As an exception, Brillo (2025) cites the reference "Lake Tourism Systems", which refers not only to tourism on the lake but also in the surrounding area (Hall and Härkönen 2006a). Integrated territorial development of the larger lake regions in Europe can offer an attractive living environment, diverse leisure opportunities for tourism, agriculture, fisheries, etc., and closer contact with nature (Ratković and Vulević, 2025). Milovanović Pešić *et al.* (2023) and other authors emphasize the importance of aquatic ecosystems, biodiversity protection and lake tourism, with regard to socio-economic and cultural factors and sustainable water resource management, since the deterioration of water quality may negatively influence water-related tourism and recreation.

Lakes offer various opportunities that can be utilised, regardless of their location, formation, or ecosystem diversity (Newsome *et al.*, 2002). In a number of cases, lake surfaces should be carefully analysed both as habitats and as exploitable resources and assets. For example, water sports can negatively impact the aquatic ecosystem, which could reduce a lake's tourism attractiveness (Jennings, 2007). Until recently, lakes were considered as recreational areas associated primarily with rural settings. However, today many countries have natural or artificial lakes that offer recreation in or near cities (Hall and Härkönen, 2006a).

Climatic factors also influence the tourism significance of lakes (Lin and Matzarakis, 2008). The climate affects lake biodiversity and water temperature – a key factor for

swimming suitability. Climate also impacts the seasonality of tourist visits, with lakes in warmer climates being the most visited. Examples of such lakes in Central Europe are Lake Constance and Lake Maggiore, which are also popular recreation spots (Dávid and Baros, 2007; Dávid *et al.*, 2012). Areas around lakes often serve as cultural destinations as well. In some countries (such as Hungary, Turkey and Switzerland), lakes host music festivals. The physical and economic environment of lakes also influences the development of tourist infrastructure and superstructure on their coasts (Dredge, 2001).

Depending on tourist demand and preferences, lake destinations – if they make use of their available potential – can be marketed with abundant tourist content and can be ideal choices for fans of water sports (swimming, water skiing, etc.), birdwatchers, and those seeking special interest activities (kayaking, sailing, scuba diving, etc.).

In many parts of the world, lakes are central to sports, recreation, and tourism as sites for leisure activities. Lakes are also extensively used in tourism promotional campaigns, either to promote a destination or as attractive additions to other leisure activities (Hall and Härkönen, 2006a).

The economic and tourism value of lakes is difficult to define, as lake tourism encompasses both the lake itself and its surroundings. This type of tourism includes lakeshores and related facilities, infrastructure, and content within the local and wider environment that support the lake's role as a tourist destination. The ecological system that supports lake tourism is usually much larger and encompasses the entire lake basin (Lerner and Haber, 2001).

Lake tourism affects specific natural environments, which – due to their unique ecological characteristics – can be distinctive locations where the environment itself attracts certain activities and promotes the ecological values of the destination (Hall and Härkönen, 2006b).

Tourism based on natural resources is one of the pillars of the tourism industry and has significant economic value. Many countries consider lakes to be primary resources for developing tourism based on natural values. Any resource used for tourism purposes must possess either natural or constructed quality content, as well as public access (Middleton and Hawkins, 1998). To make lake destinations more appealing to a broader range of tourists, such sites must have adequate infrastructure (roads, trails, viewpoints, etc.). Proper infrastructure greatly improves tourist and hospitality services and supports the development of local businesses. As such, infrastructure is a key factor in destination development and in the growth of small tourism enterprises (Goeldner *et al.*, 2000; Lerner and Haber, 2001).

In Serbia, lakes and reservoirs are given less attention as tourist assets compared to mountain, rural, spa, and urban tourism. Their significance and potential have not been seriously assessed, nor has the benefit of developing and improving this type of tourism been thoroughly explored. Additionally, legislation barely addresses recreational activities such as boating on reservoirs, underwater fishing, and activities in protected areas.

The Lithuanian region of Eastern Aukštaitija is well known for its numerous lakes with aesthetic significance, offering unique experiences for visitors (Lithuania Travel, 2025).

This region is considered to be one of the most promising areas in Lithuania for tourism development (Gražulis and Narkūnienė, 2017). The tourism development in this region is based on natural resources, unique culture, protected areas, tourist attractions, recreational activities, etc., and it “depends on tourism planning and management, skills of human resources, public-private sector cooperation, legal base, project development and implementation, tourism development strategy, tourism research” (Gražulis and Narkūnienė, 2017, p. 24). Important factors for the development of lake tourism are the lake’s area, landscape structure and accessibility by roads (Daubarienė, 2018). Some good examples of a developed lake-based tourist destination with a compact cluster of tourism activities which includes several interconnected lakes offering the opportunity to discover all of them in a kayak, as well as a different kind of activities like swimming, glamping, examining local natural and cultural landmarks or cuisine, fishing etc., are located in this region. The area around the lakes is set aside for public recreation and is accessible for all forms of exploration and leisure (Lithuanian State Department of Tourism under the Ministry of Economy: European Commission, 2010).

In order to develop and improve this kind of tourism, at the same time relying on the resources and potentials of the lakes, rivers, forests, mountains, cultural heritage, kind people, etc., the municipalities in Western Serbia should focus on the development of: diverse services, all-season tourism, infra and superstructure, trained staff, the local population’s awareness on sustainability, public-private partnerships, and the adoption of relevant strategic documents that should be based on detailed research in the field of tourism (Gražulis and Narkūnienė, 2017; Pantić and Milijić, 2021).

In the context of the so-called lake regions, ESPON developed a framework concept that enables more integrated development in such regions. The program aims to raise the awareness and visibility of regions with lakes and to facilitate cooperation between local and regional stakeholders. It includes several development policy options related to the following indicators: regional integration; integration of land and lakes; cross-sectoral cooperation; vertical integration (the role of lakes in overarching policies); and the European integration of multiple lake-rich regions. The contribution of lakes to regional development is determined by the totality of their benefits, as well as by residents’ perceptions of lakes as valuable resources. The areas around large lakes are functional, with numerous resources such as preserved ecosystems, landscapes, cultural and historical heritage, and local identity, which have contributed to the development and promotion of tourism (ESPON, 2022).

CONCLUSIONS

The significance and attractiveness of tourism on lakes and reservoirs in Serbia would be at a higher level if these destinations were, in addition to spatial plans, also included in action plans. The development of an action plan would be implemented by local self-governments and relevant tourism development agencies. Necessary support in the preparation of the action plan could be provided, for

example, by regional development agencies and local tourism organisations.

Lake-based tourism in Serbia, as well as the existing structure and quality of accompanying services, still lags behind similar tourism products offered by more developed destinations on domestic and international markets. The main qualitative characteristics of lake tourism products should be based on ecotourism, with a structurally diverse, flexible, dynamic, complementary, and functionally integrated role. Such an approach would enable a sustainability concept, making the area economically more competitive and functionally more capable of fulfilling various tourist needs.

In a competitive tourism market, it is desirable to develop economic and social opportunities through the promotion of tourism content and products. This would be achieved through adequate stimulation of tourism development and sustained efforts in preserving and improving the natural and social environment. When defining the conditions for the development of tourism, it is necessary to align the possibilities of attracting domestic and foreign tourists with the diverse and rich potential offered by lake and reservoir environments. A tourist destination must be carefully analysed with all of its advantages and limitations so that within it, the selection and curation of tourism content for utilisation can be carried out. The development of tourism also requires the definition of tourism activities and the proper arrangement of tourist spaces. The most important considerations include: setting criteria for long-term tourism development; analysing and evaluating the condition of the potentials and limitations of the tourism supply (natural and man-made conditions); analysing and evaluating the state and trends of the tourism demand; understanding the geopolitical and socio-economic development context; addressing issues of tourism infrastructure and superstructure; the dependence of tourism development on complementary activities and services; and sustainable tourism development in accordance with environmental protection requirements and the preservation of natural and cultural values.

An increased level of tourism development and the exchange of tourism offers is possible through coordination and regional, inter-municipal, or cross-border cooperation. From a tourism perspective, development should focus on improving the potential for various forms of tourism; establishing a tourist information centre; building accommodation facilities and improving the quality of accommodation; promoting and branding lake tourism; creating tourism products; drafting strategic plans for the most prevalent types of tourism; networking of all tourism stakeholders; and continuous efforts in the education and training of personnel from various fields of tourism.

The mentioned reservoirs, with their favourable geographic locations, and natural and man-made values, provide opportunities for water, mountain, hunting, fishing, sports and recreational, ecological, rural, and other forms of tourism. Furthermore, their natural features and a healthy environment create preconditions for year-round tourism development. The operational objectives for the development and enhancement of tourism should be based

on the development of an integrated tourism offer in the area, aligned with protection regimes and measures for water quality, natural and cultural values, and the creation of conditions to meet year-round, primarily day-trip demand from the urban populations of nearby major cities and municipal centres, with specialised sports and recreational activities and content offerings.

In order to define the real market and the needs of potential tourists, the following research should be conducted in the future in the case study area:

- demand for tourist products such as preserved nature, cultural and historical monuments, etc.;
- categories of tourists who consider lake tourism attractive (age, educational, economic, social, etc.);
- awareness of the local population on tourism relevance for the economic development of the area;
- potential and limitations of the tourist offer on the lakes;
- traffic accessibility to the lakes; and
- equipment with superstructure in the surroundings of the lakes.

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