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HISTORICAL UNDERGROUND STRUCTURES OF BELGRADE: IDENTIFICATION, CLASSIFICATION, AND URBAN POTENTIAL FOR SUSTAINABLE CITY DEVELOPMENT

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Abstract: The rapid growth of the global population has intensified the imbalance between urban expansion and sustainable resource management, including water, materials, energy, air, and space. In response, contemporary urban planning increasingly explores the integration of underground spaces to enhance sustainability, functionality, and spatial efficiency. Historically, underground spaces have served military, religious, infrastructural, economic, and residential purposes, often emerging from necessity rather than systematic planning. Today, their identification, analysis, and classification are crucial for strategic urban planning, particularly in cities with significant historical and cultural contexts. This study examines Belgrade's underground structures, developed over its urban history, with the aim of inventorying, categorizing, and establishing typologies to inform future interdisciplinary planning. Notably, Serbia's legal framework does not recognize underground urbanism, emphasizing the need for scientific research and policy development in this field. The research methodology includes direct and indirect observation, institutional and field data analysis, and classification based on four key criteria: construction material, spatial dimension, current function, and historical origin. The study examines over 160 documented underground structures, excluding those under the jurisdiction of the Ministry of Defense. Institutional control and restricted access have historically limited documentation efforts, yet public interest in Belgrade's underground heritage has grown in recent decades. This research contributes to the development of scientifically grounded criteria for evaluating and integrating underground spaces into urban sustainability frameworks. The findings offer insights into the socio-historical significance of these spaces and provide recommendations for their future use and conservation.

Keywords: Underground Structures of Belgrade, Urban Underground Heritage, Valorization[3], Identification and Classification

1. INTRODUCTION

Increasing urbanization and the scarcity of surface resources are increasingly emphasizing the need for strategic utilization of underground spaces as a spatial-functional asset in contemporary urban development. Confronted with global challenges such as climate change, overpopulation, and spatial crises regarding infrastructure and public services, cities are progressively incorporating underground space into urban policies—not merely as a technical solution, but as an integral component of resilience, circular economy, and cultural identity preservation [1] [2]. Unlike the historical, predominantly reactive development of underground structures—driven by wartime

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[3] In this paper, the term valorization is used in the sense commonly applied in European heritage studies, meaning not only the evaluation and recognition of the cultural and historical significance of underground heritage, but also the process of its activation, adaptive reuse, and integration into contemporary urban development.

conditions, climate extremes, or technical necessities—contemporary trends emphasize proactive and holistic planning, supported by digital tools such as 3D modeling and geographic information systems (GIS) [3] [4] [5].

At the same time, growing attention is being directed toward historical underground spaces, which often remain outside the scope of official urban planning documentation despite their cultural, spatial, and social potential. As Heyns et al. [6] emphasize, underground spaces are not merely physical volumes, but carriers of cultural memory and symbolic meaning, and should be integrated into future urban scenarios as active resources. In this context, Belgrade—with its multilayered urban history and over 160 identified underground structures (excluding military and police facilities)—represents a significant yet underutilized potential. Despite increasing public interest and the cultural value of these spaces, there is a lack of systematic planning and regulatory support necessary to enable their functional and cultural reintegration into the modern city [7] [8]. The absence of a legal framework and the fragmented nature of existing knowledge further complicate decision-making processes related to their protection, transformation, or adaptive reuse [9] [10].

This paper aims to lay the foundation for a strategic and scientifically grounded understanding of Belgrade's underground heritage through (1) a systematic inventory and categorization of subsurface structures; (2) analysis of key parameters such as material, dimensions, function, and historical origin; (3) development of guidelines for interdisciplinary planning and integration into urban policies; and (4) recommendations for preservation and future use in accordance with principles of sustainable development and cultural valorization. Drawing from global best practices and contemporary theoretical approaches, the study highlights the importance of underground heritage as an active urban asset and a catalyst for new models of planning and cultural governance.

Documenting Subsurface Structures: Between Historical Legacy and Contemporary Planning

Subsurface structures have a long and diverse history dating back thousands of years, serving as shelters, water reservoirs, religious sanctuaries, infrastructure conduits, and defense systems. From the tunnels of Petra and the Eupalinian aqueduct on Samos, to the Roman catacombs and the underground cities of Cappadocia, these spaces attest to the capacity of ancient societies to respond to spatial, climatic, and security challenges with a high degree of technical sophistication [11] [12] [13] [14]. These historical underground forms are not merely remnants of the past—they embody collective memory, technological innovation, and spatial survival strategies. Contemporary authors such as Varriale [10] and Sandford [15] emphasize that underground heritage must be viewed as a dynamic resource, not a passive relic. As Sandford notes, "heritage is not what we inherit, but what we choose to carry into the future." Documenting underground spaces, therefore, is not only an academic imperative—it is a strategic step toward planning more sustainable cities. At the same time, Heyns et al. [6] warn that subsurface planning must also account for intangible dimensions—collective memory, local narratives, and cultural significance. This is particularly relevant in historically layered cities, where ignoring symbolic meanings can lead to spatial injustice. Belgrade is a prime example, with its multi-layered urban development comprising Roman corridors, medieval lagums (subterranean cellars), and modern underground infrastructures. More than 160 documented structures (excluding military and police-controlled underground facilities) testify to an informal yet functional development of the subsurface—most often as a response to war, climate stress, or infrastructural needs. Despite growing public interest, institutional barriers and the legal invisibility of underground space in Serbia continue to hinder its systemic valorization and integration.

The study by Qiao et al. [16] highlights the spatial dilemma facing historic cities: the tension between preserving cultural heritage and accommodating the demands of contemporary urban development. They propose underground solutions as a viable compromise—allowing the physical separation of new functions from heritage assets, but only under conditions of meticulous planning that considers the depth of intervention, cultural appropriateness, and anticipation of future needs. For this reason, Costa and colleagues [9] advocate for the planning-based classification of "Urban Underground Heritage" (UUH), which encompasses both the physical and symbolic values of subterranean spaces. Their recommendations emphasize proactive mapping, digital documentation, and early involvement of heritage professionals in the urban planning process. The *Underground4value* handbook [17] goes a step further, calling for participatory methodologies and anticipatory tools—such as scenario planning and the "Living Labs" approach—to co-create the future of underground spaces with local communities. In this spirit, valorization is not a static act, but rather a dialogical and adaptive process grounded in continuous learning, testing, and redefinition of spatial values over time [10]. Ultimately, historical records of underground structures—including material typologies, dimensions, functions, and origins—not only preserve memory but also form the foundation for responsible urban planning. In a cityscape striving for resilience, functionality, and cultural sustainability, subsurface spaces must be integrated into the urban vision—not as invisible remnants of the past, but as visible assets for the future.

2. METHODOLOGY

The aim of the research was to systematize and classify Belgrade's underground structures in order to better understand, protect, and incorporate them into future urban development strategies. The methodological framework of the study included the following outlined steps.

2.1. Data Collection

The following methods were used:

- **Direct observation**: Field visits to accessible locations, conducted in collaboration with local institutions and guides.
- **Indirect observation**: Analysis of existing archives, publications, digital sources, and visual materials.
- **Institutional data analysis**: Incorporating information from urban planning institutes, heritage conservation bodies, and municipal administrations.
- **Field research**: On-site data collection and comparative verification of available information.

2.2. Classification criteria

The classification of subsurface structures was based on a set of interdisciplinary parameters designed to reflect both their physical characteristics and historical-functional relevance. Key criteria included:

- **Construction material** (e.g., loess, limestone, clay, brick, concrete),
- **Size and surface area**, distinguishing small (up to 200 m²), medium (200–500 m²), and large structures (over 500 m²),
- **Historical period** of construction (e.g., pre-17th century, Ottoman period, Austro-Hungarian period, WWII, SFRY, post-socialist period),
- **Original and current function** (e.g., wine cellar, warehouse, shelter, tunnel, tomb, etc.),
- **Current state** (e.g., active, abandoned, collapsed, conserved, repurposed), and
- **Geological context**, such as the type of substrate in which the structure was built.

These classification criteria provided the basis for statistical analysis and the development of planning recommendations (Figures 1).

Угриновачка 12	Земун	Loess	Brick, Concrete	24,64	small	Lagum		Collapsed		Austro-Hungarian (18th–19th century)
Угриновачка 17	Земун	Loess	Brick, Concrete, Loess	Око 50	small	Lagum		Collapsed		Austro-Hungarian (18th–19th century)
Угриновачка 23	Земун	Loess	Loess, Brick	35,07	small	Lagum		Collapsed		Austro-Hungarian (18th–19th century)
Угриновачка 24	Земун	Loess	Brick, Concrete, Loess	Око 50	small	Lagum		Collapsed		Austro-Hungarian (18th–19th century)
Гаврла Принципа 45	Савски венац	Limestone	Brick, Concrete	41,1	small	Hospitality facility		Active		Ottoman period (19th century)
Угао Ч. Антине и В. Пелагића	Савски венац	Sarmatian sediments	Brick, Concrete	17,55	small	Shelter		Active		World War II period
Симићева 17	Савски венац	Senonian sediments	Brick, Concrete	61,25	small	Depot		Active		World War II period
Прокоп	Савски венац	Sarmatian sediments	Brick, Clay	219,2	medium	Depot		Collapsed		World War II period
Бул. војводе Мишића 83	Савски венац	Limestone	Concrete	221	medium	Depot		Collapsed		Ottoman period (18th–19th century)
Сање Живановић 1	Савски венац	Limestone	Concrete	417,6	medium	Shelter		Active		Socialist Federal Republic of Yugoslavia

Figure 1. Section of database collected through fieldwork, sorted in Excel spreadsheet

2.3. Scope of research

The research encompasses an analysis of more than 160 documented subsurface structures within the territory of the City of Belgrade, excluding facilities under the jurisdiction of the Ministry of Defense and Ministry of Interior due to access restrictions and security protocols. The data have been systematically organized by city municipalities (11 out of 17 Belgrade municipalities, as no underground structures were identified in the remaining ones), including precise addresses, ownership status, functional designation, and current physical condition of each structure. All data were entered into a tabular database using Microsoft Excel, enabling further processing, classification, and graphical presentation through a series of simple and comparative analyses.

Simple Analyses

The simple statistical analyses were conducted to provide an initial identification of the spatial and structural distribution of urban built heritage (UBH). These included the following parameters:

1. Distribution of structures by municipality;
2. Proportional presence of structures across different geological environments;
3. Prevalence of building material types;
4. Total floor area (in m²) of all structures;
5. Size categorization: small (<200 m²), medium (200–500 m²), and large structures (>500 m²);
6. Functional range of use;
7. Assessment of current physical condition;
8. Chronological distribution of construction periods.

Comparative Analyses

The comparative analyses use the same criteria as the simple ones but enable deeper insights into intersections among various parameters, such as:

1. Structure size in relation to historical periods of construction;
2. Functional typologies contextualized by historical eras;
3. Current condition of structures in relation to geological environments;
4. Condition of structures based on current or original use;
5. Geological characteristics per municipality in relation to the prevalence of structures;
6. Distribution of materials in specific construction periods;
7. Functional distribution of structures across city municipalities.

This data structure and set of derived analyses provide the basis for establishing evaluation criteria, as well as guidelines for the preservation, revitalization, and strategic inclusion of UBH in sustainable urban development models. The author considers the chosen analytical framework to offer a reliable foundation for future interdisciplinary spatial interventions.

2.4. Ethical and Safety Considerations

The research was conducted in accordance with established ethical principles and safety protocols. No underground structure was physically altered or forcibly accessed; all site visits were carried out only with the consent of property owners or relevant institutions. Special attention was given to safety risks, including damaged structures, unstable soil conditions, and insufficient ventilation.

3. RESULTS OF THE STUDY

3.1. Results of Basic Statistical Analyses

Based on data derived from the accompanying diagrams, a statistical analysis was conducted on the underground structures in Belgrade, focusing on their function, physical condition, construction period, surface area, municipal distribution, and building materials used. The following are key findings:

1. The highest concentration of underground structures is located in the municipality of Zemun (45.73%), followed by Stari Grad (17.07%), Čukarica (7.93%), Rakovica (6.71%), and Novi Beograd (6.10%). Other municipalities such as Palilula (4.27%), Vračar and Savski Venac (each 3.66%), Zvezdara (2.44%), Voždovac (1.83%), and Grocka (0.61%) show significantly lower representation.
2. Regarding presence of structures across different geological environments, loess is dominant (51.22%), followed by limestone (32.93%) and clay (8.54%). Sandstone (3.05%), sarmat (1.83%), and sand (0.61%) are minimally used (Figures 2). When material combinations are considered, the most prevalent are loess and brick (25.00%), brick, concrete and loess (23.17%), and brick and concrete (16.46%). Limestone alone accounts for 12.80%, while other material combinations such as concrete, brick, and clay occur in less than 8% of the structures.
3. The most common functions of these spaces include wine cellars and storage vaults (lagums) (48.17%), followed by warehouses (13.41%), shelters and bunkers (each 10.37%). Transportation tunnels make up 6.10%, mines 4.27%, while tombs (1.83%), garages, depots, and gas plants (each 1.22%) are much less represented. Fishponds, Roman baths, and hospitality venues hold a marginal share (each 0.61%).
4. In terms of current condition, the majority of structures are partially collapsed (39.63%), followed by abandoned (25.61%), conserved (17.68%), and active (9.15%). Renovated structures account for 7.32%, while demolished ones are very rare (0.61%) (Figures 3).
5. As for the period of construction, most structures date back to the Austro-Hungarian era (18th–19th century, 51.83%), followed by the World War II period (19.51%) and the Ottoman period (18th–19th century, 12.80%). Other historical phases—pre-17th century, Socialist Federal Republic of Yugoslavia, and post-socialist period—each account for 3.05–3.66%, while early 20th century, the second half of the 18th century, and the 19th-century Ottoman era are represented at only 0.61%.
6. The total estimated floor area of underground structures is 344,676 m². Large structures dominate in size with 338,400 m², while medium-sized (2,952 m²) and small ones (3,324 m²) occupy significantly less space. Small structures represent the majority in number (70.73%), followed by medium-sized (16.46%) and large ones (12.80%).

Simple Analyses II		DIAGRAM
Loess	51.22 %	
Clay	8.54 %	
Limestone	32.93 %	
Limestone, Loess	1.22 %	
Sand	0.61 %	
Sandstone	3.05 %	
Senonian sediments	0.61 %	
Sarmatian sediments	1.83 %	

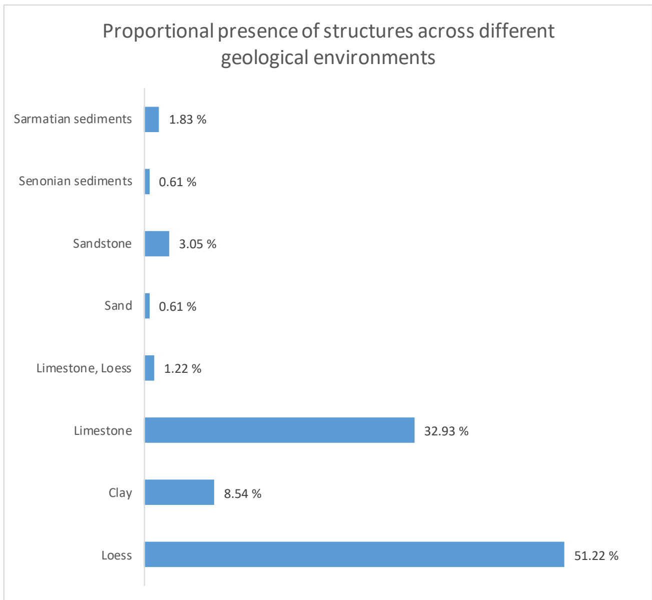


Figure 2. Results of basic analysis of proportional presence of structures across different geological environments.

Simple Analyses VII	
Active	9.15 %
Abandoned	25.61 %
Collapsed	39.63 %
Conserved	17.68 %
Repurposed	7.32 %
Demolished	0.61 %

DIAGRAM

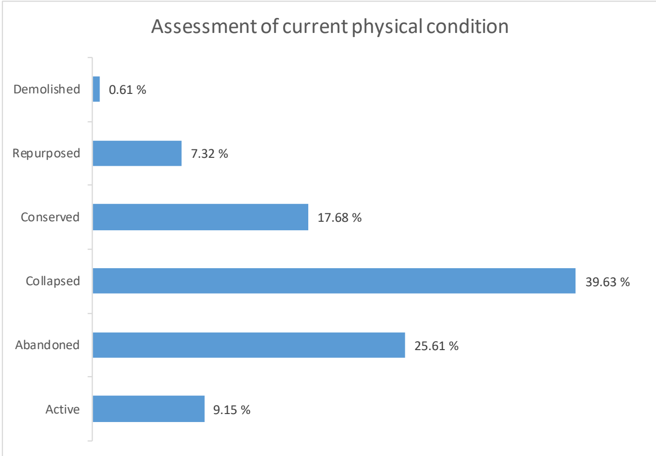


Figure 3. Results of basic analysis of current physical condition of structures.

The analysis reveals that underground structures in Belgrade are primarily lagums and warehouses constructed in loess and limestone, with the highest concentrations found in Zemun and Stari Grad. While most structures originate from the Austro-Hungarian era, a significant portion is either collapsed or abandoned, highlighting the urgent need for conservation or adaptive reuse. Although fewer in number, large underground structures account for most of the total floor area, pointing to their considerable potential for future urban development initiatives.

3.2. Results of Comparative Analyses

Comparative analyses of underground structures in Belgrade, conducted using various criteria (function, geological context, construction materials, historical period, and current condition), reveal a significant degree of spatial and historical diversity.

The distribution of functions by municipality highlights a strong dominance of certain structure types in specific areas. In Zemun, wine cellars and vaults (lagums) dominate (94.67%), while shelters are most represented in Voždovac (100%) and Palilula (71.43%). In Stari Grad and Savski Venac, storage facilities prevail (53.57% and 50% respectively), while bunkers are predominant in Čukarica (76.92%). Rakovica shows a balanced representation of mines and bunkers (36.36% each), whereas Vračar and Grocka include more specialized structures such as tombs.

The geological base across municipalities also reflects territorial specificity. Loess soils are prevalent in Zemun and New Belgrade, while older urban cores like Stari Grad and Palilula are predominantly founded on limestone. Clay is the dominant substrate in Voždovac and Grocka, and mixed formations (limestone, clay, sandstone, sarmatian sediments, and senonian sediments) are registered in Rakovica, Čukarica, and Savski Venac. These geological conditions directly influence the stability, durability, and preservation of the structures.

Construction materials, in a historical context, indicate that loess and brick were dominant during the Austro-Hungarian period (95.12%). In the Ottoman era, concrete, brick, and limestone were more commonly used. During the Socialist and post-Socialist periods, concrete became the prevailing material, signaling a shift in construction technologies and material availability. Brick remained a consistently used material across nearly all periods, while limestone was crucial during the Ottoman and Royal (Kingdom of Yugoslavia) periods (Figures 4).

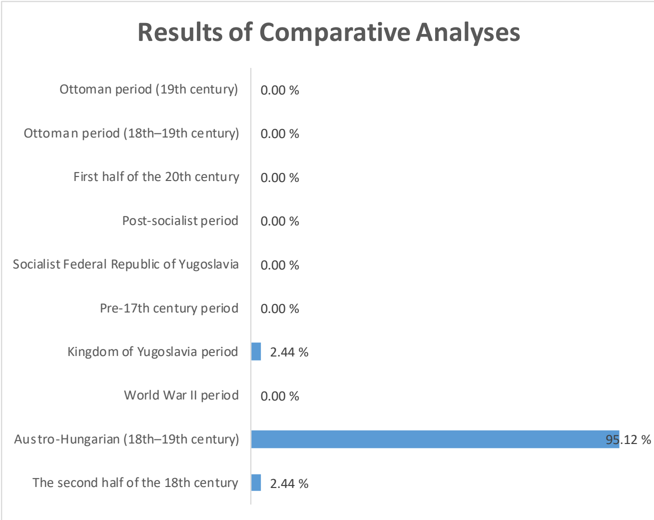
Simple Analyses III/Simple Analyses VIII Loess, Brick	Loess, Brick	DIAGRAM
The second half of the 18th century	2.44 %	
Austro-Hungarian (18th–19th century)	95.12 %	
World War II period	0.00 %	
Kingdom of Yugoslavia period	2.44 %	
Pre-17th century period	0.00 %	
Socialist Federal Republic of Yugoslavia	0.00 %	
Post-socialist period	0.00 %	
First half of the 20th century	0.00 %	
Ottoman period (18th–19th century)	0.00 %	
Ottoman period (19th century)	0.00 %	

Figure 4. Results of comparative analysis of material distribution across construction periods, with brick- and loess-built structures as evaluation criteria.

When analyzing the size of structures in relation to their construction period, smaller structures were typical of earlier times (Austro-Hungarian – 68.97%; pre-17th century – 19.05%), while large structures became dominant in the post-Socialist period (28.57%). Medium-sized structures peaked during World War II (25.93%) and in the 18th–19th centuries.

Functional distribution across time periods reflects the evolution of urban and security needs. Lagums prevailed during the Austro-Hungarian era (90.59%), while shelters and bunkers were characteristic of the WWII period. In the SFRY and post-socialist periods, traffic-related structures and garages became dominant, signaling a new functional direction for underground urban space.

Preservation status relative to geological environment indicates that structures built in loess are generally partially collapsed or abandoned, while those in limestone are often preserved or still functional. Clay-based structures show moderate preservation, whereas those built in alluvial and senonian sediments-dominant soils are in the best condition, likely due to advanced construction techniques. Structures in sandstone are fully abandoned, while those in sarmatian sediments environments show a balanced condition profile.

Finally, preservation by function shows that traffic tunnels and shelters are most often active, while lagums and bunkers are largely abandoned or collapsed. Conserved structures are mostly warehouses and shelters, while repurposed ones are typically former bunkers and shelters. Demolished structures were exclusively former shelters, often due to human factors.

These results provide a complex picture of Belgrade's underground heritage in terms of historical, geological, and functional heterogeneity. They serve as a foundation for setting priorities in preservation, further research, and potential adaptation of these spaces within the framework of modern urban development.

3.3. Socio-Historical Analysis

In recent decades, there has been a noticeable rise in public interest in Belgrade's underground heritage, driven by a combination of interconnected socio-historical factors. Firstly, urban expansion and renewed interest in alternative spaces within the city fabric have created a demand for the revitalization of neglected or forgotten underground structures. This is particularly evident in municipalities such as Zemun[4] and Stari Grad[5], where the

[4] Zemun is today a municipality of Belgrade, historically a separate town situated on the right bank of the Danube River, with a strong Austro-Hungarian architectural and cultural influence, distinct from Belgrade's Ottoman and later Serbian urban layers.

[5] Stari Grad (Old Town) is the historic core of Belgrade, located at the confluence of the Sava and Danube rivers, characterized by its layered urban fabric that includes Roman, Ottoman, and Serbian heritage.

concentration of historical wine cellars and storage facilities is the highest. At the same time, increasing ecological and cultural awareness among citizens and professionals has led to a new valorization of these spaces as potential cultural, touristic, and communal assets. A trend has emerged toward transforming former military and industrial facilities into public and commercial venues such as museums, galleries, wine cellars, and cultural centers. From a historical perspective, most of these underground structures originate from the Austro-Hungarian and Ottoman periods, which further enhances their cultural and historical value and their potential integration into collective memory narratives. On the other hand, a significant number of structures are in a state of collapse or neglect, indicating uneven preservation policies but also highlighting opportunities for intervention and investment. Technological advancements and the growing popularity of urban exploration, along with the development of new mapping and evaluation methodologies—such as the concept of Underground Built Heritage (UBH)—are contributing to the institutionalization of this topic within urban planning, conservation strategies, and cultural policy.

In summary, underground structures have evolved beyond their original, often forgotten functions to become subjects of growing social, professional, and political interest. This shift opens up new possibilities for their protection, adaptive reuse, and integration into the contemporary urban life of Belgrade.

4. DISCUSSION

It should first be noted that the implementation of this research was constrained by specific factors that influenced the scope, accessibility, and depth of the analysis of Belgrade's underground architectural heritage in the following ways:

- **Institutional barriers and restricted access**: Entry to certain structures was either impossible or severely limited due to their classification as closed, secured, or military-controlled zones, particularly those managed by the Ministry of Defense and the Ministry of Internal Affairs.
- **Incomplete historical documentation**: A significant portion of structures built before the 20th century is inadequately documented, complicating precise reconstruction of their original functions, configurations, and transformations over time.
- **Limited digitalization of archives**: The lack of access to digital archival resources further complicated the consolidation of data, especially concerning legal status, functional use, and ownership of underground structures.
- **Temporal limitation of data**: The study included only structures documented up to the year 2018, meaning that more recent underground interventions and constructions were not part of the analysis.
- **Undocumented sites and oral traditions**: There is a likelihood that additional underground structures exist, yet remain undiscovered and are passed down only through oral history and local narratives. Although not included in the formal research scope, these elements represent a valuable basis for future investigations.
- **Presentation constraints**: Due to the volume of material and spatial constraints of this work, it was not possible to present the entire database or the full results of the graphical analyses. Nevertheless, key findings and conclusions are discussed in the "Discussion" section, accompanied by a critical review of the results.

These limitations do not undermine the relevance or validity of the research, but they must be considered when interpreting the results and planning subsequent research or intervention phases.

The integration of Belgrade's underground structures into sustainable urban development requires a clearly defined balance between the preservation of cultural heritage and the fulfillment of the city's contemporary needs. Research findings indicate that underground facilities—particularly the lagums in Zemun and storage spaces in Stari Grad—hold significant potential for revitalization. However, their current condition (39.63% collapsed and 25.61% neglected) highlights an urgent need for systematic mapping and digital documentation, as proposed by Costa et al. [9]. These findings also confirm the challenges outlined in the "Study on the Development of Urban Underground Spaces" [18], which notes that underground structures remain largely excluded from Belgrade's strategic spatial planning frameworks.

UNESCO's Historic Urban Landscape (HUL) approach [8] advocates a holistic view of integrating subsurface spaces into the broader urban context, relieving pressure on surface infrastructure while contributing to the preservation of spatial identity. In this sense, Belgrade could alleviate the strain on its above-ground assets by incorporating and functionally rehabilitating segments of its underground infrastructure—particularly those structures with cultural, historical, or touristic value. However, the current legal framework in Serbia remains fragmented and only partially addresses this domain. The Law on Cultural Heritage [19] recognizes underground structures as part of immovable cultural assets but lacks clear guidelines for their adaptive reuse. Similarly, the Law on Planning and Construction [20] does not provide concrete tools for incorporating underground spaces into spatial planning documents, while the Law on Emergency Situations [21] addresses shelters purely from a safety perspective, overlooking their historical and cultural significance. The Rulebook on Specific Conditions for Establishing Institutions for the Protection of Cultural Heritage [22] and the Rulebook on the Content, Manner, and Procedure of Developing Spatial and Urban Planning Documents [23] leave room for interpretation but are seldom directly applied to underground structures.

International authors such as Peng [24], Li [25] and Bobylev [26] emphasize the importance of underground spaces as assets for sustainable development—not only for transport and utility infrastructure, but also as spatial reserves for new cultural, educational, and commercial functions. Belgrade's underground structures, particularly those in Zemun, Stari Grad, and Čukarica, could be strategically repurposed to support local economic development and tourism. The 2024 study [18]. further highlights the absence of mechanisms for categorizing underground spaces based on usability and infrastructural capacity. It critically notes the lack of a centralized database and standardized criteria for identifying potential, risks, and degrees of endangerment. Despite the formally stated need for underground integration, actual implementation remains limited by institutional barriers, fragmented jurisdiction, and the absence of a coherent financial framework.

However, as Zhang et al. [27], emphasize, the creation of plans alone is insufficient without clear implementation mechanisms, institutional coordination, and public engagement. To date, Belgrade has not developed a comprehensive database of underground structures, nor does it possess a strategy for their valorization and activation. An analysis of international case studies—such as Lisbon, Paris, and Tokyo—demonstrates that the successful integration of underground heritage depends on the existence of a regulatory framework that fosters collaboration among urban planners, archaeologists, ecologists, and technological innovators. In Belgrade, such a multidisciplinary approach has yet to be systematized. The authors of the 2024 study [18] suggest that the most urgent step is the development of pilot projects in municipalities with the highest concentration of underground structures (Zemun, Stari Grad), aligning with recommendations from international literature [28] [24].

An additional challenge lies in the unresolved issue of jurisdiction. The study emphasizes the need to clearly define whether the management of underground spaces falls under the authority of local governments, the Institute for the Protection of Cultural Monuments, or a dedicated agency. The absence of an integrated management system leads to institutional passivity, leaving many significant underground structures outside the scope of urban development processes.

The geological characteristics of Belgrade—comprising layers of loess, limestone, clay, and sandstone—present both a challenge and an opportunity for the further understanding and classification of underground structures. Materials such as loess exhibit a higher tendency toward collapse, while structures built in limestone are generally well-preserved and stable. In this context, the digitalization and 3D mapping of the subsurface emerge as crucial steps toward improved planning and utilization of these spaces.

In addition to technical and legal aspects, attention must also be given to intangible values—collective memory, legends, and urban myths associated with these structures. Authors such as Heyns [6] and Pace [17] emphasize the importance of involving the local community in planning and decision-making processes. In Belgrade, this could be implemented through pilot projects or initiatives such as "living labs," particularly in areas of the city with a pronounced historical memory.

Also, Belgrade possesses a rich and diverse stock of underground structures that—if properly valorized—could contribute to relieving surface-level urban pressure, enhancing the city's cultural offer, and increasing its functional resilience, as illustrated by international examples from Lisbon, Madrid, or Kyoto. However, without reform of the legal framework, the creation of a functional registry, financial support, and pilot adaptation programs, this potential remains marginalized. To unlock it, clear management strategies, adequate financial backing, and, crucially, strong socio-political will are essential. In this context, the "Urban Underground Space Development Study" represents an important step toward institutional awareness, but it must be followed by concrete regulatory, budgetary, and urban planning measures [18].

Finally, to move from descriptive mapping to concrete planning, an evaluation framework was developed and presented (Table 1). This framework operationalizes the reuse potential of historical underground structures through explicit criteria, enabling planners to establish priorities for interventions in future planning. Such a methodology aims to achieve comprehensive and systemic urban planning.

Table 1. *Evaluation Framework for Reuse Potential of Underground Structures*

Criterion	Description	Indicators / Parameters	Possible Values
Physical condition	Degree of preservation of the structure	Conserved / Active / Neglected / Collapsed	Active / Neglected / Collapsed
Geological stability	Subsoil type and construction material	Loess / Limestone / Clay / Sandstone	Stable / Unstable
Historical-cultural value	Cultural and symbolic importance of the structure	Heritage status / Local significance / None	High / Medium / Low
Location and accessibility	Position within the city and accessibility to users/visitors	Central / Peripheral / Easily accessible / Remote	Easily accessible / Limited access
Reuse potential	Suitability for adaptive reuse in a contemporary context	Tourism / Cultural / Commercial / Civic functions	High / Limited
Regulatory framework	Legal status and planning documentation	Cultural heritage site / No status / Planning act	Protected / Unprotected

This model can be applied to a comparative analysis between two or more types of structures. For example, Zemun's wine cellars (lagumi), despite their deteriorated condition and unstable loess geology, demonstrate exceptional cultural and touristic reuse potential. Conversely, storage facilities in Stari Grad, built in limestone and partially conserved, represent a more immediate and feasible opportunity for adaptive reuse into museums or cultural centers. This comparison can be visualized in Table 2.

Table 2. *Evaluation Framework for Two Comparative Case Studies*

Criterion	Description	Indicators / Parameters	Example (Zemun – Wine Cellars)	Example (Stari Grad – Storage Facilities)
Physical condition	Degree of preservation and usability without major interventions	Active / Conserved / Neglected / Collapsed	Mostly neglected or collapsed, approx. 65%	Partially conserved, some repurposed
Geological stability	Stability of subsoil and construction material	Loess / Limestone / Clay / Sandstone	Loess – prone to collapse, requiring remediation	Limestone – more stable, suitable for reuse
Historical-cultural value	Cultural and symbolic significance for the local and wider community	Monument status / Local significance / None	High historical and touristic value	High cultural value (trade, urban heritage)
Location and accessibility	Position within the urban fabric and accessibility for visitors/services	Central / Peripheral / Easily accessible	Good accessibility within Zemun urban core	Central location – Old Town
Reuse potential	Suitability for new functions in a contemporary context	Cultural / Touristic / Commercial / Civic	High potential for tourism and wine-related uses	High potential for museums and galleries
Regulatory framework	Legal status and planning instruments for protection/adaptation	Cultural heritage site / No status / Planned	Partial protection, lacking clear planning tools	Protected sites, but no reuse guidelines

Based on the evaluation framework (Table 1), a priority ranking of reuse potential was established (Table 3). This ranking allows planners to distinguish between high-priority structures that can immediately contribute to cultural and touristic development (e.g., wine cellars in Zemun, storage facilities in Stari Grad) and those with medium or low potential requiring long-term strategies (e.g., bunkers in Čukarica, mines in Rakovica, shelters in Palilula and Voždovac).

Table 3. *Priority Ranking of Reuse Potential for Belgrade's Underground Structures*

Location / Type	Physical Condition	Cultural Significance	Geological Stability	Reuse Potential	Priority
Zemun – Wine Cellars (Lagumi)	Neglected / Collapsed	High	Loess – unstable	Tourism, wine routes, cultural functions	**High** (with remediation)
Stari Grad – Storage Facilities	Conserved / Partially active	High	Limestone – stable	Museums, galleries, cultural centers	**High**
Čukarica – Bunkers	Partially preserved	Medium	Mixed substrate	Educational and memorial centers	**Medium**
Rakovica – Mines	Partially collapsed	Medium	Clay / Limestone	Industrial heritage, thematic parks	**Medium**
Voždovac – Shelters	Active / Conserved	Low	Clay – moderately stable	Civic / Safety functions	**Low**
Palilula – Shelters	Neglected	Low	Limestone	Limited technical potential	**Low**

5. CONCLUSION

Belgrade possesses a layered heritage of underground structures—lagums, bunkers, shelters, mines, and storage spaces—that represent a significant yet overlooked asset within the city's urban fabric. Analysis shows that the largest concentration and surface area of these structures are found in Zemun and Stari Grad, primarily built during the Austro-Hungarian period within loess and limestone formations. Unfortunately, more than 65% of them are currently in a state of neglect or collapse, highlighting a lack of systematic care and a clearly defined institutional framework. At the same time, the Study on the Development of Urban Underground Spaces in Belgrade emphasizes the urgent need to recognize these spaces not as infrastructural burdens, but as urban resources.

A key challenge in the revitalization of underground spaces lies in the legal and planning vacuum: although the Law on Cultural Heritage recognizes certain structures as cultural monuments, there are no guidelines for their adaptive reuse or integration into contemporary urban planning. In practice, current spatial plans almost entirely overlook the existence of these structures, preventing their contribution to relieving public surface space or fostering tourism and cultural development. Moreover, the lack of coordination between the heritage protection sector and infrastructure management further delays any concrete interventions.
The solution lies in initiating institutional and operational mechanisms that place the underground realm at the forefront of spatial and cultural development. It is essential to establish specialized teams for mapping, evaluation, and management of subterranean structures, alongside the implementation of digital databases and the active involvement of local communities through participatory models. Adaptive reuse pilot projects—such as the transformation of lagums into museum spaces—can serve as replicable models for broader application. Ultimately, Belgrade's underground spaces have the potential not only to contribute to the preservation of the city's identity, but also to become catalysts for its sustainable development—provided they are properly integrated into urban planning strategies and public policies.

Belgrade's underground cannot be fully understood without considering its deeply rooted socio-historical context. Over the centuries, the city's subterranean structures have been shaped by complex interactions among military, political, economic, and cultural forces. The lagums in Zemun date back to the Austro-Hungarian period, originally serving as wine and goods storage facilities, while bunkers, shelters, and mines across other municipalities emerged during turbulent eras such as World War II, socialist industrialization, and the Cold War. These structures are not merely technical installations—they are physical embodiments of collective memory, reflecting the shifts in Belgrade's urban identity, from a commercial crossroads to a city continuously shaped by political and security pressures.

For this reason, the revitalization of these spaces should not be viewed solely as a functional or aesthetic task, but rather as a socio-cultural project. Shaped by wars, political regimes, trade routes, and everyday life, Belgrade's underground structures hold the potential to become educational and symbolic spaces of memory and identity. Their adaptive reuse—as museums, galleries, public spaces, or even climate-resilient infrastructure—can bridge the city's past and present, adding meaningful value for the local community. The preservation and activation of these sites must therefore be guided by an awareness of their cultural and historical significance, fostering a balance between urban development and respect for the city's layered heritage.

As a synthesis of the findings and a step toward practical applicability, Tables 1 and 2 present an evaluation framework and a priority ranking for the reuse potential of Belgrade's underground structures. These tools are not only intended to guide immediate planning interventions but also to serve as a methodological reference for future research.

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