Digital Methods for Urban Heritage Analysis: A Structured Review

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Abstract. This paper examines digital methods employed in urban heritage analysis. Based on sources indexed in the Web of Science Core Collection (2010–2026) and following the PRISMA 2020 reporting framework, 69 studies are analysed through a structured approach. The review identifies the main methodological families and the dominant types of spatial data and analytical outputs.

Keywords: Systematic Review, Digital Analytical Tools, Urban Heritage, Spatial Data, PRISMA 2020.

1 Introduction

Urban science is a broader discipline that includes numerous sub-fields or disciplines, such as urban geography, urban morphology, and urban history. Due to the rapid urbanisation and technological advancements, various digital tools have been developed in order to ensure spatial indicators, such as density, walkability (Drăghici et al., 2025), and transport analysis (Antoniu et al., 2019).

Following the introduction of the historic urban landscape (HUL) in 2011 (UNESCO, 2011), the practice of analysing and interpreting historic areas has evolved progressively, although the geographical discrepancies remain unaddressed, along with the challenge of contextualization of local endeavours. HUL promotes interdisciplinary research, but lacks specific direction on the application of the analysis (Ginzarly et al., 2019; Rong, 2025). In this context, heritage urban analysis is a broad topic, that encompasses both tangible and intangible elements. Various disciplines and sub-disciplines can be applied in this type of examination, ranging from engineering to urban science, sociology, philosophy or sustainability (Chieffo et al., 2019). However, given the exponential advancement in the field of sustainability in urban planning, the article does not aim to debate this discipline (Belkhiri et al., 2026; Zhang et al., 2023).

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Recent advancements in technology have led to the optimisation of cultural heritage assessment or multidisciplinary examination (Builes-Vélez et al., 2021; Jaillot et al., 2020; Moufid et al., 2025; Zhang et al., 2023). The classification provided by (Jaillot et al., 2020) include the broader area of digital tools: "digital representation of the city (e.g. maps, 3D modelling, etc), multimedia data (textual data, audio stories, images, videos, etc) (..) and participatory functionalities (comments, forums, submission of multimedia, etc)" (Jaillot et al., 2020, p. 2). Despite these efforts, the existing literature still lacks a clear overview of how digital analytical tools are used and the discipline fields classified in urban heritage research.

This study aims to achieve three main objectives: (1) Systematic identification of digital tools used in urban research; (2) Classification of identified tools into methodological families and examination of the types of spatial data used as analytical inputs and (3) Analysis of the forms of analytical output generated and the construction of a coherent image of current digital practices in urban heritage research.

Based on these objectives, the study addresses the following analytical questions:

- **RQ1:** Which digital analytical tools are used in urban heritage research, and how can they be classified into methodological categories?
- **RQ2:** What types of spatial data are used as analytical inputs in these studies?
- **RQ3:** What forms of analytical output are generated in urban heritage research?

This article contributes to the field by understanding and examining *which* tools are being used, not just *how they are applied.* The article links disciplines, fields, method families, and analytical output types, offering a broader overview of digital practices.

2 Methodology

2.1 Data Source and Collection

Systematic reviews depend on data transparency and reproducibility as a way to synthesise research findings while minimising data bias. It is suitable for research that aims to answer multiple questions and interpret data critically (Snyder, 2019).

2.2 Data Search Strategy

The methodology is based on a systematic literature review methodology, conducted on 24 February 2026, to ensure data accuracy. PRISMA 2020 (Page et al., 2021) is used as a protocol (flowchart, checklists) to ensure academic rigour (Pickering et al., 2021; Randles & Finnegan, 2023; Snyder, 2019). Academic resources were collected using Web of Science (WOS) as a primary database source, including the Web of Science Core Collection, including all editions SCI-EXPANDED, SSCI, AHCI, CPCI-S, CPCI-S, CPCI-SSH, BKCI–SSH, ESCI, CCR-EXPANDED, IC.

The starting point of the research lies in the research questions that the study aims to examine. Additionally, the strategy is developed around them and comprises several major steps, as stated below.

2.3 Key words

The conceptualisation of the keywords is conducted in relation to the first research question.

Accordingly, the search strategy defines three thematic clusters: heritage (A), analysis type (B) and scale (C), as shown in Table 1. However, the term used in heritage areas varies substantially, even if they describe the same operation or scale. Therefore, cluster A includes a collection of the most used terms in the articles we try to include. Cluster B defines the most commonly used terms used to describe various urban analysis types. It is implied that urban analysis uses a digital tool; the keywords used in cluster B relate to the theoretical field, rather than specific tools, in order to include more relevant data. Cluster C defines the scale.

It is beyond the scope of the article to examine the links between the built heritage (buildings, artefacts) and digital tools.

The search terms are linked by the "OR" operator to ensure a broad and relevant set of documents, as shown in Table 1. Using "query builder" in The Web of Science Core Collection (WOSCC) database, clusters were searched independently, returning the following results: i) 77,918 for Cluster A; ii) 734,420 for Cluster B; and iii) 55,021 for Cluster C. Afterwards, by using the boolean operators "AND", the clusters were combined, resulting in 133 documents.

Table 1. Clusters and search keywords.

Cluster	Thematic (ALL)	Key Words
A	Heritage	urban heritage OR historic urban landscape OR HUL OR heritage conservation OR historic urban areas OR cultural heritage
B	Analysis type	spatial analysis OR geospatial analysis OR urban analysis OR spatial modelling OR digital analysis OR remote sensing OR network analysis OR landscape metrics OR space syntax OR urban morphology OR urban spatial structure OR GIS OR geospatial OR multicriteria evaluation OR map translation
C	Scale	metropolitan area OR urban region OR urban district OR historic quarter OR landscape scale OR territorial analysis OR historic district OR historic city OR multi-scalar OR historic area

Furthermore, the filtering and selection criteria at this stage are: 1) documents are written in English (1 in Russian, 2 in Spanish; n=3) , 2) documents are written between 2010 and 2026 (1 written in 1996, 3 written in 2009; n=4) and 3) data retrieved is of the type: peer-reviewed article, book chapters, review articles (45 articles of proceedings paper type; n=47). Conference proceedings were not included. The time period criterion is introduced because of the latest advancement in the digital field, and also, because it marks the introduction of the *historic urban landscape*. After filtering, the results came to 81 articles. No duplicates have been identified at this stage.

2.4 Screening and Review Process

The screening process was conducted by reviewing the titles of the articles in Zotero (version 7.0.32), using the inclusion and exclusion criteria stated above.

Inclusion criteria. The documents marked as eligible must relate to the following topics: urban analysis, heritage, and a broader urban scale, or multi-scalar framework. Studies focusing on the relationship between buildings and digital tools used were excluded.

Exclusion criteria. At this stage, the exclusion criteria were established to eliminate records addressing topics beyond the scope of the present study, such as climate change (1), archaeology (4), material artefacts, and risk management or seismic vulnerability (12). Therefore, 12 documents have been retracted. After the screening process, 69 articles were considered eligible for full-text review.

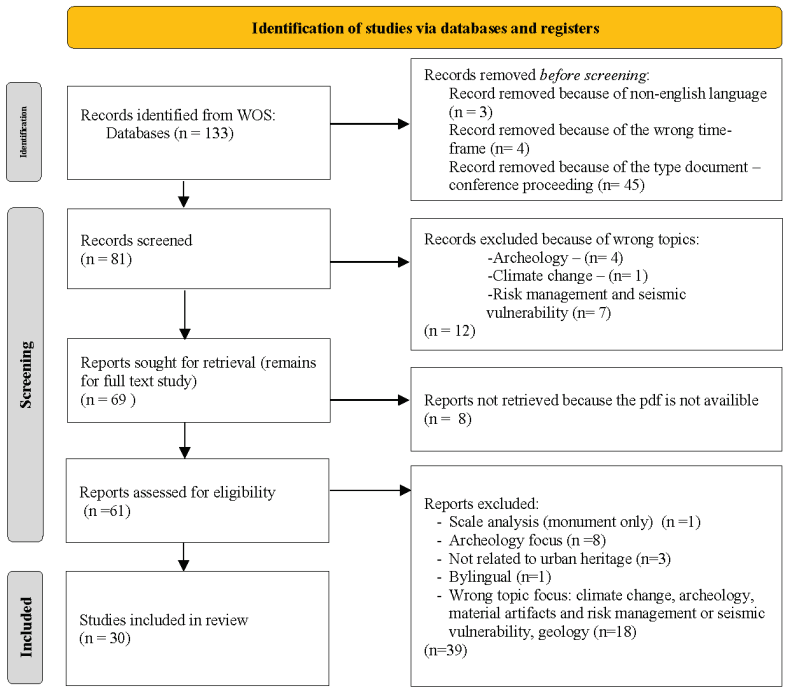

Fig. 1. Flowchart systematic review filtering process.

2.5 Full-text Review and Data Extraction

Selected articles (69) have been imported into Zotero, version 7.0.32. Eight were excluded because the full-text PDF was not available to the authors. This exclusion is also reflected in Figure 1.

At this stage, the eligibility criteria are established based on the full text, in order to ensure a broader screening process. The detailed search process is detailed in Figure 1.

The articles were excluded if they: 1) the scale of analysis is more focused on building(s), monument – (1); 2) the article is about or related to archaeology (8); 3) the analysis is focused on specific niches of urban heritage (such as geology, energy planning in urban planning, computer gaming HBIM, blue-green spaces (18); 4) the articles are not related to urban heritage (3). The retrieved articles are stated in APPENDIX 1. Additionally, one article was retrieved despite having the abstract in English but the full text in Spanish. A total of reports excluded: 39 articles.

The articles were included if the analysis focused on urban heritage, even if it was interdisciplinary. A total of 30 articles were selected for full-text assessment and data extraction.

2.6 Analysis

Eligible full-text documents were classified by: methododological family, specific method, spatial data type, analytical output type, theoretical framework, identified digital tools and disciplinary field. The full classification is shown in Appendix 2. All reports analysed are journal article type (see Appendix 2).

Firstly, an analysis by year of publication was conducted, concluding that 2025 had the most publications (9), as shown in Figure 2. Also, 18 studies use the district as the scale of analysis, as shown in Figure 3.

The results section will further detail the relationships and comparisons between the classification criteria.

2.7 Limitations

The abundance of overlapping and semantically similar terms – such as “historic district” or “historic quarters” or “urban heritage areas”- creates significant challenges in identifying the most relevant documents. This redundancy complicates search precision, increases the risk of retrieving less pertinent results, and hinders effective literature filtering, particularly when using automated search tools.

The data were obtained by searching a single database, resulting in the omission of several studies. Further research should include another scientific database, such as Scopus.

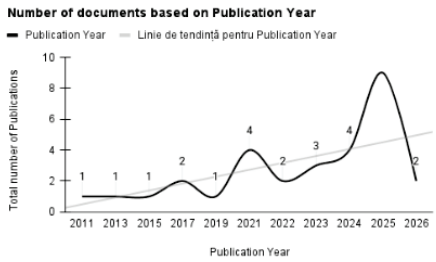

Fig. 2. Number of articles by published year.

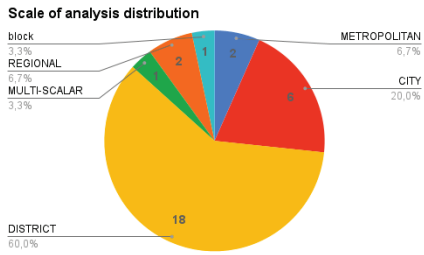

Fig. 3. Scale of analysis type distribution.

3 Results

The results section is divided by the research questions, as stated in Table 2:

Table 2. Research questions and section coordination.

Research Question	Description	Analytical Framework
RQ1	Which digital analytical tools are used in urban heritage research, and how can they be classified into methodological categories?	Classification and methodology - Digital tools - Specific method - Methodological family - Disciplinary field and theoretical framework
RQ2	What types of spatial data are used as analytical inputs in these studies?	Technical specificity - Analytical output type
RQ3	What forms of analytical output are generated in urban heritage research?	Practice and interpretations - Methodological family – analytical output type - discipline

3.1 Classification Methodology

Specific Method. The analysis of the specific methods used in the selected studies reveals a clear predominance of spatial analytical approaches applied to the structure of urban environments. The distribution of these methods is presented in Figure 4, where GIS-based analysis and configurational methods such as *space syntax* emerge as the most frequently used analytical approaches.

Other identified methods include multi-criteria evaluation techniques, such as AHP (Oumelkheir & Nadia, 2021; Saygi, 2026; Song et al., 2025; Suprapti et al., 2022; H. Wang et al., 2025), spatial density analysis methods such as *kernel density estimation*, as well as data-driven spatial approaches. In several cases, additional sources such as surveys, social media data or pedestrian flow analysis are integrated into the analytical workflow (Song et al., 2025; H. Wang et al., 2025).

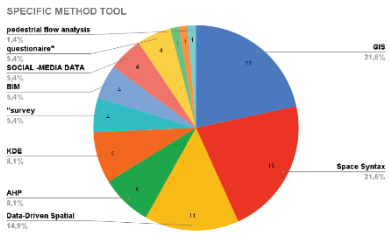

Fig. 4. Specific method.

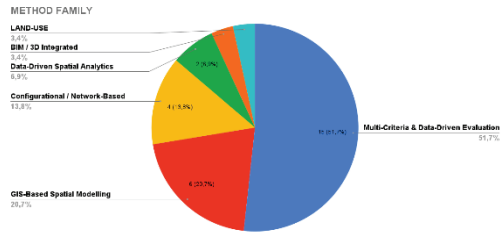

Fig. 5. Methodological family distribution.

These methods are primarily employed to investigate the relationships between the structure of urban networks, the distribution of urban functions and the dynamics of activities within historic urban areas.

Overall, the results indicate that the analysis of historic urban areas is strongly dominated by methods that explore spatial relationships within urban systems, confirming the central role of spatial analysis in contemporary urban heritage research.

Methodological Family. To better understand the methodological structure of the analysed studies, the identified methods were grouped into several broader methodological families. The distribution of these families is presented in Figure 5. The results indicate a strong predominance of multi-criteria (15 studies) (Alsaffar et al., 2025; Carone et al., 2017; Fezzai et al., 2025; González et al., 2024; Hegazi & Fouda, 2019; Lyu et al., 2025; Sarihan, 2021; Saygi, 2026; Serrano-Estrada et al., *2024*; Sukwai et al., 2022; Tafahomi, 2021; Tao & Duan, 2024; Y. Wang et al., 2025; Yu et al., 2026) and data-driven evaluation approaches (2 articles) (Fu et al., 2025; Zhu et al., 2017), representing approximately half of the analysed studies.

GIS-based spatial modelling represents the second most frequent methodological family – 6 studies (Li et al., 2024; Merciu & Paunescu, 2013; Oumelkheir & Nadia, 2021; Song et al., 2025; Suprapti et al., 2022; H. Wang et al., 2025), followed by configurational or network-based approaches - 4 studies (Lyu et al., 2023; M. Wang et al., 2021; Wu et al., 2025; Xu et al., 2023), such as space syntax analysis. Other methodological families, including data-driven spatial analytics, land-use analysis – 2 articles (Megahed et al., 2015; Vaz et al., 2011) and BIM/3D integrated methods – 4 articles (Akl et al., 2023; González et al., 2024; Sarihan, 2021; Sukwai et al., 2022) appear only marginally within the analysed corpus.

Digital Tools. Articles were classified according to the digital tools explicitly stated by the authors. The distribution of these tools is presented in Figure 6. The most frequently used software for spatial analysis is ArcGIS – 15 articles, 14.3%; followed by DepthmapX (UCL) – 12 articles, 11.4%; which is commonly employed in configurational analyses such as space syntax.

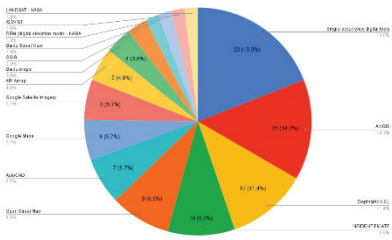

Fig. 6. Digital tools distribution.

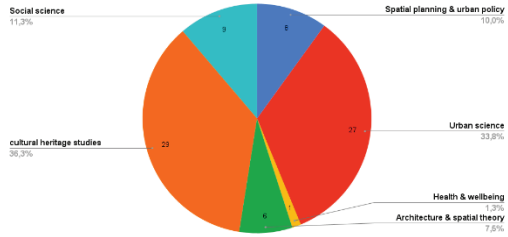

Fig. 7. Disciplinary field and theoretical framework distribution.

In terms of spatial data sources and mapping platforms, OpenStreetMap (OSM) appears as the most frequently used dataset for street network extraction and spatial reference – 9 articles. Other commonly used tools include AutoCAD – 7 articles - for spatial representation and modelling, as well as widely accessible mapping platforms such as Google Maps and Google Satellite Imagery – 6 articles each.

The results also indicate that a notable number of studies do not explicitly declare the software used for analysis or post-processing, highlighting a lack of methodological transparency in parts of the analysed literature.

Disciplinary Field and Theoretical Framework. After the introduction of the *historic urban landscape* (UNESCO, 2011), studies on historic areas analyse the city from multiple points of view, being interdisciplinary and multi-disciplinary in nature. While analysing the data, it became increasingly clear that all studies relate at least two disciplinary fields, such as cultural heritage studies and urban studies. The analysis was conducted by manually sorting each study, to reduce bias.

Disciplinary fields sorting: (i) urban science, including urban morphology and its sub-criterias, (ii) spatial planning & urban policy, including conclusions or debates in the studies relates to policy in urban planning, (iii) cultural heritage studies, relating to debates about the heritages debates or sub-fields, (iii) social science, meaning the examination of human perception, or sensory mapping, (iv) health & wellbeing, examining the health metrics in urban areas, and (v) architecture & spatial theory, that relates mostly in the analysed studies, to the theoretical fields, or spatial narrative.

3.2 Technical Specificity

The technical specificity of the analysed studies reflects the strong integration of digital spatial analysis tools within urban heritage research. The reviewed articles employ a wide range of digital tools and spatial datasets to investigate the structure, accessibility

and functional dynamics of historic urban areas. To better illustrate the relationships between methodological families, analytical outputs and the digital tools used in the analysed studies, Figure 8 presents a synthesised visualisation of the methodological workflows identified in the reviewed literature. The diagram highlights how different methodological families generate specific analytical outputs, which are subsequently implemented through various digital platforms and spatial datasets.

The visualisation indicates that GIS-based spatial modelling and multi-criteria data-driven evaluation represent the most prominent methodological families, generating analytical outputs such as spatial metrics, accessibility analysis, thematic mapping and decision-support frameworks. Configurational or network-based approaches are primarily associated with analyses of spatial visibility and urban network structure, commonly implemented through space syntax methodologies.

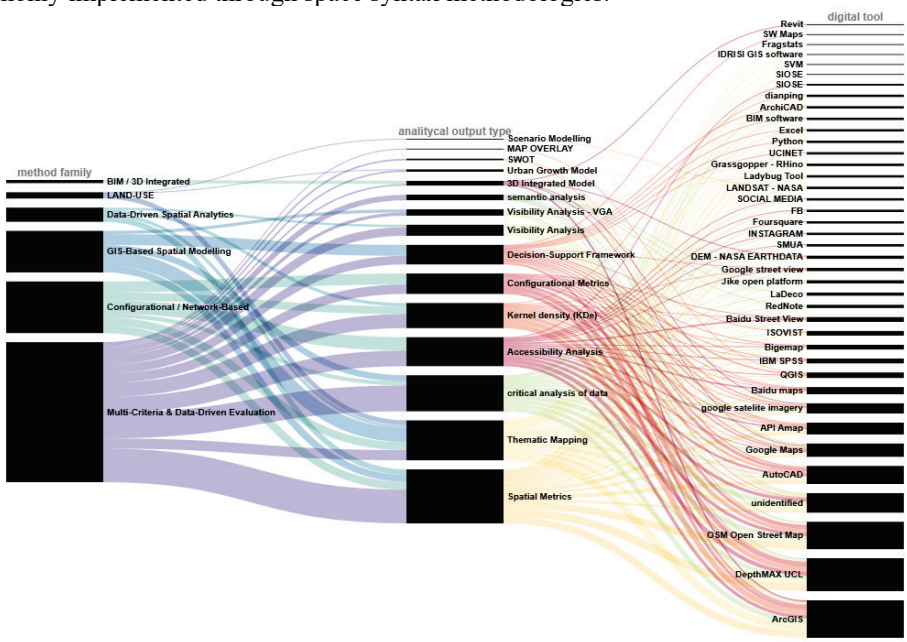

Fig. 8. Relationships between method families, analytical outputs and digital tools used in the analysed studies.

In terms of digital tools, GIS platforms such as ArcGIS emerge as the most frequently used analytical environments, followed by specialised configurational analysis software such as DepthmapX. Open spatial datasets, particularly OpenStreetMap (OSM), are widely used for street network extraction and spatial referencing. Additional tools identified in the analysed corpus include AutoCAD, Google Maps, Google Satellite Imagery, and various other software environments used for spatial modelling, visualisation, or data processing.

The diagram also illustrates the diversity of digital tools used across the analysed studies and the frequent combination of multiple tools within the same analytical work-

flow. However, a number of studies do not explicitly specify the software used for spatial analysis or post-processing, suggesting a certain level of methodological opacity in parts of the analysed literature.

Analytical Output Type. The analysed studies generate a diverse range of analytical outputs derived from digital spatial methods. As illustrated in Figure 8, the most frequent outputs include spatial metrics, thematic mapping, and accessibility analysis, which are commonly used to examine the spatial structure and functional organisation of historic urban areas. Other outputs include configurational metrics, kernel density estimation (KDE) and visibility analysis (VGA), while some studies produce more complex results such as decision-*support* frameworks, scenario modelling, or urban growth models. These outputs reflect the central role of spatial analysis in understanding urban dynamics within historic environments.

3.3 Practice and Interpretation

The reviewed studies demonstrate that digital spatial analysis methods are primarily applied to interpret the spatial structure and dynamics of historic urban areas. The analytical outputs are commonly used to identify patterns of accessibility, spatial visibility, functional distribution and urban density within heritage contexts. In many cases, these results support the interpretation of urban morphology and the evaluation of spatial relationships between historic structures, public spaces and circulation networks. The findings are frequently used to inform heritage management strategies, urban planning decisions and conservation policies.

At the same time, several studies illustrate a particularly creative integration of digital tools. Some research combines GIS with multiple sources of spatial data to support land-use analysis and multi-source spatial integration (Megahed et al., 2015). Other studies integrate GIS with configurational methods such as space syntax and broader spatial theory in order to better understand the relationship between urban morphology and movement patterns in historic areas (Tafahomi, 2021). In addition, GIS has also been used in combination with historical cartography and archival planning documents, allowing researchers to integrate historical maps with contemporary spatial datasets and analyse the evolution of historic urban landscapes over time (Oumelkheir & Nadia, 2021).

Recent studies also attempt to reconnect spatial analysis with cultural interpretation. Concepts such as Cultural DNA (C-DNA) suggest that cultural values, social practices and behavioural patterns can act as generative principles shaping urban morphogenesis and spatial organisation (Alsaffar et al., 2025). By combining configurational analysis with cultural interpretation, such approaches indicate that spatial metrics may reveal deeper socio-cultural structures embedded within historic urban fabrics.

The predominance of GIS-based and configurational approaches observed across the reviewed studies can be explained by several converging factors. It is, first, a consequence of the increasing availability of geospatial datasets and open-access mapping platforms, which have facilitated the adoption of GIS as a standard analytical

framework. It is also linked to methodological standardisation within disciplines such as urban studies and spatial planning, where reproducible, data-driven approaches are preferred. At the same time, configurational meth-ods, such as space syntax, offer structured tools for interpreting spatial relationships, making them particularly suitable for analysing urban morphology and movement patterns. However, this dominance may also indicate a methodological bias, as approaches relying on readily available data tend to be favoured over more qualitative, interdisciplinary, or context-specific methods.

4 Conclusions

The widespread use of digital tools and analytical software has significantly improved the capacity to analyse historic urban landscapes, enabling the integration of spatial data, analytical methods and theoretical perspectives from multiple disciplines. As demonstrated by the analysed studies, digital methods increasingly function as a bridge between different disciplinary fields, connecting urban science, cultural heritage studies, spatial planning and social sciences within a shared analytical framework, reducing the risks (Azap et al., 2018) and increasing overall cohesion.

The review highlights three key directions, summarised as follows:

- digital tools act as integrative platforms connecting multiple disciplinary fields;
- methodological fragmentation highlights the need for coherent and unified classification frameworks;
- emerging technologies remain underexplored at the urban scale in urban heritage research.

The study also revealed the absence of a clear and widely accepted classification of digital tools and analytical frameworks used in urban heritage research. Many studies develop their own methodological cat-egorisations depending on the authors' disciplinary background or the specific research objectives. This fragmentation highlights the need for integrative frameworks capable of connecting methodological families, analytical outputs and digital tools within a coherent structure.

The correlation between disciplinary fields and theoretical frameworks suggests the emergence of a three-layered methodological structure that may guide future research: a theoretic-historical layer, which provides the conceptual and heritage-related context; an analytical layer, based on digital spatial methods and data-driven analysis; and an interpretative layer, where analytical results are translated into planning strategies, heritage management approaches (Moșiu et al., 2025) or urban policy recommendations (Onescu et al., 2023). In this sense, the proposed structure can function not only as an interpretative model, but also as a practical framework that supports the organisation of future research workflows, from data acquisition and analysis to interpretation and decision-making. Future research should further explore the relationships between these layers and develop clearer methodological frameworks for their integration.

At the same time, the review highlights certain methodological limitations in the current body of research. Despite the rapid development of digital technologies, approaches based on digital twins, virtual reality, or advanced urban simulations remain

largely absent from studies focusing on historic urban areas at the urban scale (Moufid et al., 2025). Although several studies employing such technologies were identified during the screening process, they were excluded from the present review because their analytical focus was limited to the architectural or building scale rather than the urban scale required by this study.

This observation suggests that while digital tools are widely used for spatial analysis and evaluation, integrating advanced simulation environments and digital twin models into urban heritage research remains an emerging direction that warrants further exploration.

Overall, this study contributes to a clearer understanding of how digital analytical methods are currently struc-tured and applied in urban heritage research, while highlighting the need for more transparent, integrative, and interdisciplinary methodological frameworks.

Declaration on Generative AI

The authors used AI language tools solely to assist with translation and improve the grammar, clarity, and readability of the manuscript. These tools were not used to create scientific content, develop ideas, analyse data, or make conclusions. The authors are fully responsible for the scientific work, including framework, methods, data interpretation, and conclusions. The authors reviewed and edited all AI-assisted text to ensure it is accurate, original, and meets academic standards.

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