ICCAUA Proceedings Journal
Proceedings of the international conference of contemporary affairs in architecture and urbanism-ICCAUA
Volume 9 (December 2026), 2610045

Journal homepage: https://journal.iccaua.com/

DOI: https://doi.org/10.38027/ICCAUA2026EN0045

Criteria for Selecting and Analyzing Present and Past Cities to Compare Their "Smartness" Across Time

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Received: 29.04.2026
Revised: 28.06.2026
Accepted: 01.07.2026
Available online: 10.07.2026

This article has been selected and peer-reviewed for publication in this journal as part of the 9th International Conference of Contemporary Affairs in Architecture and Urbanism, held on 7–8 May 2026 in Istanbul, Türkiye.

A b s t r a c t

This paper proposes a methodological framework for comparing historical and contemporary cities in relation to urban smartness. The study aims to identify transferable criteria that enable cities from different periods to be assessed without reducing smartness to digitalisation. Alexandria, Rome and Antioch were selected for their strategic Mediterranean position, historical representativeness and long-term continuity. Using an interdisciplinary qualitative-comparative method, ten criteria, i.e., infrastructure, mobility, innovation, sustainability, governance, resilience, quality of life, health, culture and urban justice, were applied across ancient, medieval and contemporary periods. The results show that organisation, efficiency, adaptability and sustainability persisted over time, although they assumed different historical forms. The main contribution is a transferable framework linking smart-city studies with urban history by assessing long-term urban smartness through continuity, adaptability and resilience, while offering a replicable tool for comparative urban research across diverse contexts and cases.

K e y w o r d s : Smart cities; Ancient; Historical representativeness; Governance; Technology.

1. Introduction

The concept of "smart city" is usually associated with digitalisation, data platforms and technology-based governance. For contemporary analysis, this perspective is useful, but for long-term urban continuities it remains incomplete because it places social structures, institutions, culture, and resource management in the background, even though these dimensions allow historical forms of efficient organisation and urban adaptation to be observed (Sharifi, 2023).

Recent literature increasingly links smart city to sustainability, equity and resilience. Debates on the 15-minute city, green infrastructure, climate justice and access to services show that urban performance is formed through physical, institutional and social interactions (Caggiano et al., 2023; Grabowski et al., 2023; Gu et al., 2025; Mouratidis, 2024; Amen et al., 2023). In the same logic, smart sustainable cities must be assessed multidimensionally, through environment, society, governance and economy (Shao & Min, 2025).

Against this background, this research asks whether cities from different periods can be compared through stable criteria capable of capturing an urban smartness that does not depend directly on the technology of each period. The proposed answer is affirmative if the analysis shifts from digital indicators to core urban functions: infrastructure, mobility, innovation, sustainability, governance, resilience, quality of life, health, culture and urban justice.

The historical component is strengthened through recent studies on Alexandria, Rome, Antioch and their regional contexts. These sources support the material, institutional, cultural and economic dimensions of urban continuity (Barber, 2025; Gutgarts & Ellenblum, 2024; Then-Obłuska & Syta, 2025; Aziz Amen & Ali, 2025).

1.1. Theoretical Context and Methodological Gap

Current smart-city models use indicators such as connectivity, energy efficiency, smart mobility and data-based services. These indicators are necessary for present-day policies, but they create a methodological rupture in historical analysis. Ancient and medieval cities cannot be assessed through the same metric, but they can be analysed through infrastructure, adaptation, administrative capacity, culture and spatial coherence.

Recent research on urban sustainability and resilience shifts the focus towards integrated socio-ecological and technological systems. Sharifi (2023) links resilience to physical, social, institutional and technological elements, while Shao & Min (2025) show that smart-city strategies become credible only when they include social and environmental dimensions.

The study translates this focus shifting into a methodology for historical comparison. Instead of asking "how digital is a city?", it asks "how coherently, adaptively and efficiently does a city function in a given context?". Urban smartness is therefore treated as an emergent property of the urban system.

1.2. Objectives, Research Questions and Working Hypothesis

The aim of this study is to build and test a comparative framework for analysing urban smartness over time, applied to Alexandria, Rome and Antioch. The specific objectives are: to justify the selection of the cities and city-period units; to define the criteria and subcriteria; to transform qualitative assessment into an ordinal scale; and to interpret the results in relation to the literature on smart cities, sustainability, resilience and equity.

The research questions address the existence of a stable set of criteria for comparisons across periods, the criteria associated with urban continuity, and the way in which differences between Alexandria, Rome and Antioch can be explained through combinations of infrastructure, governance, mobility, culture and resilience.

The working hypothesis is that urban smartness can be compared over time if the analysis follows the organisation of core functions, resource management and responses to crises. Within the proposed grid, higher scores are associated with more stable profiles of urban continuity.

1.3. Significance of Research and Structure of Article

The study provides an instrument for comparative research on historical and contemporary cities and rereads the smart-city concept through urban continuity. This contribution is relevant to contemporary urban affairs because it connects smart-city debates, historical urban performance and long-term planning assessment. The study also includes heritage, culture, institutions and resilience in the assessment of urban smartness, beyond standard technological indicators.

The article has five sections: the introduction, methodology, comparative results and descriptive statistics, discussion in relation to literature, and conclusions and implications for future research.

2. Materials and Methods

2.1. Research Methodology and Study Configuration

The methodology is comparative, interdisciplinary and multi-scalar, combining urban planning, urban history, heritage studies, urban geography, engineering, technology and the smart-city literature. The unit of analysis is the city in a historical period, resulting in nine comparative configurations.

2.2. Case Studies and Justification for Their Selection

The selection of Alexandria, Rome and Antioch is based on strategic Mediterranean positioning, historical representativeness and urban continuity. The three cities were political, economic, religious and cultural nodes, but they express different relationships between stability and rupture: Alexandria as port and through knowledge, Rome through infrastructure and institutions, and Antioch through cultural interface and vulnerability.

Recent literature supports this selection. For Alexandria, Kom el-Dikka indicates urban production and consumption between the Roman, Late Antique and early Islamic periods (Then-Obłuska & Syta, 2025). For Rome, public space, Portus Romae and hydraulic infrastructures explain centrality and medieval transformations (Barber, 2025; De Angelis et al., 2025; Gutgarts & Ellenblum, 2024). For Antioch, relations with Alexandria and identity continuities in Hatay support the role of a vulnerable cultural interface (Booth, 2021; Grigoriadis, 2022).

The nine city-period units and their comparative role are summarised in **Table 1.**

Table 1: Structure of the nine case-study units and their comparative role (Developed by the Authors).

City	Case study 1	Case study 2	Case study 3	Comparative role
Alexandria	Antiquity	Middle Ages	Contemporary	Case of urban adaptation through port, cultural and technological reconfiguration across periods.
Rome	Antiquity	Middle Ages	Contemporary	Case of robust urban continuity supported by institutions, infrastructure and historical memory.
Antioch	Antiquity	Middle Ages	Contemporary	Case of vulnerable urban continuity marked by geopolitical, seismic and religious crises.

2.2.1. Comparative Profile of the Nine Units of Analysis

Each unit of analysis combines a city and a period. Ancient Alexandria and ancient Rome serve as benchmarks for infrastructural and cultural performance, ancient Antioch for regional mediation, while the medieval units test the criteria in contexts of political, religious and economic fragmentation.

Antiquity and Middle Ages are treated as analytical periods. The first highlights connectivity, public space, ports and exchanges; the second highlights the reconfiguration of economic functions, adaptation to political ruptures and preservation of religious and cultural continuities (Osland, 2023; Zavagno, 2024).

2.2.2. Operational Delimitation of Historical Periods

The periods were delimited operationally, for comparability. Antiquity refers to the interval in which Alexandria, Rome and Antioch functioned as Hellenistic, Roman and Late Antique centres, with Mediterranean integration, complex infrastructures, political or cultural centrality and high connectivity. For Alexandria and Antioch it includes the Hellenistic, Roman and Late Antique phases up to the transformations in seventh and eighth centuries, while for Rome it includes the Republican, imperial and Late Antique periods.

Middle Ages refers to the reconfiguration of the three cities in different political, religious and economic contexts. For Alexandria and Antioch, it includes integration into early Islamic structures and medieval commercial, religious and cultural networks; for Rome, it refers to the post-imperial and papal period, with the reuse of ancient infrastructures and restructuring of habitation.
The contemporary period refers to the late modern and current phase, analysed through infrastructure, mobility, sustainability, digitalisation, heritage, quality of life, accessibility, resilience and urban justice. For Antioch, it also includes reconstruction after the 2023 earthquakes.
The three periods are not simple chronological labels, but comparative analytical frames that make it possible to observe fundamental urban functions in distinct historical contexts, without imposing modern indicators that are not applicable to the past.

2.3. Analytical Criteria and Their Operationalisation

The methodology uses ten qualitative criteria, each with two subcriteria: infrastructure and urban planning; mobility and transport; education and technologies; sustainability and resource management; governance and civic involvement; quality of life and inclusion; public health and medical services; religion and culture; resilience from the perspective of urban smartness; and economy and urban justice. The formula remains sufficiently general for different periods, yet precise enough to limit ambiguity. Each subcriterion was first assessed separately on a 1–5 ordinal scale, and the criterion score resulted from aggregating the two assessments. If the levels coincided, the score was taken directly; if they differed, the mean of the two subcriteria was rounded to the nearest ordinal level and checked through interpretation of the historical context.
To make the scoring procedure explicit, **Equation 1** establishes the score of criterion i for unit u, where A_{iu} and B_{iu} are the subcriterion scores. The criterion score therefore results from a controlled assessment of the two operational dimensions.

$$S_{iu} = \text{round}\left(\frac{A_{iu} + B_{iu}}{2}\right)$$

Equation 1. Score of the unit of analysis.

Initially, eight criteria were defined and presented to experts to verify their grounding, practicality and applicability to ancient, medieval and modern cities. The consultation validated these criteria and led to the addition of resilience and economy with urban justice.

2.3.1. Expert Consultation and Validation of the Criteria

To strengthen methodological validity, the initial criteria were reviewed by ten experts, two from each field: urban planning, archaeology, smart urban planning, engineering and technology. Selection considered relevant academic or professional experience, familiarity with historical or contemporary urban analysis, and capacity to assess the applicability of criteria to different urban contexts. Semi-structured interviews took place in February–March 2026 and focused on relevance, clarity, applicability and overlaps. The answers were synthesised thematically by identifying convergences. The consultation validated the eight initial criteria and led to adding urban resilience and economy to urban justice. The process was anonymous and non-invasive; no sensitive personal data were collected and opinions were not assigned to individual names.

2.3.2. Logic of Criteria Grouping

The criteria are grouped into four families: material-territorial, institutional-political, socio-human and symbolic-cultural. This grouping shows that the methodology integrates complementary dimensions of the urban system.
This logic explains the use of the notion of "smartness" in a non-exclusively technical sense. A city may be materially strong but institutionally fragile, or the reverse; for this reason, the assessment uses a matrix rather than a single indicator of smartness.
The ten analytical criteria and their operational subcriteria are presented in **Table 2.**

Table 2: The ten analytical criteria and their operational subcriteria (Developed by the Authors).

Criterion	Subcriterion A	Subcriterion B
1. Infrastructure and urban planning	Technical-utility infrastructure and water-supply systems	Spatial organisation of cities
2. Mobility and transport	Transport infrastructure	Internal and external connectivity
3. Education and technologies	Education and human capital	Technological innovations
4. Sustainability and resource management	Sustainable management of natural resources	Waste-management methods
5. Governance and civic involvement	Governance structure	Participation of citizens / urban actors
6. Quality of life and inclusion	Quality-of-life factors	Social, economic and cultural inclusion
7. Public health and medical services	Medical services	Public health and epidemics
8. Religion and culture	Religion and the configuration of space	Cultural diversity and tolerance
9. Resilience from the perspective of urban "smartness"	Adaptation to economic crises, conflicts or disasters	Resilient infrastructures
10. Economy and urban justice	Urban economy and commercial integration	Equal access to rules and institutions

2.4. Sources, Procedures and Analytical Protocol

Data comes from recent literature on smart cities, sustainability, resilience and urban justice, from historical sources for each city, and from internal analytical sheets for the nine city-period combinations.

The analytical sheets prepared beforehand served as internal tools for each city-period combination. They recorded the historical context, main urban features, evidence for the ten criteria, qualitative justification and limits of the sources. They were not independent primary sources, but instruments for organising and interpreting the academic and historical material used in the study. Each sheet followed the same sequence: information collection, grouping by criteria and subcriteria, qualitative assessment and translation into an ordinal score. Triangulation between academic literature, historical sources and internal coherence of the matrix ensured traceability, score justification, and comparability of cases. The protocol comprised six stages: defining the problem, selecting cities and periods, formulating criteria, preparing comparative sheets, converting assessments into a 1–5 ordinal scale, and synthesising results in tables, figures and matrices. Figure 1 summarises the process.

The preliminary scores were assigned by the first author on the basis of sheets, subcriteria and decision rules. They were then reviewed methodologically together with the second author, checking the coherence of description, sources, and score. No statistical inter-rater procedure was applied; ambiguities were resolved by returning to subcriteria and methodological consensus.

2.4.1. Bibliographic Filtering and Quality Control of References

Priority was given to articles published between 2022–2026, with direct theoretical, methodological or interpretative relevance. Filtering checked both reference currency and the correspondence between citations and source role. Works from 2021 were retained as exceptions because they address Roman Alexandria and Alexandria–Antioch relations in the early Abbasid period, topics insufficiently covered by 2022–2026 literature.

Recent historical sources cover antiquity, Late Antiquity and Middle Ages directly or contextually, strengthening the interpretation and reducing dependence on contemporary smart-city literature.

The methodological logic of research, highlighting the relationship between the research issue, objectives, analytical criteria, assessment procedure and interpretation of results applied in the study is illustrated in **Figure 1.**

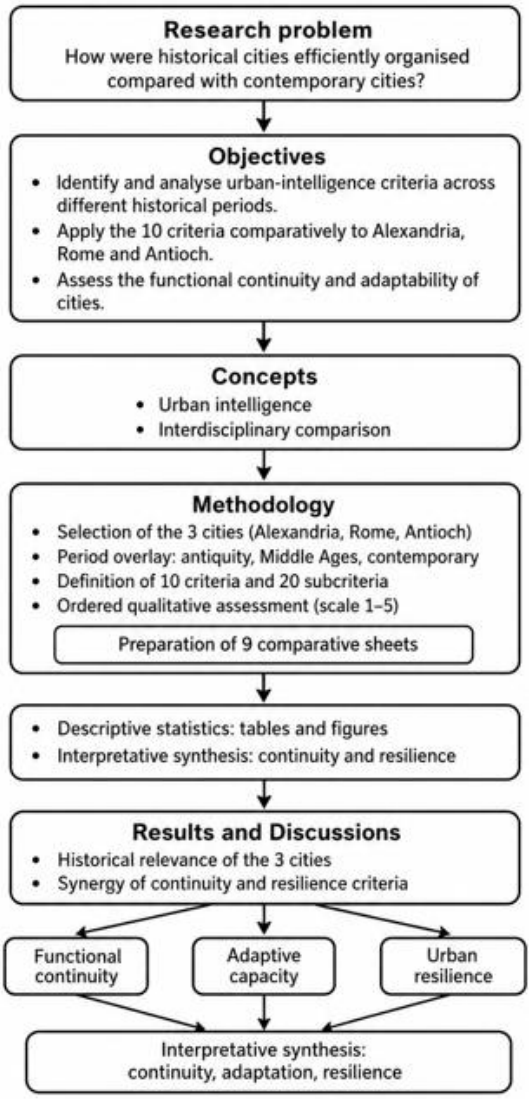

Figure 1. Schematic Representation of the Methodology (Developed by the Authors).

2.4.2. Decision Framework for Qualitative Assessment and Ordinal Scoring

To limit arbitrariness, the assessment used an explicit decision framework, applied to all criteria, subcriteria and units. Each criterion was first classified qualitatively on five levels—very low, low, medium, high and very high—then linked to a 1–5 ordinal scale. Score 5 was reserved for very high and systemically relevant performance; score 4 indicated high performance without the same centrality; score 3 described moderate functional situations; scores 2 and 1 represented low and very low levels, retained for scale completeness.

For transparency, levels 3–5 were anchored in types of evidence. Score 3 indicates the functional presence of the criterion, score 4 performance documented through relevant infrastructures, institutions or urban practices, and score 5 a structural role in centrality, continuity, adaptability or regional influence.

Scores 1 and 2 were not detailed in the anchoring table because they represent deficient levels already defined as "very low" and "low". In this sample, made up of major historical cities with demonstrable continuity, these levels appear rarely or not at all, since all cases show at least a minimum functional form of the analysed criteria. The table therefore details levels 3–5, where differentiation occurs between functional presence, high performance and systemic role. Scores 1 and 2 remain part of the scale and may be used in future studies of cities with severe discontinuities, absent functions or insufficient evidence.

The interpretative anchors used for assigning ordinal scores are detailed in **Table 3.**

Table 3: Interpretative anchors for assigning ordinal scores 3–5 (Developed by the Authors).

Criterion	Score 3 – medium	Score 4 – high	Score 5 – very high
Infrastructure	Functional infrastructures, but partly fragmented or limited.	Coherent infrastructures with an important urban role.	Major, integrated infrastructural system, decisive for city functioning.
Mobility	Internal and external connectivity present, but moderate.	Efficient and relatively stable transport networks.	Major node of regional or imperial mobility, with strategic impact.
Education and technologies	Functional presence of knowledge or innovation.	Clear role in the production, circulation or application of knowledge.	Major centre of innovation, education or technology for the analysed period.
Sustainability and resources	Minimally functional resource management.	Consistent practices for managing water, waste or the environment.	Advanced resource-management system, essential for continuity.
Governance	Administrative structures exist, but with moderate effectiveness.	Stable governance with capacity for urban coordination.	Strong, integrative governance, decisive for city organisation.
Quality of life	Functional but uneven urban conditions.	High level of services, accessibility and housing.	Very high urban quality for the period, with systemic effects on city attractiveness.
Public health	Sanitary or medical mechanisms present, but limited.	Services and sanitary practices relevant to the population.	Medical, sanitary or hygiene system with a major role in urban functioning.
Religion and culture	Cultural or religious role present.	High cultural and religious centrality.	Cultural, religious or symbolic centre of regional/imperial importance.
Resilience	Moderate capacity to adapt to crises.	Documented adaptation to crises, conflicts or major changes.	Exceptional capacity for continuity and reorganisation after major shocks.
Economy and urban justice	Economic activity and institutional access functional, but limited.	Economic integration and relatively stable urban rules.	Major economic node, with institutions and rules essential to city functioning.

The anchors functioned as interpretative reference points, not as rigid quantitative thresholds; close scores were established according to the systemic role of criterion and coherence with the profile of analysed unit.

2.5. Operationalisation of the Ordinal Scale and Descriptive Analysis of Results

Qualitative assessments were operationalised on the ordinal scale: very low = 1, low = 2, medium = 3, high = 4, very high = 5. The mean and standard deviation were used only as auxiliary descriptors of internal distribution, not as interval measurements or inferential indicators. The results were read together with the median, minimum–maximum range and contextual justification. For each unit, the overall mean score was computed, and for each criterion the mean, median, standard deviation and extreme values were computed. To make the calculation procedure explicit, **Equation 2** establishes the mean score S_u of unit u, where s_{iu} is the score of criterion i and n = 10 is the number of criteria.

$$S_u = \left(\frac{1}{n}\right) \times \Sigma\, s_{iu}$$

Equation 2. Mean score of the unit of analysis.

2.5.1. Why a Qualitative Method and Not an Exclusively Quantitative One

The method is predominantly qualitative because analysed cities and periods have uneven or unavailable standardised data. The inter-case mean adds comparative readability and indicates the dimensions with highest ordinal means, without transforming the study into a strictly quantitative research design.

2.6. Considerations on Validity, Limitations and Usefulness of the Method

Internal validity is supported by applying the same grid and defining criteria, subcriteria and scoring rules. Robustness was strengthened through an audit trail: each score was traced back to the criterion, subcriteria, analytical sheet and relevant sources. Ambiguous scores were reviewed by returning to the subcriteria and literature. External validity remains limited by the sample size of three cities; the study proposes a methodology that should be tested later, not a statistical generalisation.

3. Results

3.1. Comparative Results by Historical Period

Within the proposed grid, the period-based analysis indicated a relative hierarchy: ancient units concentrated highest means, the contemporary period occupied an intermediate position, and medieval units had lower aggregate levels. This hierarchy reflects the operationalisation of criteria, not the historical superiority of one period. Antiquity is favoured by high scores for infrastructure, mobility, governance and culture; the Middle Ages reflect political, economic and religious reconfigurations; the present recovers functional advantages but retains vulnerabilities and inequalities.

Historical studies support this statement. For Rome, medieval transformations indicated the rearrangement of infrastructures and habitation under climatic pressures, including the abandonment of systems such as Aqua Claudia (Gutgarts & Ellenblum, 2024). In the Byzantine area, the transition towards Middle Ages involved administrative, coastal and commercial continuities (Zavagno, 2024).

Antiquity stood out through high scores for infrastructure, mobility, culture and governance. Ancient Rome reached the peak through institutions and urban investments, Alexandria through the port, hydraulic infrastructures, culture and innovation, while Antioch had a similar, but more vulnerable profile in terms of resilience and urban justice.

The Middle Ages reduced aggregate performance, especially in mobility, innovation, quality of life and public health, reflecting more fragile connectivity and institutional stability. Even so, resilience can remain relevant when the city preserves its essential functions.

3.1.1. Results by Criteria Families

By functional families, the results showed uneven distributions. The material-territorial family had high values in antiquity and present, the institutional-political family differentiated the cities, the socio-human family varied more between periods, and the symbolic-cultural family remained relatively stable. Infrastructure, culture and resilience appeared as dimensions with more constant ordinal values.

The resulting ordinal scoring matrix is presented in **Table 4.**

Table 4: Ordinal scoring matrix for the nine case-study units (Developed by the Authors).

Criterion	A-Alex	M-Alex	C-Alex	A-Rom	M-Rom	C-Rom	A-Ant	M-Ant	C-Ant
Infrastructure	4	3	4	5	4	5	4	3	3
Mobility	4	3	4	5	4	4	4	3	3
Innovation	4	3	4	4	3	4	3	3	3
Sustainability	3	3	4	3	3	4	3	3	3
Governance	4	3	3	5	4	4	4	3	3
Resilience	4	4	4	5	4	4	3	3	3
Quality of life	4	3	3	4	3	4	3	3	3
Health	3	3	4	4	3	4	3	3	3
Culture	5	4	5	5	5	5	5	4	4
Urban justice	3	3	3	3	3	4	3	3	3

***Methodological Note**. A = Ancient; M = Medieval; C = Contemporary; Alex = Alexandria; Rom = Rome; Ant = Antioch. Matrix scores: 1 = very low; 5 = very high. Matrix scores derived from the analytical sheets prepared for each city-period unit. For each criterion, the two operational subcriteria were assessed, aggregated and checked against historical sources, academic literature and profile of analysed unit. The procedure followed an audit trail: criterion → subcriteria → documentary evidence → qualitative justification → final ordinal score. The table presents the result of a systematised comparative assessment, not of intuitive global judgements. Values are descriptive ordinal scores, not interval measurements.*

The distribution of ordinal scores across criteria, cities and periods is visualised in **Figure 2.**

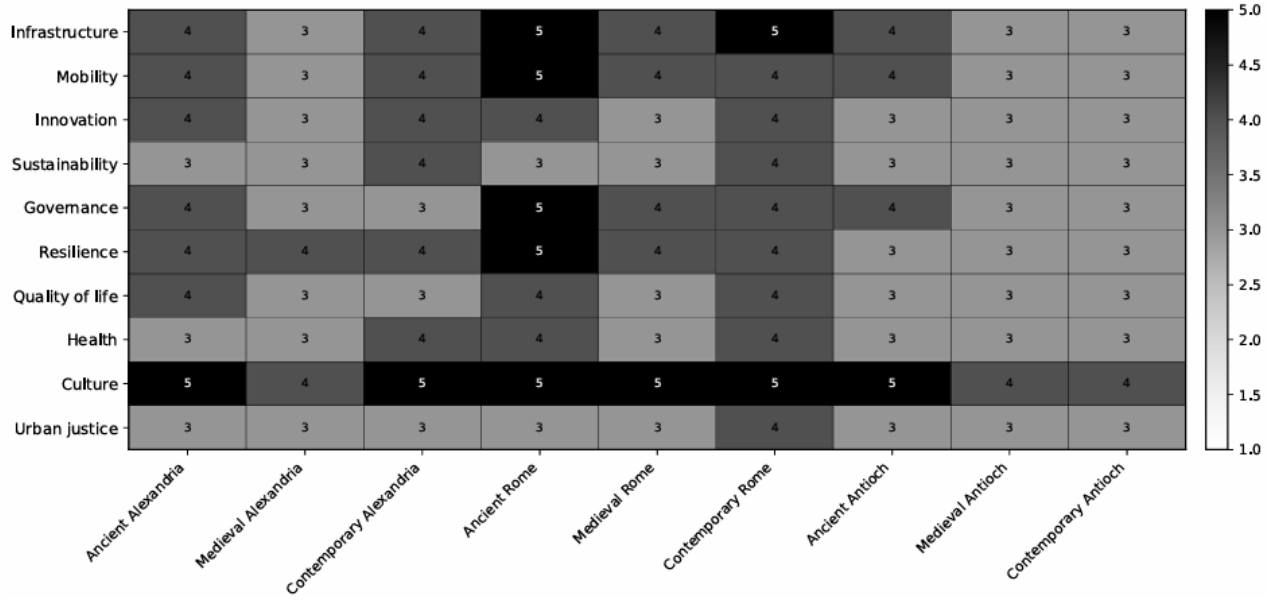

Figure 2. Heatmap of Comparative Ordinal Scores Across Criteria, Cities and Periods (Developed by the Authors).

3.2. Comparative Results by City

Within the proposed ordinal matrix, city profiles showed descriptive differences between configurations of urban performance. These differences are results of the qualitative grid, not inferential statistical hierarchies. In the contemporary period, sustainability, health and urban justice became more visible; in antiquity, higher scores concentrated around infrastructure, mobility and culture. Based on descriptive ordinal means, Rome had the highest aggregate profile, but this position reflects an internal synthesis of the matrix, not statistically demonstrated superiority. Rome was defined by a relatively balanced association between infrastructure, governance, culture and resilience. Alexandria alternated between high performance and reconfiguration; in antiquity and today, it scored well through its infrastructural, port and cultural roles and openness to innovation. In the Middle Ages, the mean decreased without indicating rupture, making Alexandria a case of adaptation rather than linear decline. Antioch had the lowest mean, but should not be read as "less urban"; it is more vulnerable to exogenous geopolitical, route-related and regional pressures.

Comparatively, the three cities outline three interpretative models: robust continuity in Rome, adaptation through reconfiguration in Alexandria and vulnerable continuity in Antioch. The typology is not universal, but it supports the theoretical contribution.

3.2.1. Profile of Alexandria

Alexandria was defined by infrastructure, external openness and cultural capital. In antiquity, the port, supply networks, intellectual functions and Mediterranean mediation support its competitive profile. In the Middle Ages, performance became more moderate and depended on reconfiguration; in the present, modern infrastructures, digitalisation and economic repositioning partially recovered this tradition.

For Roman Alexandria, Kom el-Dikka provided an important basis for interpreting spatial organisation and continuity. Roman streets and houses showed a regular residential structure with secondary streets, plots, courtyards and architectural elements combining Greco-Roman traditions with local Egyptian features, supporting high scores for infrastructure, culture and adaptability (Majcherek, 2021). Research on glass and beads from Roman, Late Antique and early Islamic contexts also indicated material circulation and persistent economic and cultural practices (Then-Obłuska & Syta, 2025). Relations between Alexandria and Antioch in the first Abbasid century showed that Alexandria remained a religious and intellectual node after political change (Booth, 2021). In the contemporary period, this reconfiguration continued through heritage, mobility and public-space quality; the Ras El-Teen Palace Street case showed that sustainable mobility in historic quarters requires demand management, accessibility and environmental improvement (Hassan et al., 2023).

3.2.2. Profile of Rome

Rome had the most coherent distribution across criteria and periods. Antiquity concentrated the highest score through infrastructure, mobility, institutions and political centrality; the Middle Ages reorient, without cancelling, the urban system; and the contemporary period maintains a high profile through heritage, connectivity and institutional capacity.

Roman hydraulic infrastructure supported this positioning. Aqueducts expressed not only monumental power, but also urban organisation related to size and population (Hanson et al., 2026). Waterproof mortars from Rome, Pompeii and the Bay of Naples highlight material innovations between the first century BCE and the fourth century CE, supporting the scores for infrastructure, innovation and resilience (McLennan et al., 2026).

For late ancient Rome, public space remained relevant to urban smartness because protests, negotiations and political opposition used places with civic and symbolic functions (Barber, 2025). At the scale of the extended urban system, Portus Romae shows how port, funerary and commercial networks supported Rome beyond its monumental core (De Angelis et al., 2025). In the Middle Ages, changes on the Caelian Hill and decline of hydraulic infrastructures indicate not urban disappearance, but a transformed relationship between water, habitation, climate and institutions (Gutgarts & Ellenblum,

2024). For contemporary Rome, the 15-minute city analysis shows unequal access: the dense historic city differs from car-dependent peripheral areas with fewer services (Chiaradia et al., 2024).

3.2.3. Profile of Antioch

Antioch highlighted the difference between historical importance and cumulative urban performance. In antiquity, the city was a commercial and cultural node, but more exposed to external instability; in the Middle Ages and present, moderate scores reflected vulnerabilities of position and context. Late Antique crises showed how political, military, economic and administrative pressures affected stability without cancelling the city's regional and cultural role (Bjornlie, 2023).

For Antioch, vulnerability should not be confused with lack of continuity. Relations between Alexandria and Antioch in the first Abbasid century show persistent patriarchal and cultural connections after political transformations in the eastern Mediterranean (Booth, 2021). The Greek Orthodox community in Hatay confirms the survival of cultural and religious memory despite geopolitical repositioning between Greece, Syria and Turkey (Grigoriadis, 2022). In the contemporary period, the 2023 earthquakes made resilience central: research on reconstruction shows the role of education, cultural identity and place attachment in rebuilding the city, supporting the interpretation of Antioch as vulnerable urban continuity (Aydin et al., 2025).

3.3. Descriptive Statistical Analysis of Ordinal Scores

The ordinal scores descriptively synthesised the performance of the three cities in the three periods. Because data is ordinal, the analysis used only descriptive parameters: mean, median and sample standard deviation. The mean indicates ancient Rome as the profile with the highest descriptive value, followed by contemporary Rome, ancient Alexandria and contemporary Alexandria; medieval and contemporary Antioch and medieval Alexandria are at lower levels.

The median was computed by ordering the scores. For ancient Alexandria: [3,3,3,4,4,4,4,4,4,5], and the median is (4+4)/2 = 4. The sample standard deviation describes internal dispersion relative to the mean and has a strictly descriptive, not inferential, role.

To clarify the dispersion measure used in the descriptive analysis, **Equation 3** was used to establish s - the sample standard deviation, where x_i = score of criterion i; $\bar{x}$ = mean score for the unit of analysis; n = 10 = number of analysed criteria.

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Equation 3. Sample standard deviation.

The sample standard deviation was used as an auxiliary descriptor of internal dispersion. Lower values of s, such as in contemporary Rome or medieval Alexandria, indicated more uniform distributions between criteria; higher values, such as in ancient Rome, indicated differentiation between very high and moderate criteria. The indicator did not express statistical precision, but descriptive variation of the ordinal profile.

Descriptive analysis by criteria indicated high ordinal means for infrastructure and culture, followed by mobility and resilience. Health, urban justice and quality of life had lower means, being more sensitive to period, sources and contemporary standards. The distribution suggested an interpretative association between infrastructure, culture and continuity, without generalisable causality.

3.3.1. Statistical Significance in the Context of a Small Sample

For the nine units of analysis, statistics were strictly descriptive, not inferential. They did not test hypotheses or generalise, but synthesise the distribution of scores, consistency of assessment and variation between criteria and cases.

The descriptive statistics for each case-study unit are shown in **Table 5.**

Table 5: Descriptive statistics for each case-study unit (Developed by the Authors).

Unit of analysis	Mean	Median	Standard deviation	Min	Max
Ancient Rome	4.30	4.50	0.82	3	5
Contemporary Rome	4.20	4.00	0.42	4	5
Ancient Alexandria	3.80	4.00	0.63	3	5
Contemporary Alexandria	3.80	4.00	0.63	3	5
Medieval Rome	3.60	3.50	0.70	3	5
Ancient Antioch	3.50	3.00	0.71	3	5
Medieval Alexandria	3.20	3.00	0.42	3	4
Medieval Antioch	3.10	3.00	0.32	3	4
Contemporary Antioch	3.10	3.00	0.32	3	4

The mean scores of the nine case-study units are visualised in **Figure 3.**

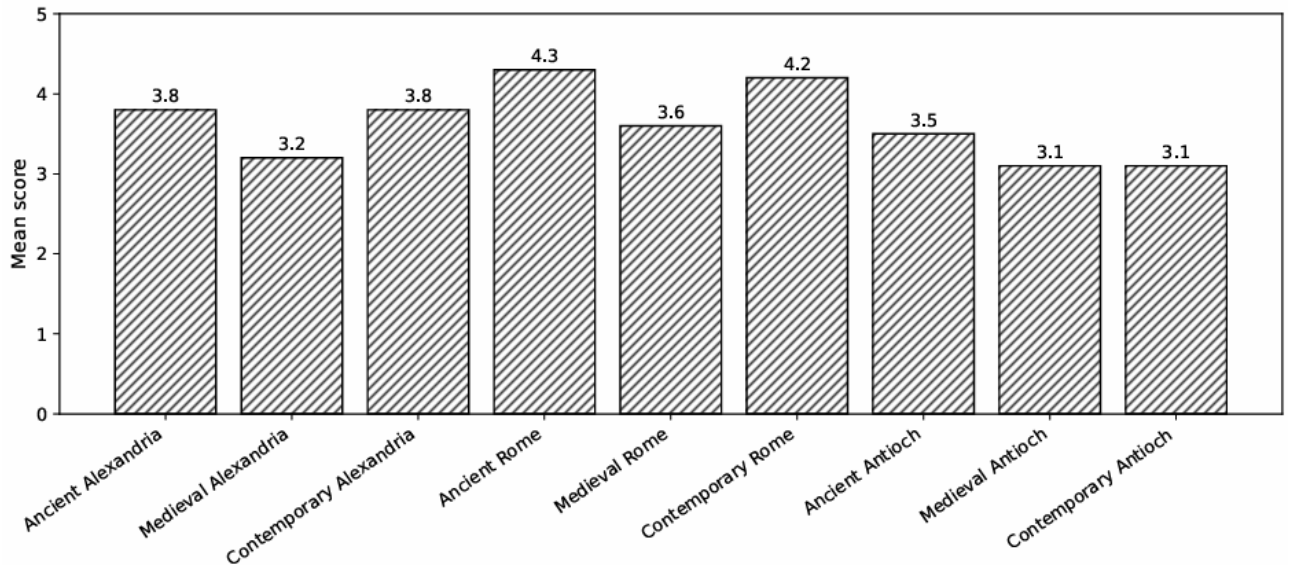

Figure 3. Mean Score of Each Case-Study Unit (Developed by the Authors).

3.4. Convergence Between Data Types and Integrated Reading of Results

The statistical subsection complemented the qualitative approach. Descriptive statistics did not demonstrate the superiority of a city, but made explicit the distribution of scores and coherence of narrative reading with the assessment matrix.

The qualitative description, matrix, statistics and graphs convergently supported the interpretation that infrastructure, governance and resilience were associated with urban continuity, modulated by mobility, culture and sustainability.

Tables synthesise performance, figures make patterns visible, and the text explains the historical mechanisms. The results therefore function as an integrated analytical narrative, not as a list of ratings.

3.4.1. Relationship Between Historical Readings and Graphical Representations

Graphs do not replace historical explanation; they highlight patterns that are difficult to follow textually alone. The heatmap, mean-score chart and criteria hierarchy visually organise the comparison.

3.5. Dominant Patterns and Reading of the Comparative Matrix

A simultaneous reading of Table 4, Table 5 and Figure 2 allows the inductive identification of three interpretative patterns. These were not defined beforehand as hypotheses and are not statistical categories; they result from the comparative reading of ordinal scores, descriptive means and criteria distribution across the nine units. The first pattern is infrastructural-institutional, where high infrastructure and governance values often occur together in more stable profiles. The second is cultural-resilient, where culture, religion and resilience help maintain identity and urban functions in unstable contexts. The third is sustainability-equity, more visible today, where resource management, health, accessibility and urban justice become more relevant. These patterns are interpretative syntheses, not statistically demonstrated causal relations.

The typology suggests that the analysis of historical cities should follow the mechanisms that support continuity, not abstract performance. The matrix thus becomes an instrument for classification and for formulating hypotheses to be tested later.

4. Discussion

The results allow the mechanisms of urban continuity to be interpreted and related to debates on smart cities.

4.1. Interpretation of Key Findings

The first finding is that the smartness of cities can be analysed without being reduced to digitalisation. Across the nine units, performance is interpreted more coherently through infrastructure, governance and resilience than through technological innovation alone. Technology matters, but produces effects only when supported by institutions and coherent spatial organisation.

The second finding is the primacy of the continuity–adaptation relationship over the tradition–modernity opposition. The analysed cities are “smart” through their capacity to preserve or reconfigure essential functions: robust continuity in Rome, reconfiguration in Alexandria and vulnerable continuity in Antioch.

4.1.1. Infrastructure as Material Memory of Urban Smartness

Infrastructure functions as material memory of urban smartness: it expresses technical capacity, the organisation of resources, distribution of functions and stabilisation of internal and external relations. Rome links infrastructural density to institutions, Alexandria to port and water, while Antioch recalls that historical importance does not guarantee robustness in unstable contexts.

Historical sources support this interpretation. In Rome, aqueducts and waterproofing technologies indicate planning on an imperial scale and material durability (Hanson et al., 2026; McLennan et al., 2026). Portus Romae extends the city

through material networks, while the degradation of some medieval systems shows the infrastructure–climate–resilience relation (De Angelis et al., 2025; Gutgarts & Ellenblum, 2024). Alexandria preserves traces of economic and cultural connectivity, and Antioch traces of religious and identity memory (Grigoriadis, 2022; Then-Obłuska & Syta, 2025).

4.2. Comparison With Recent Literature

The results are compatible with literature that criticises the separation between smart and sustainable city. Gu et al. (2025) show the overlap between concept, and results indicate that historical smartness depends on the combination of infrastructure, governance, mobility and culture, not only on technology.

They are also compatible with Sharifi (2023), who describes the city as a socio-ecological-technological system. In our matrix, infrastructure, sustainability, health and urban justice form parts of the same systemic performance, in agreement with studies on green infrastructure and urban adaptation (Caggiano et al., 2023; Grabowski et al., 2023).

In relation to historical studies, results show that antiquity and Middle Ages can be read through the same functional logic, although indicators differ. Medieval urban economy confirms the role of cities as spaces of production, consumption and exchange (Osland, 2023), while Byzantine studies highlight connectivity and administration in the Late Antique transition (Zavagno, 2024). The contemporary component confirms the role of sustainable mobility, accessibility, heritage, resilience and equity (Aydin et al., 2025; Chiaradia et al., 2024; Hassan et al., 2023).

4.2.1. Relevance for Debates on Equity, Health and Mobility

The framework integrates themes that are fragmented in the smart-city literature: mobility, health, equity and access to services. Recent studies on microtransit, gentrification, energy transition, urban health monitoring and sensor deserts show that innovations can produce inequalities if they are not assessed critically (Bills et al., 2022; Bunten et al., 2024; Hong et al., 2025; Rouhana et al., 2024; Zhai et al., 2025).

The relative importance of the criteria for long-term urban continuity is summarised in **Table 6.**

Table 6: Relative importance of criteria for the long-term continuity of cities (Developed by the Authors).

Criterion	Mean score	Interpretative rank	Observation
Culture	4.67	Very high	Identity and symbolic continuity
Infrastructure	3.89	High	Material capacity for organisation
Mobility	3.78	High	Connects internal/external networks
Resilience	3.78	High	Capacity to withstand crises
Governance	3.67	Medium	Coordination and institutional stability
Innovation	3.44	Medium	Adaptation and efficiency
Health	3.33	Medium	Management of public-health risks
Quality of life	3.33	Medium	Socio-urban performance
Sustainability	3.22	Moderate	Resources and functional continuity
Urban justice	3.11	Moderate	Equity of access to benefits

Methodological Note. *Interpretative ranks were established on the basis of descriptive ordinal means obtained for each criterion across the nine units of analysis. The thresholds used were: 3.00–3.24 = moderate, 3.25–3.74 = medium, 3.75–4.24 = high and ≥ 4.25 = very high. These thresholds have an exclusively interpretative and descriptive role and were used to order criteria internally within the analysed sample. They do not represent inferential statistical thresholds and should not be interpreted as exact quantitative differences between criteria.*

The relative importance of criteria in the long-term continuity of the three cities is visualised in **Figure 4.**

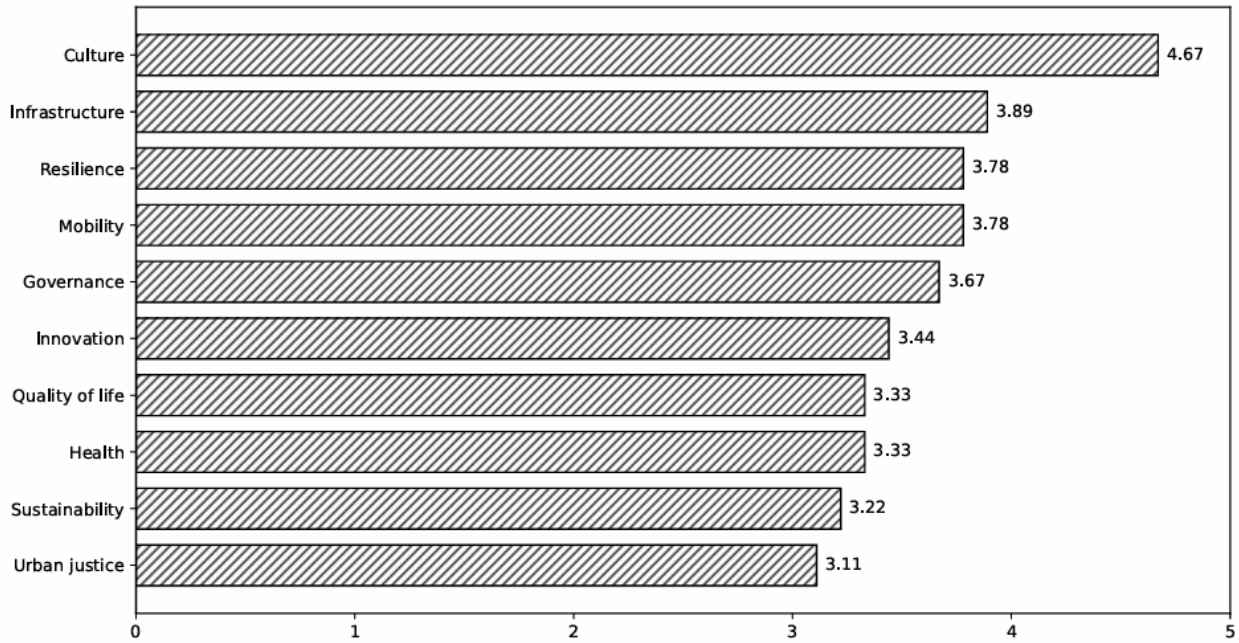

Figure 4. Mean Score. Relative Importance of Criteria in the Long-Term Continuity of the Three Cities (Developed by the Authors).

4.3. Strengths and Limitations of the Study

The main strength is the methodology comparable across periods, which links urban history to debates on smart cities, sustainability and resilience. The integration of interpretative text, matrix, descriptive analysis and graphs strengthens the readability and traceability of results.

The limitations are explicit. Scoring includes expert judgement, controlled through criteria, subcriteria, rules and audit trail. Historical sources are uneven in density, typology and preservation, influencing the level of interpretation. No formal inter-rater verification or agreement calculation was applied; scores were established through internal review and consensus. The results are therefore ordinal interpretative syntheses, not objective measurements.

4.4. Contribution of the Study and Future Directions

The study proposes a conceptually extensible comparative framework, but one not empirically tested on other cities. It should be understood as an exploratory methodological proposal, applied to the three cities and nine city-period units. The combination of qualitative description, matrix, descriptive analysis and graphs provides a basis for future testing on larger samples.

The limitations remain linked to the interpretative nature of assessment and uneven distribution of sources. Three cities and nine units are sufficient for the methodological demonstration, but not for extended generalisations.

The main contribution is the methodology for comparing the smartness of cities over time. For urban theory, it extends the city smartness towards infrastructure, institutions, culture and adaptation; for urban history, it offers a grid across periods without anachronistic indicators.

The framework is relevant because it combines historical reading with the formalisation of procedures, being useful for urban history, smart-city studies, planning assessment and sustainability analysis.

Future research can expand the sample, transform subcriteria into measurable indicators and integrate GIS, geospatial instruments and time series for contemporary periods.

4.4.1. Usefulness of the Framework for Comparative Research on Historical Cities

In historical studies, comparison is limited by sources, terminology and scale. The proposed framework does not eliminate these difficulties, but allows urban functions to be compared through the same analytical questions, and is also useful for future research.

5. Conclusions

5.1. Summary of Key Findings

The study shows that historical and contemporary cities can be compared through a common framework if the assessment follows fundamental urban functions, not only the technology of period. The application of the ten criteria and twenty subcriteria to Alexandria, Rome and Antioch indicates an association between infrastructure, governance, resilience and continuity. Rome appears as a profile of robust continuity, Alexandria as adaptation through reconfiguration, and Antioch as vulnerable continuity. The historical bibliography reduces the rupture between smart-city theory and the urban analysis of antiquity and Middle Ages.

These findings support the working hypothesis that urban “smartness” can be compared across historical periods when it is understood as the organisation of core urban functions, resource management, institutional capacity and resilience, and the study contributes to the existing literature by connecting smart-city theory with urban history through a transferable qualitative-comparative framework.

5.2. Implications of the Findings for Research and Practice
For research, smart-city studies can benefit from openness towards urban history and comparison. For practice, infrastructure, culture, equity and resilience should be treated in an integrated way; heritage and digitalisation thus become complementary resources for the smart functioning of the city.

5.3. Limitations
The qualitative-comparative methodology is both a resource and a limitation. It allows historical context to be integrated and cities with uneven data to be compared, but also involves expert interpretation in scoring. Although controlled through criteria, subcriteria, decision rules, analytical sheets and audit trail, scores remain descriptive ordinal assessments, not objective or inferential measurements. Another limitation is the heterogeneity of historical sources for Alexandria, Rome and Antioch: documentary density, archaeological preservation and source type differ across cities and periods. The absence of formal inter-rater verification and sensitivity analysis also affects methodological robustness.

5.4. Recommendations for Future Research
Future research can develop the framework in several ways. First, it should be tested on a broader sample of Mediterranean or other historical cities to verify transferability. Second, where sources allow, some subcriteria can become measurable indicators, complementing qualitative assessment with quantitative or geospatial data. Third, inter-rater verification should be introduced, with scores assigned independently and then compared. For contemporary periods, GIS tools, urban databases, time series and indicators of accessibility, climate risk, quality of life and spatial equity can be integrated. The framework may thus evolve from an exploratory tool into a more robust comparative method for analysing urban smartness over time. Overall, the study achieves its objective by demonstrating that historical and contemporary cities can be compared through a common set of urban-intelligence criteria, without reducing smartness to digital technology. The results support the working hypothesis that long-term urban "smartness" can be assessed through the organisation of core urban functions, resource management, institutional capacity, adaptability and resilience. By applying this framework to Alexandria, Rome and Antioch across ancient, medieval and contemporary periods, the study shows that urban continuity is produced by different combinations of infrastructure, governance, culture and resilience. Its theoretical and methodological contribution lies in linking smart-city studies with urban history and in offering a transferable qualitative-comparative framework for future research on long-term urban performance.

Acknowledgements
The authors thank "Ion Mincu" Doctoral School of Urban Planning and consulted experts for their methodological support.

Funding
This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Conflicts of Interest
The author(s) report no conflicts of interest.

Data Availability Statement
Data comes from published academic sources, historical works and comparative syntheses prepared by the authors. The figures, matrices and tables are included in the article and can be provided in editable format. The expert consultation was methodological and anonymous; no identifiable personal data were collected. Internal notes served only to validate the criteria and do not constitute a reusable dataset.

Institutional Review Board Statement
Not applicable, as the study does not involve experiments on human participants or animals. The expert consultation was methodological, anonymous and non-invasive, with no collection of sensitive personal data or reporting of identifiable individual opinions.

CRediT Author Statement
Conceptualisation: Lucian-Marian Pavel, Alexandru-Ionuț Petrișor. Methodology, formal analysis, investigation, visualisation and original draft: Lucian-Marian Pavel. Review, editing and supervision: Alexandru-Ionuț Petrișor. All authors have read and approved the final manuscript.

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