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The journal aims to link interdisciplinary human habitat studies in the EURO-MED region, from architecture and urbanism to regional planning, including the relationship between human-dominated and natural systems. It seeks to pursue the goals of multi-stakeholder operations such as SUDs, UfM Action Plans and more, towards resilient cities and sustainable social structures.

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EDITORIAL

"Journal of Mediterranean Cities" is dedicated to focusing on habitat studies and challenges facing our cities. The journal provides science-led strategic insight and guidance for sustainable and resilient cities, with a general perspective on coastal cities, with a particular focus on the Mediterranean region. Topics draw on scientific knowledge and research to make regional policies and practices as future-proof as possible. The Schools of Architecture and Urbanism are considered as potential driving forces and hubs for the profound science-led transformation and integration in the region, and thus, the Journal aims to bring together schools of Architecture and Urban Studies from different regions, in one platform. All articles are published in English and undergo a peer-review process.

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This issue contains 8 articles. The editors seek to publish articles considering urban actions in the area of Littoral Territories, Urban Studies, Housing Strategies, Heritage & Vernacular Studies, Environmental Sciences, and educational systems in coastal regions.

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With kind regards,
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Table of Contents

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Landscape Scenario Archetypes for Desertification-Prone Oases: A Resilience Framework for the Drâa Valley

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ABSTRACT

Oasis regions in southern Morocco are increasingly under the threat of desertification, water scarcity and socio-economic pressures that undermine their long-term resilience. This study develops landscape scenario archetypes as an operational framework that links future scenarios with spatial design for the desertification-prone Drâa Valley, to address the gap between scenario narratives and implementable landscape strategies. The methodology integrates STEEP trend analysis, impact–uncertainty prioritisation and landscape assessment, along with a two-component online participatory survey in M'hamid oasis. Forty-seven drivers were identified and prioritised, structuring four contrasting socio-ecological scenarios, namely Oasis Minimisation, Oasis Emancipation, Rural Abandonment and Rural Refuge. These scenarios were translated into scenario-specific spatial design principles through a landscape building-block framework and compared through a multi-criteria assessment. The respondents consistently preferred futures that combine traditional oasification practices along with contemporary landscape strategies. Landscape scenario archetypes provide a transferable mechanism that aids in translating uncertainty into design action, supporting resilience-oriented planning, water management and adaptive capacity in desertifying oasis regions.

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1. Introduction

Desertification is considered one of the most critical environmental challenges in the drylands, with significant implications regarding ecosystem services, agricultural production and the livelihoods of local communities (Barbero-Sierra et al., 2015). According to the United Nations Convention to Combat Desertification, this phenomenon refers to the degradation of land in arid, semi-arid and dry sub-humid zones, driven by the combined action of climatic variability and human pressures (UNCCD, 2017). Morocco, particularly its southern regions, faces acute desertification threats driven by water scarcity, soil salinization, sand encroachment, and socio-economic transformations that collectively undermine the resilience of traditional oasis systems (Karmaoui, 2015).

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The Drâa Valley in southern Morocco exemplifies these challenges. As one of Morocco's most important oasis territories, the valley has sustained human settlement for centuries through sophisticated traditional water management systems, multi-layered agricultural practices, and vernacular architecture adapted to extreme aridity (Lightfoot, 1996; Baglioni et al., 2016). However, contemporary pressures - including climate change, groundwater depletion, rural-urban migration, and evolving governance structures - have destabilized these time-tested systems, raising urgent questions about the region's environmental and social future (Berger et al., 2021; Johannsen et al., 2016).

Although desertification is increasingly acknowledged as a multidimensional phenomenon demanding holistic responses, research on oasis resilience has largely focused on technical interventions in water management or agricultural productivity, with limited attention to scenario-based design approaches that could guide long-term strategic planning (Karmaoui & Moumane, 2016). Existing studies have documented the environmental degradation of Moroccan oases (Lamqadem et al., 2017; Ait Lamqadem et al., 2018), analysed socio-economic transformations (de Haas, 2003; Sobczak, 2008), and examined traditional knowledge systems (Laureano, 2012), yet few have systematically explored alternative futures through integrated landscape scenarios that link environmental drivers with spatial design.

This research addresses this gap by developing landscape scenario archetypes as a framework for exploring plausible futures for the Drâa Valley and informing resilience-oriented design strategies. Building on scenario planning methodologies from landscape ecology and futures studies (Hunt et al., 2012; Börjeson et al., 2006), this study constructs scenarios that represent distinct socio-ecological trajectories shaped by governance structures and social values. The research explicitly positions scenarios not as predictions but as exploratory tools that mediate between uncertainty and design action, enabling stakeholders to envision alternative pathways and their spatial implications (Dockerty et al., 2006).

The aim of this research is achieved through three objectives: firstly, to analyse the key STEEP drivers shaping desertification in the Drâa Valley; secondly, to construct four landscape scenario archetypes representing alternative futures for the region; and thirdly, to translate these scenarios into spatial design principles for the Drâa Valley's desertification-prone oases, demonstrated through M'hamid as a representative site. The research asks: How can landscape scenario archetypes inform resilience strategies for desertification-prone oases? What spatial interventions emerge from contrasting governance and social paradigms? And how do traditional oasification practices relate to contemporary landscape strategies in scenario-based planning?

Unlike conventional scenario-based approaches that remain at the level of narrative exploration, this research introduces a landscape scenario building block framework that establishes a direct and operational link between identified drivers and spatial design interventions. This enables scenarios to function not only as exploratory tools but as implementable design mechanisms within landscape planning processes.

It should be mentioned how this framework differs from existing scenario-to-design methodologies. Established approaches, namely scenario typologies and construction techniques (Börjeson et al., 2006), formal scenario-development protocols (Mahmoud et al., 2009), scenario-based landscape planning (Dockerty et al., 2006; Albert, 2011) and archetype analysis (Boschetti et al., 2016; Oberlack et al., 2019), provide solid procedures for constructing and communicating alternative futures. However, they generally stop at the level of narratives, indicators or visualisations. In the landscape scenario building-block framework developed in this research, each prioritised driver is carried through to a discrete and mappable landscape intervention. Thus, the scenario logics can be recombined, compared and evaluated as spatial configurations rather than remaining narrative constructs. In doing so, the study responds to the calls for participatory and place-based scenario practice in social-ecological research (Oteros-Rozas et al., 2015) and contributes an operational bridge between scenario planning and landscape design in arid regions.

2. Theoretical Background and Key Concepts

2.1. Desertification and Oasis Systems

Desertification is a multi-layered process that influences natural systems along with human settlements. Its effect is intensified in oasis environments, where the limited water resources, agricultural production and socio-economic stability are held in a fragile equilibrium (Mahmoud et al., 2009). Traditionally, oasis systems have functioned as highly adaptive landscapes, structured around a symbiotic relationship between human activity and natural resources. The typical oasis model is characterised by a multi-layered agricultural system, where date palms form the upper protective layer, followed by fruit trees and ground crops. This configuration creates a controlled microclimate that maximises productivity while minimising water loss (Oberlack et al., 2019). However, increasing pressures such as water scarcity, soil salinisation, and climate variability have disrupted this balance, leading to declining ecological performance and increased vulnerability to desertification. Socio-economic transformations, namely migration, land-use change and the weakening of local management institutions, further compound these dynamics (Boschetti et al., 2016; Hunt et al., 2012). The structure and functioning of oasis systems are illustrated in Figure 1.

Figure 1. Cross-section of oasis system illustrating vegetation stratification, water management, and microclimatic regulation

2.2. Scenario Planning and Landscape Approaches

Scenario planning has been widely used as a tool to explore uncertain futures, particularly in contexts where long-term environmental and socio-economic changes are difficult to predict. Unlike predictive models, scenario approaches allow for the exploration of multiple plausible futures, providing a framework for understanding the potential consequences of different development pathways (Baker et al., 2004; Mahmoud et al., 2009). Within landscape architecture, scenario-based approaches enable the integration of spatial, ecological, and social dimensions into a coherent structure. They support the interpretation of complex systems and facilitate communication between different stakeholders involved in planning processes. However, while scenario planning is effective in generating future narratives, its application in spatial design often remains limited, with a lack of clear mechanisms for translating scenarios into actionable interventions.

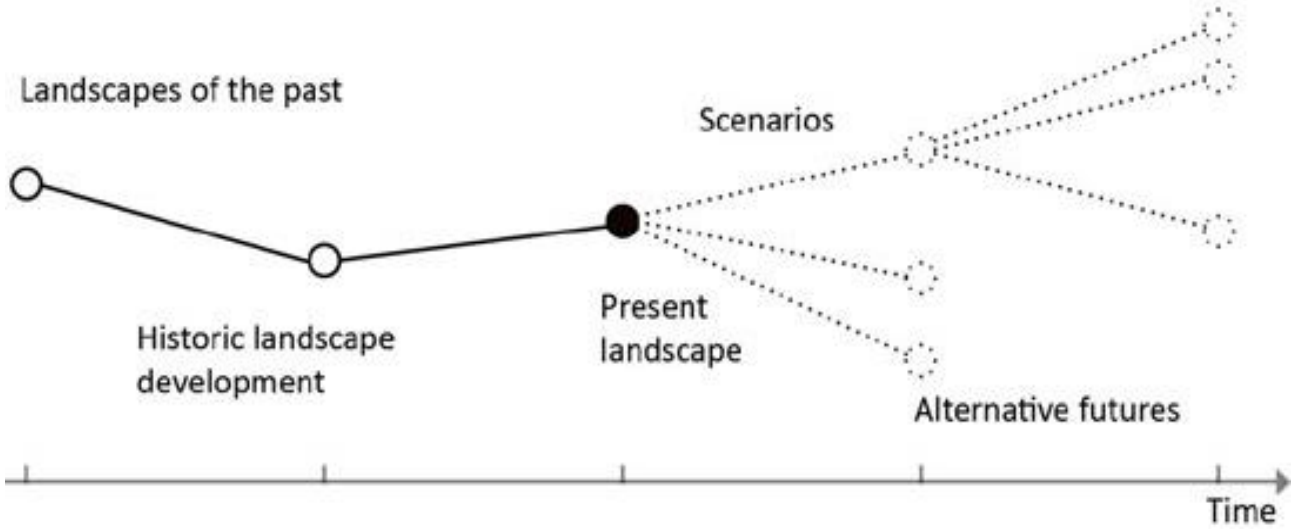

Figure 2. Scenario framework illustrating alternative futures and archetypal trajectories (based on Hunt et al., 2012).

2.3. Scenario Archetypes and STEEP Drivers

To construct meaningful future scenarios, it is necessary to identify and organise the driving forces that influence system dynamics. Scenario archetypes provide a structured approach to this process, allowing for the classification of trends and the development of comparable future conditions (Boschetti et al., 2016). The number of scenarios typically ranges between three and six, with four scenarios being the most commonly adopted configuration in scenario planning studies (Hunt et al., 2012). This structure enables the representation of contrasting yet plausible futures within a clearly defined framework.

The identification of key drivers is supported with analytical tools such as the impact–uncertainty matrix, which ranks drivers according to their level of influence and degree of uncertainty (Maack, 2001). This process allows for the selection of the most critical variables that shape future outcomes. To ensure a comprehensive understanding of the system, the STEEP framework (Social, Technological, Economic, Environmental, Political) is employed to categorise and analyse the drivers influencing desertification processes. This approach enables the integration of multiple dimensions of change and supports the development of holistic and context-specific scenarios (Maack, 2001; Hunt et al., 2012). Furthermore, the use of archetype-based scenarios has been applied in various environmental contexts to explain large-scale transformations and their impacts on local systems (Oberlack et al., 2019). This reinforces the relevance of scenario archetypes as a methodological tool for addressing complex socio-ecological challenges.

2.4. From Scenario Narratives to Spatial Design

To construct plausible scenarios, it is necessary to define a set of variables that reflect the identified drivers and their interactions (Mahmoud et al., 2009). However, a key limitation in existing scenario-based approaches lies in the gap between conceptual scenario development and practical spatial implementation. While scenarios effectively describe potential futures, they often remain abstract and lack direct applicability within design processes. This limitation is particularly evident in landscape architecture, where the translation of narratives into spatial strategies is essential for implementation.

This research addresses this gap by introducing the concept of landscape scenario building blocks, which function as an intermediate layer between scenario narratives and spatial design. These building blocks represent specific landscape interventions derived from STEEP drivers and scenario conditions, enabling the operationalisation of scenarios within the design process. By structuring scenarios into spatially explicit components, this approach facilitates the evaluation and comparison of alternative interventions, supporting decision-making in complex and uncertain environments.

3. Study Area: The Drâa Valley

3.1. Regional Context: Drâa Valley

The Drâa Valley stands out among the oasis territories of southern Morocco in regard to its scale and cultural significance, extending as a linear corridor organised by the Drâa River. Its climate ranges from arid to hyper-arid, combining scarce and strongly seasonal rainfall along with high evapotranspiration rates. These environmental conditions make the valley highly dependent on controlled water management systems for sustaining agricultural production and human settlements.

Historically, the valley has functioned as a continuous oasis network, where settlements are closely linked to irrigation systems and agricultural land. The spatial organisation of the valley reflects this dependency, with palm groves, cultivated fields, and compact settlements forming an integrated socio-ecological system. However, over recent decades, this system has been increasingly affected by reduced water availability, irregular rainfall patterns, and upstream water regulation, leading to a decline in agricultural productivity and increased land degradation.

3.2. M'hamid Oasis: A Representative Lower-Valley Site

M'hamid oasis, at the southern edge of the Drâa Valley, is taken here as a representative case of the lower valley's desertification-prone oases for detailed spatial demonstration; it marks the transition between the cultivated landscape and the Sahara Desert. Due to its geographical position, the area is particularly exposed to desertification processes, including sand dune encroachment, soil degradation, and water scarcity.

The oasis has historically relied on traditional irrigation systems and agricultural practices to sustain local livelihoods. However, the reduction in water flow and the deterioration of irrigation infrastructure have significantly weakened these systems. As a result, agricultural land has progressively declined, and the ecological balance of the oasis has been disrupted.

In addition to environmental challenges, M'hamid is affected by socio-economic pressures, including population decline, migration, and limited economic opportunities. These factors contribute to the abandonment of agricultural land and the deterioration of the built environment, further accelerating desertification processes (Domínguez Martínez et al., 2017).

3.3. Key Challenges and System Dynamics

The challenges faced by the oases of the Drâa Valley are the result of interconnected environmental and socio-economic processes. Water scarcity remains the most critical factor, influencing agricultural productivity, settlement viability, and ecosystem stability. The reduction of water resources is linked to both climatic variability and upstream water management, highlighting the multi-scalar nature of the problem. At the same time, land degradation is intensified by soil salinisation, overexploitation of resources, and the expansion of desert conditions. These environmental pressures are closely linked to social and economic dynamics, including changes in land use, shifts in livelihood strategies, and reduced community engagement in traditional management systems.

The interaction of these factors reflects the complexity of desertification as a socio-ecological process, where environmental degradation cannot be separated from governance structures, economic conditions, and social behaviour. This complexity reinforces the need for integrated approaches that consider multiple dimensions of change, as addressed through the STEEP framework applied in this research.

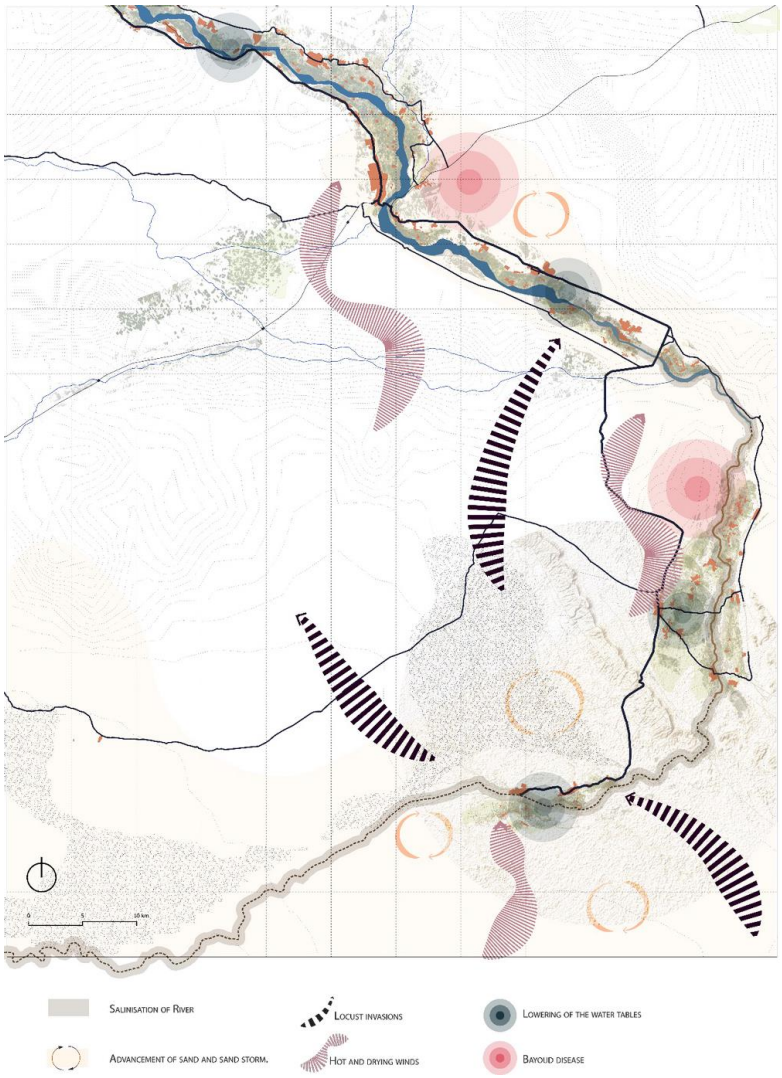

Figure 3. Threats and concerns map of the lower Drâa Valley illustrating sand encroachment, water scarcity, and environmental pressures.

4. Methodological Framework

This research employed a mixed-methods approach integrating descriptive analysis, scenario development, and participatory inquiry. The methodological framework consisted of four phases: (1) literature review and STEEP driver analysis; (2) landscape assessment and cultural landscape documentation; (3) scenario prototype development through iterative refinement; and (4) participatory validation through an online community survey. This approach aligns with established scenario planning protocols while incorporating spatial design translation specific to landscape architecture (Dockerty et al., 2006; Albert, 2011). The overall research process is summarised in Figure 4 and Table 1.

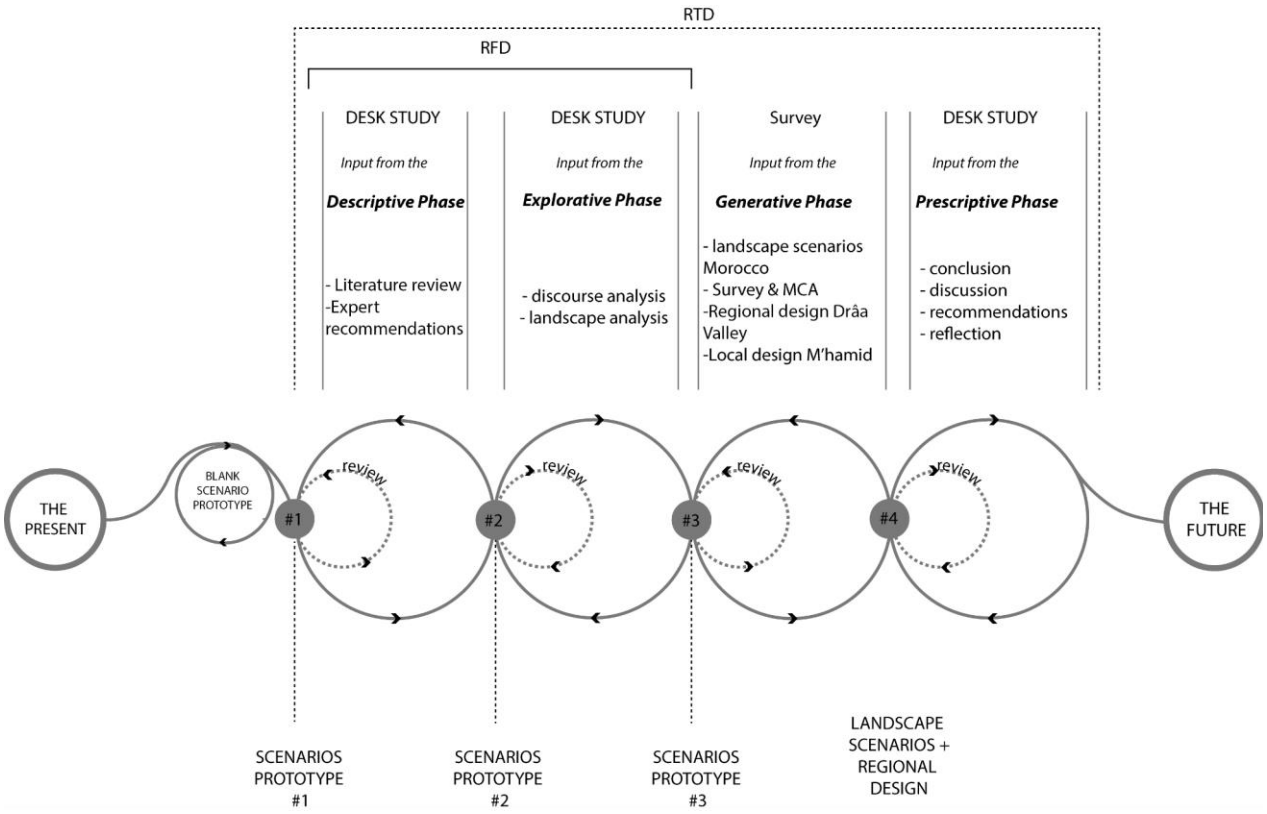

Figure 4. The methodological framework illustrates four iterative phases (descriptive, exploratory, generative, and prescriptive), including evaluation loops for scenario refinement.

Table 1. Summary of the methodological framework: phases, data sources, analytical procedures and outputs.

Phase	Data / participants	Analytical procedure	Output
1. STEEP driver analysis	Peer-reviewed literature, governmental reports, virtual observation of M'hamid (2020–2022); survey-nominated driving forces	STEEP categorisation; qualitative impact–uncertainty rating (low/medium/high) triangulated across three evidence streams	47 drivers; prioritised scenario axes (governance mode; social values)
2. Landscape assessment	Cartographic and remote-sensing sources; cultural landscape documentation; virtual site reconnaissance	Descriptive spatial analysis of oasis structure, threats and dynamics	Threats and concerns mapping (Figure 3); landscape system understanding
3. Scenario development	Outputs of Phases 1–2; scenario literature	Three iterative prototypes; cross-checking narratives against drivers; archetype structuring in a 2×2 scenario space	Four scenario archetypes and narratives

4. Online participatory survey (2 components)	Scenario/building-block evaluation: n = 20 residents (6 farmers, 8 tourism operators, 2 construction professionals, 4 government employees); driving-forces questionnaire: n = 15; posted 1 July 2022, open ≈ 1 month	Structured and open-ended questions; frequency comparison and thematic interpretation	Plausibility check; community preferences; scenario refinement
5. Spatial translation and evaluation	Building blocks derived from drivers; survey and expert input	Mapping of building blocks to scenarios; qualitative multi-criteria assessment across five equally weighted criteria	Scenario-specific spatial principles; synthesis strategy for M'hamid (Section 5.5)

4.1. STEEP Driver Analysis

Following Hunt et al. (2012), desertification drivers were systematically categorized across five domains: Social (demographic patterns, education, cultural values, migration), Technological (irrigation methods, agricultural mechanization, infrastructure), Economic (market forces, poverty, tourism), Environmental (water availability, soil degradation, biodiversity loss, climate variability), and Political (governance structures, legislation, resource management policies). Driver identification drew from peer-reviewed literature, governmental reports, along with a structured virtual observation of M'hamid oasis, namely satellite imagery, cartographic material and documentary sources, undertaken between 2020 and 2022.

Each driver was assessed for importance (impact magnitude on landscape change) and uncertainty (predictability of future state) through a structured qualitative evaluation combining the literature review, the participatory survey and the landscape analysis. Drivers exhibiting high importance and high uncertainty were prioritized as scenario-defining axes, following established scenario construction protocols (Börjeson et al., 2006). This categorisation provides transparent criteria for driver prioritisation and scenario axis selection. The prioritisation of key drivers is conducted using an impact–uncertainty matrix (Figure 5). Drivers were assessed using a qualitative ranking approach (low, medium, high) based on triangulation between literature review, survey responses, and virtual landscape observation, ensuring consistency in the identification of high-impact and high-uncertainty variables.

The driving forces nominated by the survey participants, as each respondent was asked to list at least three forces they considered the most important, were consolidated with those identified through the literature review and landscape analysis. After eliminating any redundancies, they were condensed into fifteen aggregate change driving forces, classified according to their direct (n = 6) or indirect (n = 9) impact on the oasis ecosystem. The importance was ranked through pair comparison, combining the frequency with which each force is mentioned in the literature along with the participants' votes, and drawing on the landscape analysis to separate the forces occupying the same rank. The uncertainty was assessed based on the tendencies of each force's past evolution within the current socio-economic context, and it was cross-checked against the participants' own ratings: around half of the respondents judged governance to be highly uncertain, while roughly 70% rated poverty and changing social values as both highly important and highly uncertain. The four forces that combine the highest importance and uncertainty, namely inadequate governance, changing social values, land-use change and poverty, underpinned the selection of the governance and social-values axes structuring the scenario space. Since the ratings are qualitative, no numerical weighting or inter-rater reliability statistic was computed; the implications of this choice are discussed in Section 6.4.

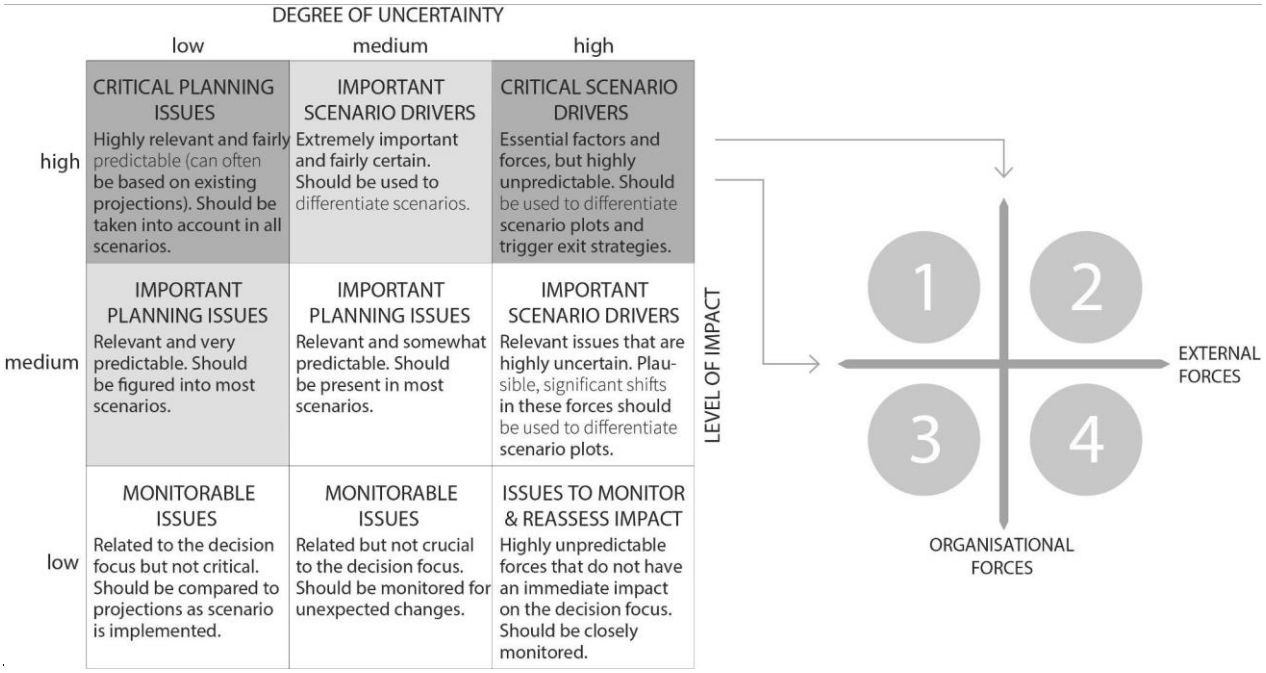

Figure 5. Impact–uncertainty matrix used to prioritise STEEP drivers based on their level of influence and uncertainty (adapted from Maack, 2001).

4.2. Scenario Development Process

Scenario construction followed a three-stage iterative process. In Prototype 1, preliminary scenarios were drafted based on STEEP analysis and existing desertification literature. Prototype 2 refined these scenarios by incorporating critical uncertainties around governance mode (top-down versus bottom-up) and social values (reactive individualism versus proactive solidarity), creating a two-dimensional scenario space. Prototype 3 validated internal consistency through cross-checking scenario narratives against identified drivers and ensuring that scenario combinations represented genuinely distinct futures rather than variations on similar themes.

The four final scenarios -Oasis Minimisation, Oasis Emancipation, Rural Abandonment, and Rural Refuge- were developed as archetypes rather than precise forecasts. This archetypal approach, widely recognized in scenario literature, enables pattern recognition across case studies while acknowledging local specificity (Hunt et al., 2012; Eisenack, 2012).

4.3. Landscape Building Blocks and Spatial Translation

To translate abstract scenarios into spatial design frameworks, landscape building blocks were identified as discrete spatial elements responding to specific STEEP drivers. Examples include mixed-cropping systems (responding to environmental and social drivers for biodiversity and self-sufficiency), solar energy parks (responding to technological and economic drivers), and rural revitalization programs (responding to political and social drivers for population retention). Each building block was mapped to its driving forces and then recombined within scenario contexts to generate scenario-specific spatial configurations for the Drâa Valley's oases, demonstrated through the representative site of M'hamid.

4.4. Participatory Survey

A participatory survey was conducted to validate the scenarios and to collect the community preferences. Due to travel restrictions, the survey was conducted online. The questionnaire was prepared in English and translated into the local languages (Arabic and French) to ease the communication with the community. It was posted on the first of July 2022 in different community groups on social media, specifically Facebook, along with being circulated by direct e-mail to local business owners and professionals. The survey remained open for approximately one month, with around two weeks of back-and-forth communication with the community after the post was uploaded. The instrument combined open-ended, dichotomous and multiple-choice questions with visual representations of the scenarios, which were presented in random order so that the participants' opinions were not influenced by the order.

The survey comprised two components. In the scenario and building-block evaluation (n = 20 Drâa Valley residents: 6 farmers, 8 tourism operators, 2 construction professionals and 4 government employees), participants assessed the plausibility of the scenario prototypes and the landscape building blocks, identified preferred futures and suggested additions or removals; their feedback informed the revision of the scenario prototypes and the final selection of building blocks reported in Section 5.5. In the driving-forces questionnaire (n = 15 completed responses), respondents nominated and ranked at least three driving forces they considered most important, feeding the driver consolidation described in Section 4.1. Female participation remained limited (n = 2), reflecting broader gender marginalisation in public discourse within the study region. The sample is small and self-selected; therefore, it is not statistically representative. The survey feedback has been weighed alongside the literature and landscape analysis within the multi-criteria assessment, rather than being the sole factor, and the results were used to test plausibility and elicit preferences rather than to generalise to the wider population.

4.5. Validation and Consistency

To ensure consistency between scenarios and their corresponding spatial strategies, the research employs an iterative evaluation process across all phases of development. Scenario prototypes are continuously refined through the integration of literature findings, landscape analysis, and participatory feedback. Validation is achieved through:

- cross-referencing identified drivers with existing literature
- comparing scenario outcomes against survey responses
- evaluating building blocks through multi-criteria assessment

This approach ensures that the developed scenarios remain coherent, context-specific, and grounded in both empirical data and stakeholder perspectives. The survey combined structured questions with open-ended responses, allowing both quantitative comparison of preferences and qualitative insights into local perceptions. Responses were analysed through frequency comparison and thematic interpretation.

5. Results

5.1. STEEP Driver Characterization

Analysis identified 47 distinct drivers distributed across STEEP categories. Environmental drivers dominated in both numbers (n=14) and assessed impact, with water scarcity, sand encroachment, and soil salinization identified as critical threats. Social drivers (n=12) centered on demographic shifts, particularly youth out-migration and declining agricultural succession. Economic drivers (n=9) reflected tension between traditional subsistence agriculture and emerging tourism-based economies. Technological drivers (n=7) encompassed both traditional systems (khettara, seguia) and modern interventions

(motorized wells, greenhouse agriculture). Political drivers (n=5) highlighted governance gaps in water allocation, land-use planning, and environmental regulation enforcement.

Table 2. Classification of desertification drivers based on STEEP categories and their impacts on the landscape system.

Driver category (STEEP)	Key drivers and indicators
Desertification drivers by STEEP category	
Socio-cultural	Age, family, household and ethnic structures; regional and national migration patterns; spatial distribution of population; wealth distribution, including regional and national poverty rates.
Technological	Farming methods, water management and mechanical structures to fight sand encroachment; level of technology in key industries; emerging technologies; capacity to manufacture technology for export.
Economical	Change in size, type and ownership of firms; formal and informal labour-force structure by region; employment rate; changes in economies of scale and structure of key industries; style of tourism; consumer spending patterns (urban/rural, national/regional); international demand for key exports; distribution and efficiency of rural and urban markets; impact of the informal sector; sources of competition (national, regional, international).
Environmental	Energy prices and availability (likelihood and impact of an oil shock); raw materials (rate of depletion, ease of access); sustainability (strategic use of resources); regional distribution of natural resources.
Political	Change in governmental development strategy and policy (privatisation); changes in legislation (regulation, creation of an enabling environment); changes in the structure and responsibility of ministries; changes in rules governing the formation and functioning of parties; stability of government and likelihood of change; governmental environmental action.
Associated concerns for the oasis landscape system	
Water scarcity	Weak mobilisation of surface waters; population growth; oasis communities no longer isolated; urban sprawl; tourism development; agricultural expansion and intensification; extension onto rangelands; low level of awareness; non-application of, or insufficient respect for, the laws in force.
Biodiversity degradation	Population growth creating additional needs for food and medicine; expansion of residential and infrastructural building at the expense of natural areas; absence of ex-situ conservation programmes and gene banks; irrational water management; changing consumption patterns; change in land use; market forces; locust invasion; tourism development.
Sand encroachment	Unsuitable means and techniques to fight sand encroachment; excessive livestock; agricultural expansion; anarchic construction that eliminates natural barriers.
Oasis lifestyle	Accentuation of poverty; ignorance and illiteracy; exclusion and marginalisation; new needs created by necessity or the pursuit of luxury and well-being; market forces; lack of communication and transport.

Four cross-cutting issues emerged as highest priority: water deficit (affecting 89% of agricultural households; Alhejazi, 2022), sand dune advancement (threatening 12 of 28 settlements; Alhejazi, 2022), biodiversity degradation (a 22% loss of vegetated oasis area between 1984 and 2016, with the densely

vegetated area contracting to roughly one third of its former extent; Lamqadem et al., 2017), and deteriorating living conditions (45% poverty rate, 68% youth unemployment; Alhejazi, 2022). These issues exhibit complex interdependencies: water scarcity drives agricultural abandonment, which reduces vegetation cover, which accelerates sand encroachment, which further degrades soil and water resources.

5.2. Scenario Archetypes

Four distinct landscape scenarios emerged from the iterative development process, positioned along axes of governance structure (top-down to bottom-up) and social values (reactive individualism to proactive solidarity). Each scenario represents a coherent socio-ecological trajectory with specific implications for desertification processes, landscape configuration, and community well-being. The four scenarios are positioned within a structured scenario space, as illustrated in Figure 6.

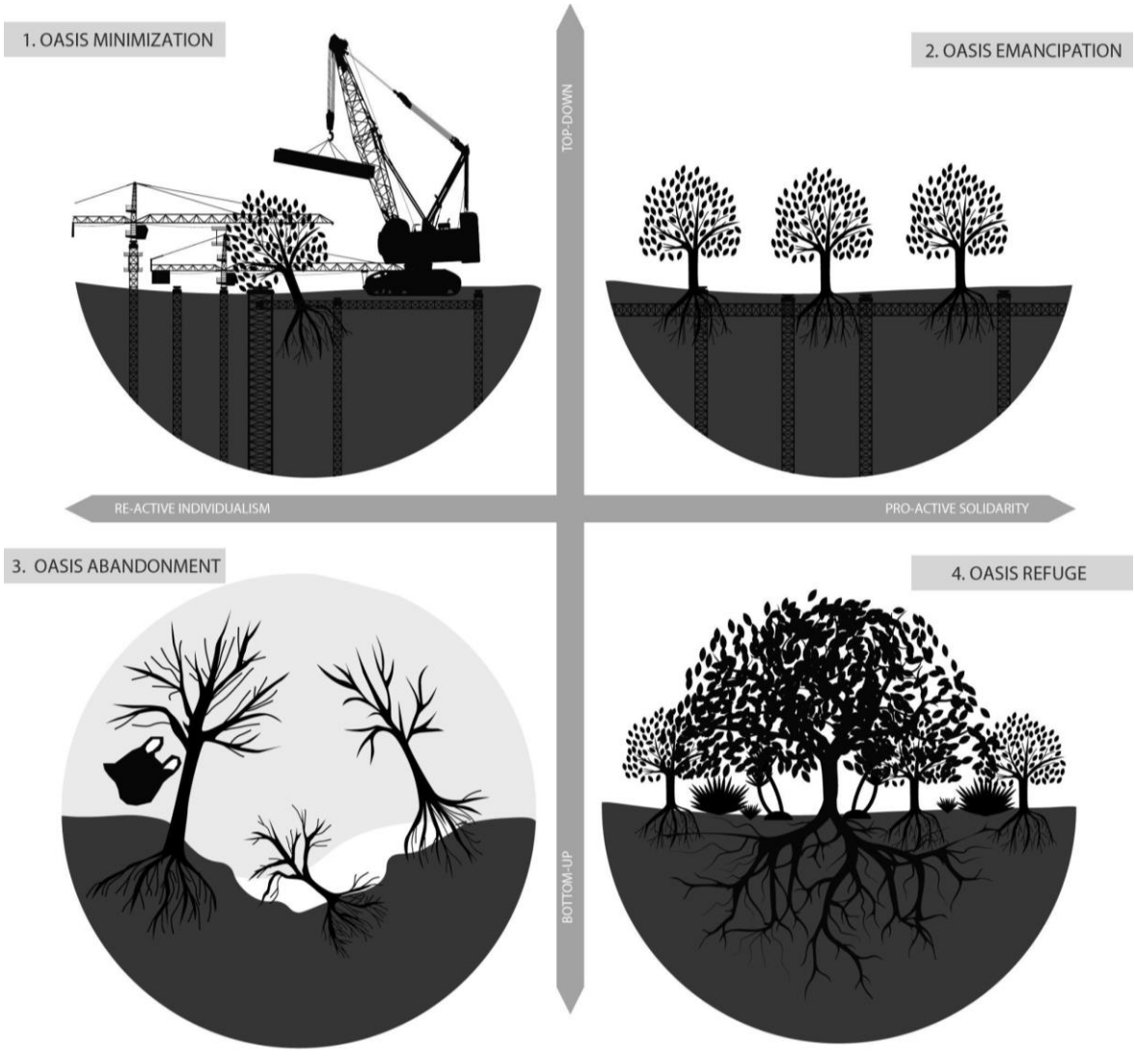

Figure 6. Scenario space illustrating four landscape archetypes structured along governance and social value axes.

5.2.1. Scenario 1: Oasis Minimisation

This scenario depicts strong state intervention combined with market-driven individualism. Large-scale agricultural corporations operate precision-farmed monocultures using sensor networks and automated irrigation. Settlement concentrates in planned urban zones with controlled access and protective infrastructure against sand encroachment. Traditional oasis areas are abandoned or repurposed for industrial agriculture and solar energy generation. Water resources are managed through centralized infrastructure connecting to national grids. Desertification accelerates in unmanaged areas as vegetation removal and soil compaction from industrial operations trigger erosion and gullying. Social outcomes include high migration rates, loss of traditional knowledge, economic polarization between corporate employees and displaced farmers, and dissolution of community-based resource management institutions.

5.2.2. Scenario 2: Oasis Emancipation

This scenario features coordinated state-led environmental restoration combined with collective social values. Comprehensive reforestation programs stabilize dunes using native species. Urban areas implement green infrastructure and mandate earthen construction. Agricultural systems transition to certified organic and regenerative practices supported by technical extension services. Water management integrates modern wastewater treatment with restored traditional systems. Eco-tourism and Agri-tourism generate economic value while preserving cultural heritage. Environmental sensors monitor ecosystem health, with data informing adaptive management. Desertification is slowed or stabilized through systematic intervention, though urban expansion continues creating localized land-use pressures. Social outcomes include reduced out-migration, revitalized rural settlements, improved environmental quality, but potential loss of local autonomy to bureaucratic structures.

5.2.3. Scenario 3: Rural Abandonment

This scenario portrays governance failure coupled with fragmented individualistic responses. Weak or absent state presence creates regulatory vacuums filled by informal practices. Illegal well drilling proliferates as households prioritize immediate survival over collective resource management. Agricultural land is progressively abandoned as youth migrate and elderly farmers cannot sustain labour-intensive traditional systems. Sand dunes advance unchecked, engulfing settlements and palm groves. Urban areas fragment into disconnected enclaves with inadequate infrastructure. Water pollution from untreated sewage contaminates remaining aquifers. Desertification accelerates dramatically through compound degradation: vegetation loss, soil erosion, groundwater depletion, and biodiversity collapse. Social outcomes include extreme poverty, educational collapse, health crises from waterborne disease, gender-based violence, ethnic conflict over dwindling resources.

5.2.4. Scenario 4: Rural Refuge

This scenario envisions bottom-up community organization guided by solidarity values. Self-organizing cooperatives manage water, agriculture, and land stewardship through revitalized traditional institutions. Mixed agroforestry systems combine date palms with vegetables, medicinal plants, and nitrogen-fixing species. Scattered reforestation efforts by community groups protect settlements from encroaching dunes. Households generate energy through small-scale solar installations. Eco-tourism operates on community-controlled terms emphasizing cultural exchange over profit maximization. Improved rural connectivity through enhanced roads and digital communication enables market access while maintaining settlement character. Desertification is locally managed through nature-based solutions and traditional ecological knowledge, though coordination challenges limit landscape-scale effectiveness.

Social outcomes include strong community cohesion, preservation of cultural practices, environmental stewardship, but potential vulnerability to external economic shocks.

5.3. Spatial Design Principles by Scenario

Translation of scenarios into spatial configurations for M'hamid oasis revealed distinctive landscape patterns. In Oasis Minimisation, urban expansion occurs on desert margins with defensive perimeters, large-scale solar parks occupy abandoned palm groves, and precision agriculture operates in consolidated parcels. In Oasis Emancipation, urban growth is contained by green belts, reforestation creates continuous corridors, wastewater treatment enables grey-water reuse, and revitalized ksour serve as cultural tourism nodes. In Rural Abandonment, urban fragmentation creates disconnected patches, abandoned farmland converts to wilderness with advancing sand. In Rural Refuge, scattered community forests protect settlements, mixed agriculture maintains palm grove structure, and community-managed commons provide shared spaces. The translation of STEEP drivers into spatial elements is represented through landscape scenario building blocks (Figure 7). The integration of these elements into spatial strategies is illustrated in Figure 8.

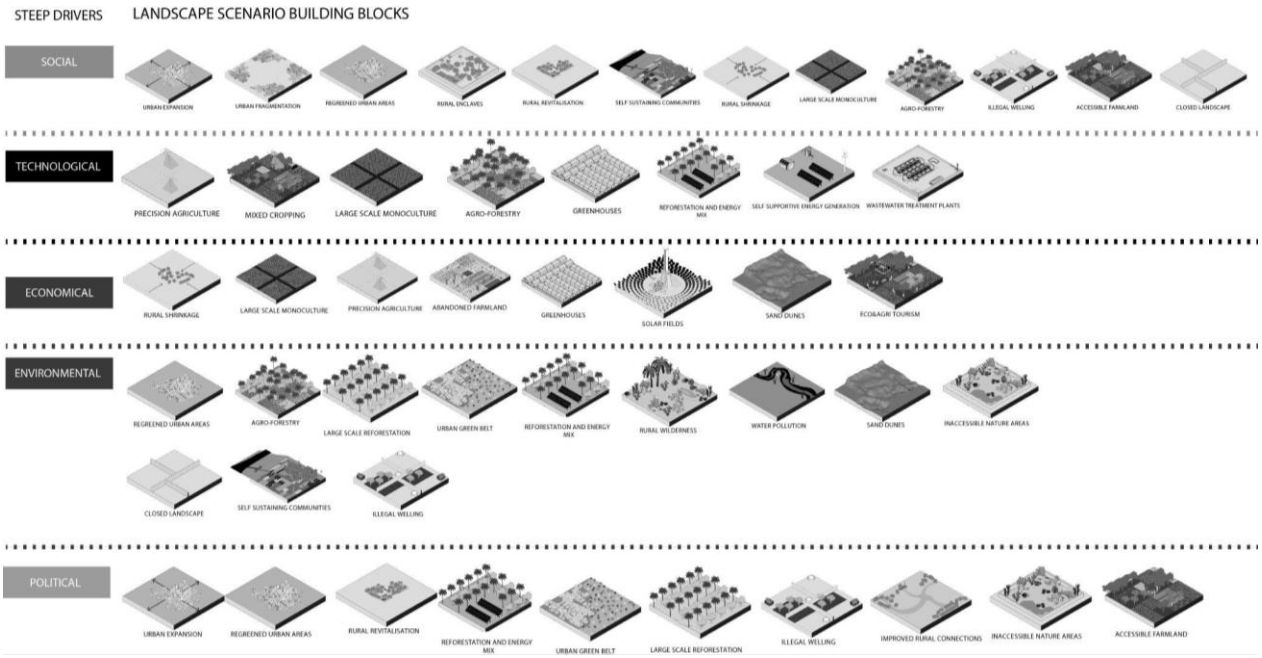

Figure 7. Landscape scenario building blocks derived from STEEP drivers and their relationships within the landscape system

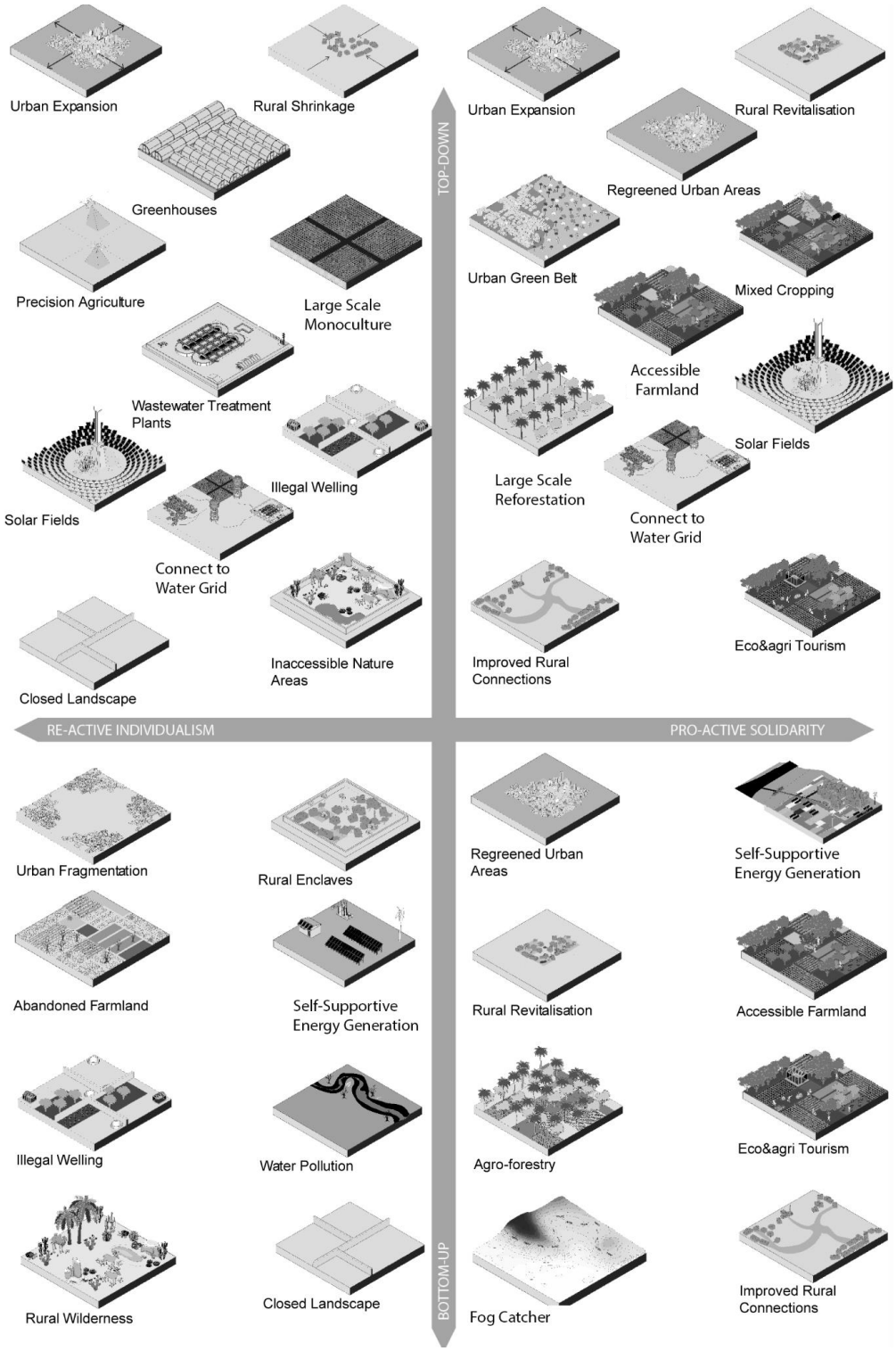

Figure 8. Spatial configuration of landscape scenario building blocks within the four scenario frameworks for M'hamid oasis.

5.4. Evaluation of Landscape Interventions

The landscape scenario building blocks are evaluated through a multi-criteria assessment framework, based on five dimensions:

- social acceptance
- political feasibility
- economic viability
- environmental impact
- technological feasibility

This evaluation process allows for the comparison of different interventions across scenarios, supporting the identification of the most desirable and feasible strategies. The results indicate that interventions combining ecological restoration with socio-economic benefits, such as agroforestry systems, water harvesting techniques, and eco-tourism, demonstrate higher levels of acceptance and feasibility across multiple criteria. The conducted evaluation was a comparative qualitative scoring approach, enabling the identification of interventions that perform consistently across multiple criteria rather than optimising a single dimension.

Each building block was scored qualitatively (low / medium / high) against the five criteria by the research team, drawing on the survey responses, the literature and the landscape analysis, with the survey feedback weighed alongside the other evidence rather than being the sole factor. The criteria were weighted equally, and the building blocks attaining an aggregate score above 1.0 across the five indicators were retained for the design synthesis. The respondents' judgements fed directly into this scoring: around 50% of the respondents considered the urban green belt an undesirable development, since it increases the separation between the palm groves, the agricultural lands and urban life; precision agriculture was viewed negatively by most of the farmer participants; while the solar fields received a generally positive perception, along with some concerns in regard to their maintenance and cooling-water demand. The full scoring matrix is available from the authors on request.

5.5. Synthesis into Spatial Strategy

The final stage of the results integrates the selected building blocks into a coherent spatial strategy for the Drâa Valley's oases, demonstrated through M'hamid as a representative site. The strategy aims to:

- reduce desertification through ecological restoration
- improve water availability and management
- rehabilitate degraded land through alternative agricultural practices
- strengthen socio-economic resilience through diversified activities

The building blocks retained through the multi-criteria assessment comprised the regreening of urban areas, self-sustaining communities, rural revitalisation, mixed cropping and agroforestry, urban green belts, large-scale reforestation and reforestation–energy mixes, self-supporting energy generation, eco- and Agri-tourism, accessible farmland, fog catchment, dune stabilisation and improved rural connections. This synthesis reflects the transition from scenario exploration to design implementation, where selected interventions are combined to form a context-specific and adaptive landscape strategy.

6. Discussion

6.1. Theoretical Contributions to Resilience and Scenario Planning

This research advances theoretical understanding of landscape scenarios as mediators between uncertainty and design action in complex socio-ecological systems. The study extends scenario methodology by explicitly linking archetypal narratives to spatial design through the landscape building block framework, addressing a persistent challenge in translating exploratory scenarios into actionable design guidance.

The research positions landscape scenario archetypes within resilience theory and socio-ecological systems thinking, specifically engaging debates around adaptive versus transformative responses to environmental change. Scenarios 2 and 4 emphasize adaptive resilience - maintaining system function through responsive management. Scenario 1 represents transformative change toward an industrialized system. Scenario 3 depicts system collapse from failed adaptation.

6.2. Linking Scenarios to Resilience Outcomes

This research hypothesizes that scenarios emphasizing traditional knowledge integration, participatory governance, and nature-based solutions (Scenarios 2 and 4) enhance oasis resilience more effectively than technology-substitution or laissez-faire approaches. This hypothesis derives from resilience theory principles: diversity supports adaptive capacity, modularity prevents cascading failure, and social capital enables collective action.

In resilience terms (Walker et al., 2004; Folke et al., 2010), the four scenarios can be compared against four qualitative indicators, namely the diversity of crops, livelihoods and water sources; the connectivity and modularity of the landscape mosaic; the retention of traditional ecological knowledge; and the capacity for self-organisation. Scenarios 2 and 4 rank the highest on all four indicators, Scenario 2 through institutionalised restoration and extension services and Scenario 4 through community self-organisation. On the other hand, Scenario 1 substitutes technological control for diversity, while Scenario 3 erodes every indicator simultaneously. This comparative reading, rather than any single quantitative measure, underpins the interpretation of Scenarios 2 and 4 as the more resilient trajectories. Developing measurable resilience indicators for oasis systems remains a priority for future research.

Survey participants with direct experience overwhelmingly favoured scenarios preserving mixed agriculture, community-based resource management, and cultural continuity. Historical analysis demonstrates that traditional oasis systems sustained populations for centuries by balancing resource extraction with regeneration. Contemporary case studies from other arid regions show that combining traditional practices with modern ecological engineering yields superior outcomes to purely technical interventions (Li et al., 2015). However, these scenarios may face limitations under conditions of weak institutional support or external economic pressures, highlighting the importance of governance capacity and long-term policy continuity in sustaining resilience-oriented strategies.

6.3. Scenario Plausibility, Hybrid Futures and Mediterranean Relevance

The four archetypes are exploratory rather than predictive, and their plausibility is uneven. Elements of Scenario 3 (Rural Abandonment) are already observable in the lower valley, namely the declining palm-grove density, out-migration and illegal well digging. On the other hand, the coordinated public investment assumed in Scenario 2 (Oasis Emancipation) depends on sustained national policy attention and funding continuity that cannot be guaranteed. The most likely future is therefore a hybrid condition combining features of several archetypes: community-based stewardship (Scenario 4) operating within selective state programmes (Scenario 2), or corporate agricultural enclaves (Scenario 1) co-existing with abandonment elsewhere (Scenario 3). Reading the scenario space as a continuum rather than as four

discrete futures allows planners to monitor which trajectory is being approached and to adjust interventions accordingly. The survey responses support this reading, as the participants judged a combination of Scenarios 3 and 2 to be the most likely future. They noted that the present condition of the valley is closest to Scenario 3, while the ongoing governmental agricultural programmes, along with some social movements and community activities, are working towards a future like Scenarios 2 and 4. Furthermore, the expansion of tourism facilities and commercial agriculture seems to suggest elements of Scenario 1.

Scenario trajectories will also be shaped by drivers beyond the local scale, including upstream dam operation and basin-scale water allocation, national rural development and renewable-energy policy, international tourism markets, remittance economies and migration regimes. Long-term climate projections reinforce the urgency of anticipatory planning: the Mediterranean Basin is warming considerably faster than the global average, with projected declines in precipitation and increasing drought frequency across North Africa (MedECC, 2020; IPCC, 2022), conditions under which all four scenarios face tightening water constraints. Potential conflicts between ecological restoration and development pressures, namely tourism construction, solar development and agricultural intensification, will therefore require negotiated land-use arrangements along with a phased implementation.

Positioning the findings within the wider Mediterranean and North African context underlines their transferability. Remote-sensing studies confirm ongoing desertification and field abandonment in the ancient oases of southern Morocco (Rayne et al., 2023), systematic reviews identify water-related pressures as the principal threat to traditional North African oasis agroforestry systems (Santoro, 2023), and recent work documents how rural–urban transformation reshapes oasis agriculture in Morocco (Boubou et al., 2025). The building-block approach developed here is consistent with the growing evidence base for nature-based solutions as cost-effective adaptation strategies in arid and semi-arid regions (Seddon et al., 2020; Chausson et al., 2020) and complements Mediterranean urban research linking spatial configuration to resilience (Bechlem et al., 2024). Comparable scenario exercises in other Maghreb oases and Mediterranean drylands would test the framework's transferability and refine its building-block vocabulary.

6.4. Methodological Validation and Limitations

The participatory survey process provides internal validation of scenario plausibility. However, limitations warrant acknowledgment. First, the small, self-selected online sample (15–20 respondents across the two survey components) and its composition (predominantly male, tourism-sector-biased) limit generalizability. Systematic exclusion of women's perspectives represents a critical gap. Second, while STEEP analysis provides systematic driver categorization, assessments incorporate the authors' qualitative judgement alongside survey and literature evidence. Third, scenarios represent synchronic cross-sections rather than dynamic temporal progressions.

In addition to these sampling constraints, further uncertainty is introduced by the subjective and qualitative ranking of the drivers, the narrative scenario construction that was undertaken without formal consistency algorithms or uncertainty-propagation analysis, along with validation procedures that relied on qualitative triangulation rather than statistical testing. These limitations bound the confidence with which the scenario outcomes can be compared and reinforce the exploratory status of the framework.

Findings hold direct implications for regional development planning. First, governance mode profoundly shapes landscape outcomes. Effective policy likely requires hybrid governance balancing state capacity with community participation. Second, nature-based solutions integrating traditional knowledge offer cost-effective resilience strategies. Third, scenarios highlight the inadequacy of single-sector interventions. Addressing desertification requires integrated approaches simultaneously tackling water, agriculture, energy, infrastructure, and social equity.

7. Conclusions

Addressing the three objectives set out at the outset, namely identifying the STEEP drivers of desertification, developing landscape scenario archetypes, and translating them into spatial design principles, this research demonstrates that landscape scenario archetypes provide an effective framework for exploring alternative futures in desertification-prone oases and for converting exploratory narratives into spatial design. Four distinct scenarios - Oasis Minimisation, Oasis Emancipation, Rural Abandonment, and Rural Refuge - emerged from systematic analysis of STEEP drivers and participatory validation, representing coherent socio-ecological trajectories shaped by governance structures and social values. Consistent with the study's guiding hypothesis, scenarios emphasising traditional-knowledge integration, participatory governance and nature-based solutions (Scenarios 2 and 4) were consistently preferred by participants and rank highest against the qualitative resilience indicators developed in Section 6.2.

The research makes three original contributions. First, it extends scenario methodology by developing the landscape building block framework as an explicit mechanism for translating scenarios into spatial design. Second, it positions scenarios within resilience theory, exploring how different governance-society paradigms enable adaptive versus transformative change. Third, it demonstrates the value of integrating traditional ecological knowledge with contemporary landscape strategies.

Findings indicate that combining traditional oasification practices - mixed agriculture, community-based water management, earthen construction - with nature-based solutions and appropriate technologies can enhance ecological functioning, improve resource efficiency, and strengthen social adaptive capacity. Survey results showing strong preference for scenarios emphasizing these elements suggest alignment between community values and sustainability principles.

For policy and practice, three priorities follow. Firstly, hybrid governance arrangements should pair the state investment in water infrastructure and dune stabilisation with legally recognised community water and land institutions, balancing state capacity with local participation. Secondly, the near-term implementation should prioritise the building blocks that performed consistently across scenarios and criteria, namely the agroforestry-based palm-grove rehabilitation, water harvesting and grey-water reuse, along with community-managed windbreak and reforestation belts. These interventions should be sequenced from low-cost community measures towards larger infrastructure as the institutional capacity grows, and where restoration competes with development pressures, the land-use trade-offs should be negotiated through community institutions. Thirdly, monitoring and evaluation should track early-warning indicators drawn from the scenario logics, namely groundwater levels, palm-grove density and out-migration rates, so that the strategies can be adapted as the valley's trajectory becomes clearer.

Future research directions include: (1) developing quantitative models to simulate scenario trajectories; (2) expanding participatory engagement to systematically include marginalized voices, particularly women; (3) conducting cross-case scenario development in other North African oases; and (4) implementing pilot interventions informed by preferred scenarios to assess practical feasibility. By advancing scenario-based planning for dryland regions, this research contributes methodological and substantive insights toward sustainable development in environmentally challenged yet culturally rich landscapes.

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Data Availability Statement
The survey data and the multi-criteria scoring matrix underlying this study can be obtained from the corresponding author on reasonable request.

Institutional Review Board Statement
All procedures followed established ethical research principles: survey participation was voluntary and anonymous, and every respondent gave informed consent before taking part.

CRediT Author Statement
Salwa Abdalla Alhejazi: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Visualization, Writing - original draft. Carlotta Maria Serena Fontana: Supervision, Conceptualization, Writing - review and editing, Project administration. All authors have read and approved the final manuscript.

Contribution to the Field statement
This study contributes an operational bridge between scenario planning and landscape design in desertification-prone oases. It introduces the landscape scenario building-block framework, through which each prioritised STEEP driver is carried into a discrete and mappable landscape intervention, allowing alternative futures to be compared as spatial configurations rather than remaining narrative constructs. Applied to the Drâa Valley, with M'hamid oasis as a representative site, the framework combines driver analysis, participatory input and multi-criteria assessment to identify resilience-oriented strategies, namely palm-grove rehabilitation through agroforestry, water harvesting and community-managed reforestation. The approach is transferable to other Maghreb oases and Mediterranean drylands.

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The Effects of Infrasound on Humans in Living Spaces

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ABSTRACT

Infrasound, defined as acoustic waves below 20 Hz, has been documented to influence human physiology and perception, yet remains largely absent from architectural discourse. This review synthesizes cross-disciplinary evidence from acoustics, physiology, and environmental psychology to reposition infrasound as a legitimate architectural design concern.. Findings show that everyday building services—compressors, HVAC systems, and ventilation fans—generate persistent low-frequency fields that interact with room geometry, producing localized resonance "hot spots." These amplified zones overlap with resonance ranges of the human body and neural rhythms, contributing to discomfort, fatigue, or subtle cognitive modulation. Evidence remains heterogeneous, and individual sensitivity varies, yet the architectural significance lies in recognizing buildings as resonant systems that can unintentionally sustain infrasonic fields. The study advocates integrating low-frequency awareness into design workflows, service placement, room proportioning, and post-occupancy evaluations, reframing infrasound as a spatial and environmental variable within salutogenic and evidence-based architecture.

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1. Introduction

This manuscript was initially motivated by three cases: "The Ghost in the Machine" (Tandy&Lawrence, 1998), later sensationalised as a 'ghost story', putting paranormal etiquette to infrasound; and the historical recollection of the infamous works of Victor Gavreau, later linked to patents for infrasonic weapons, which cast infrasound into the realm of fear and conspiracy. These accounts show how low-frequency resonance can provoke uncanny bodily and perceptual effects, but they remained framed outside architecture (Bowdler, 2018); the third case mentioned in this introduction connects all of the sensory experiences mentioned in the first two, through an architectural lens, by measuring the infrasound and the dimensions of the cellar where the eerie sensations were documented (Tandy, 2000).This recognition revealed that architecture itself can sustain and amplify infrasonic fields and is, in

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fact, a resonant system even for infrasound, providing the impetus to reframe infrasound as an architectural design concern.

While these cases are often cited in anecdotal or paranormal contexts, they are used here solely to illustrate measurable acoustic phenomena relevant to architectural environments. Despite documented physiological and psychological effects, architecture has rarely treated infrasound as a design concern, leaving a significant gap in architectural design.

In 1998, Vic Tandy and Tony R. Lawrence published the article "The Ghost in the Machine" in the Journal of the Society for Psychical Research, describing unusual sensations of dread, uneasiness and eerie "ghostly" presence observed in a laboratory environment. Although such experiences could easily have been interpreted as psychological or even paranormal, further investigation—prompted by the vibrating tin-foil knife on the bench—revealed a physical cause: a newly installed fan in a nearby room was emitting a frequency of approximately 19 Hz. While not clearly perceived as conventional sound, this vibration corresponded to the natural resonant frequency of the human eyeball (NASA, 1978), offering a plausible explanation for the reported visual disturbances in peripheral vision. Such effects are not universal, but they reveal how resonance phenomena can trigger perceptual anomalies in certain individuals. It is important to note that not everyone exposed to this specific frequency would necessarily experience such sensations; visual disturbance remains an individual occurrence, prompted when the eyeball itself begins to vibrate.

A strikingly similar case occurred two decades earlier involving Vladimir Gavreau, a scientist at the Centre National de la Recherche Scientifique (CNRS) in Marseille. During the mid-1960s, Gavreau's team experienced unexplained nausea, disorientation, and ear pressure in their concrete laboratory building. The source was identified as a faulty ventilator in a neighbouring facility emitting infrasound at ~7 Hz. As recounted by Bowdler (2018), the symptoms vanished once the ventilator was deactivated. This incident subsequently motivated experimental work on infrasonic generation and its possible biological effects. Subsequent studies have confirmed that whole-body resonance occurs between 3–8 Hz (NASA, 1978), while the vestibular apparatus is most sensitive to 7 Hz. Such disruptions may lead to significant vertigo and malaise (Stepanov et al., 2003; Evans & Tempest, 1972).

In 2000, Vic Tandy investigated another reported "haunted" space, a 14th-century cellar beneath the Coventry Tourist Information Centre. Visitors from different countries independently reported intense sensations—chills, a strong "presence," pressure at the threshold, and even seeing a woman's face—despite no visible stimuli. Having already experienced similar effects in the laboratory in 1998, Tandy sought a physical rather than paranormal explanation. His calculations showed that the cellar's 7.7 m length supported a standing wave at ~22 Hz, while the connecting corridor resonated at ~16 Hz. Measurements revealed a stable tone around 18.9 Hz with additional peaks near 23 Hz, consistent with predicted room modes. No mechanical source was identified, suggesting that the resonance amplified low-frequency components already present in the ambient noise field (Tandy, 2000).

The measured frequency was almost identical to that observed in the 1998 laboratory case, aligning with ocular resonance (~19 Hz), head resonance (2–20 Hz), and beta brainwave rhythms (15–30 Hz). While beta activity supports logical thinking and focus, its excessive prominence is linked to chronic anxiety and hyper-arousal (Abhang, Gawali, Mehrotra, 2016). This convergence underscores how architectural geometry itself can act as an acoustic system, unintentionally shaping human perception and well-being.

Tandy noted that the recorded non-linear modulation of the 19 Hz signal by a slower 2–4 Hz oscillation mirrors a principle relevant to acoustic disruption: temporally modulated low-frequency rhythms can be more difficult to habituate to than steady tones (Tandy, 2000; Thiel & Alexander, 2000). In animal communication research, nonlinearly modulated and acoustically unpredictable sounds such as fear screams and alarm calls are known to elicit stronger behavioural responses because their irregular

structure signals urgency and threat (Blumstein et al., 2014). While this work does not address infrasound directly, it highlights a broader acoustic principle: irregular modulation is more disturbing than steady tones. Military and security research on sonic and infrasonic weapons applies a comparable principle at far higher intensities, using pulsed or modulated acoustic fields to disturb vestibular function, cognition, or bodily comfort (Altmann, 2001; Li et al., 2026).

It is important to note that the sole aesthetic of the cellar's dim lighting, exposed sandstone, and steep stairs may also contribute to what would conventionally be considered an eerie impression. However, Bruno and Pavani stated that the perception actively reaches out instead of just receiving signals. The brain goes looking for stimulation, pulling from sight, sound, and everything in between. It pieces together whatever's available into one fluid experience, blending all the signals into something that feels real (Bruno & Pavani, 2018).

While these cases are often sensationalised in paranormal or weapon narratives, in this review they are referenced solely to illustrate measurable acoustic phenomena relevant to architectural environments. Their anecdotal framing in public discourse does not diminish their value as examples of how resonance can shape perception; however, it does highlight the need for a more systematic architectural perspective.

Taken together, the laboratory, ventilator, and cellar cases illustrate a broader principle: infrasound may undoubtedly be present in architectural spaces. The dispositions and dimensions of the first two sites were not investigated, while the Coventry case highlighted an architectural perspective: spatial geometry can unintentionally amplify or sustain low-frequency vibrations, producing perceptual and physiological responses that are easily misattributed to psychological or paranormal causes. While acoustics and medicine have documented such phenomena, architecture has rarely addressed them as design concerns.

This paper moves beyond anecdotal accounts by systematically synthesizing cross-disciplinary evidence into an architectural framework. This paper's contribution is to reposition infrasound as an architectural design concern by synthesizing cross-disciplinary evidence into implications for building practice. By examining sources of infrasound, the presence or absence of soundwave patterns, and spatial resonance mechanisms, the study highlights how everyday building services and geometries can shape low-frequency sound fields. In doing so, it bridges acoustics, physiology, and environmental psychology with architectural design, advancing salutogenic and evidence-based approaches to occupant well-being.

2. Theoretical Background

Sound is a mechanical vibration that propagates through a medium (Yost, 2006) and is conventionally divided by frequency into infrasound, audio-frequency sound, and ultrasound. Infrasound refers to acoustic waves below 20 Hz; audio-frequency sound spans 20–20,000 Hz; ultrasound exceeds 20,000 Hz (ISO, 1995; Health Protection Agency, 2010). Standard hearing-threshold curves such as ISO 226:2003 are defined only above 20 Hz for "otologically normal young adults

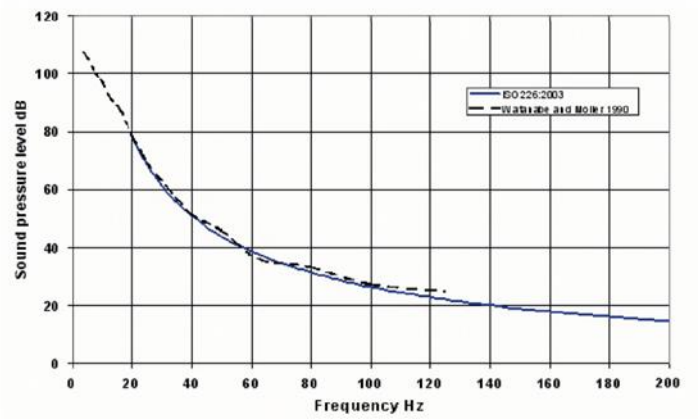

Figure 1. Comparison of hearing threshold curves and age-related hearing loss statistics (Moyano & Lezcano, 2020).

The solid line above 20 Hz represents the ISO 226:2003 standard threshold; the dashed curve (4–125 Hz) is from Watanabe and Møller (1990). The overlap is nearly perfect, with the main difference being that the ISO standard line does not depict the frequencies under 20 Hz and their possible audibility, whereas Watanabe and Møller (1990) do argue that lower frequencies may be heard if the SPL level is high (above 80 dB for 20 Hz, and around 100 Hz for around 10 Hz, as observed in the figure 1).

Infrasound is characterized by longer sound waves in comparison to higher-frequency sounds (Leventhall, 2003). Attenuation of sound waves in air is increased by the square of its frequency. As frequencies get lower, the attenuation also gets lower. Ground and other barriers also absorb the sound waves, but attenuation is also progressively lower as the frequencies get lower (Leventhall 2003). In fact, infrasound is characterized by very low absorption in various environments such as air, water and the Earth's crust (Voskoboinick, 2023) due to its long wavelengths, which allow it to diffract around obstacles, penetrate conventional insulation, and travel vast distances with minimal energy loss (Ghadiali & Trivedi, 2015).

Unlike higher-frequency sound, infrasound exhibits low attenuation due to its reduced interaction with particles and surfaces, penetrating conventional insulation more easily, making mitigation more challenging (Johnson, 1976).Conventional sound insulation materials are largely ineffective at infrasonic frequencies; mitigation in this range depends primarily on structural design, mass–spring–mass systems, façade airtightness, and in some experimental cases, metamaterials or tuned resonators, rather than on standard lightweight absorbers (Arjunan et al, 2024).

2.1. Sources of Infrasound

Sources of infrasound are both natural and anthropogenic. Large-scale events such as tsunamis, earthquakes, thunderstorms, volcanic eruptions, offshore storms, and historical explosions (e.g., Krakatoa 1883, the 1908 Siberian meteorite, and the 1945 Hiroshima and Nagasaki bombings) generate powerful infrasonic waves (Berglund et al., 1996; Moyano & González Lezcano, 2022). At lower intensities, sea waves, wind, and ordinary human activities such as running (Johnson, 1975), as well as certain animals including elephants, lions, and whales, produce infrasonic signatures (Voskoboinick, 2023).

Natural infrasound often accompanies visible cues — the rumble of a storm or seismic tremor makes contextual sense. In contrast, anthropogenic infrasound may be experienced without perceptible cause, producing sensations of vibration or pressure that feel uncanny. Contemporary exposures arise primarily from technological sources: industrial installations, low-speed machinery, and household appliances (Berglund et al., 1996; Leventhall, 2007). In buildings, compressors (refrigerators, heat pumps,

air conditioning units), ventilation fans, and other rotating machinery generate low-frequency components whenever they operate (Boabaid Neto et al., 2015; Pedersen et al., 2017). Altmann (2001) notes that wind turbines, HVAC systems, and even the aerodynamic effects of opening a car window produce infrasonic levels. Industrial equipment such as crushers, furnaces, and ship engines generates very high intensities, while blast waves form a special case: their positive overpressure peak can be extreme, though the negative phase is bounded by ambient atmospheric pressure (~101 kPa at sea level). Even neighbors contribute to low-frequency exposure, since walls attenuate high frequencies more effectively than very low ones (Leventhall, 2003).

2.2. Psychological and Physiological Effects

Physiological studies show that the human body exhibits distinct resonant frequencies in the infrasonic range: whole-body resonance at approximately 3–8 Hz, head and neck across 2–20 Hz, vestibular sensitivity near 7 Hz, and ocular resonance around 18–19 Hz (NASA, 1977; NASA, 1978; Stepanov et al., 2003). These ranges overlap with intrinsic brain rhythms: delta (0.5–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), sensorimotor rhythm (12–15 Hz), and low beta (15–20 Hz), which support sleep, drowsiness, calm wakefulness, focused relaxation, and alert problem-solving, respectively (Kasprzak, 2012). Experimental EEG work has demonstrated that low-frequency and infrasonic stimulation can suppress alpha activity and modulate SMR and beta rhythms, indicating that neural oscillations can entrain to environmental vibrations even below the threshold of conscious audibility (Kasprzak, 2012; 2014). Kasprzak (2012) summarises the main EEG rhythms and their functional roles (Table 1).

Table 1. Main brainwave types, frequency ranges, and associated functions (Kasprzak, 2012).

Brainwave	Frequency (Hz)	Function
Delta	0.5–4	Deep sleep
Theta	4–8	Drowsiness, daydreaming
Alpha	8–12	Calm wakefulness
SMR	12–15	Focused relaxation, learning
Beta	15–20	Alert thinking, problem-solving

Functional neuroimaging studies point in a similar direction. In a working memory fMRI experiment, Weichenberger et al (2015) found that brief 12 Hz infrasound bursts produced pronounced activation of primary auditory cortex and associated cortical networks, without impairing cognitive performance. A subsequent resting state study reported altered cortical and subcortical connectivity during near-threshold infrasound exposure, indicating that neural activity can be modulated by low-frequency stimulation even when subjective perception is limited (Weichenberger et al., 2017).

Two longitudinal studies conducted by Ascone et al (2021) and Forlim et al (2024) systematically examined the impact of prolonged exposure to airborne infrasound at 6 Hz on brain structure and neural connectivity. The first study showed an extremely significant structural brain change: grey matter volume reductions observed, which are linked to working memory and somatomotor coordination, and in the left angular gyrus, associated with language processing, reading, and auditory integration (Ascone et al., 2021). This is also investigated and confirmed by Berglund et al (1996).

Follow-up study (2024) revealed significant changes in resting-state functional connectivity across key neural networks, all of which are integral to introspection, planning, decision-making, and sensory-motor integration (Ascone et al., 2024). Notably, the auditory network exhibited no measurable activation, reinforcing the hypothesis that infrasound influences the brain via non-auditory neural mechanisms.

Scatterty et al (2026) conducted a controlled experiment in which participants were exposed to calming or unsettling music with an embedded 18 Hz infrasonic component or without it. Participants could not reliably detect the presence of infrasound, yet the infrasound condition was associated with

elevated salivary cortisol, increased irritability and disinterest, and a sadder appraisal of the sound environment.

Furthermore, Scatterty et al (2026) note that infrasound appears to evoke irritability and annoyance more reliably than acute anxiety, despite previous common suggestions that infrasound is anxiety-inducing. Across both animal models and human studies, low-frequency exposure is associated with aversive responding, negative appraisal, and elevated stress markers, while self-reported anxiety often remains unchanged. This pattern supports the view that infrasound functions primarily as a subtle environmental irritant or background stressor rather than a classic anxiety-inducing agent, acting on vestibular and limbic pathways in ways that may never fully reach conscious awareness (Scatterty et al., 2026). Together, these findings establish a physiological and acoustic foundation for understanding how infrasonic environments interact with architectural space and human perception.

3. Methodology

This manuscript employs a cross-disciplinary synthesis methodology, reframing established acoustic and physiological evidence through an architectural lens. The approach is analytical and integrative, designed to highlight how infrasound is generated and how it interacts with humans in architectural spaces. Relevant literature was identified through searches in major scholarly databases (Scopus, Web of Science, PubMed, Google Scholar) using combinations of keywords such as infrasound, resonance, architectural acoustics, effects of infrasound, covering publications from the 1960s—when Gavreau's CNRS ventilator case first drew attention to infrasonic effects in buildings—through to 2026.

Studies were included if they were peer-reviewed articles, technical reports, or documented case studies that reported measured acoustic data, while anecdotal or paranormal accounts without measurement were excluded. With two deliberate exceptions, all cited sources are peer reviewed: Gavreau's ventilator incident is treated as a historical case widely cited in later work, and Bowdler (2018) is used only for descriptive detail about the deactivation of the fan; all physiological claims draw on peer-reviewed sources. Selected evidence was then organised into three analytical strands: sources of infrasound (natural and anthropogenic), resonance mechanisms in the human body (ocular, vestibular and whole body resonance, as well as neural entrainment), and architectural factors that amplify or sustain low frequency fields, such as building services and room geometry.

These strands were synthesised into an architectural framing that translates acoustic and physiological findings into design implications, with an emphasis on salutogenic and evidence-based approaches. Finally, physiological resonance ranges were cross-checked against frequencies reported in architectural case studies, and patterns were triangulated across acoustics, physiology, psychology, and architecture to strengthen robustness and clarify where relationships are well supported and where they remain hypothetical. The synthesized process is shown in the diagram in Figure 2.

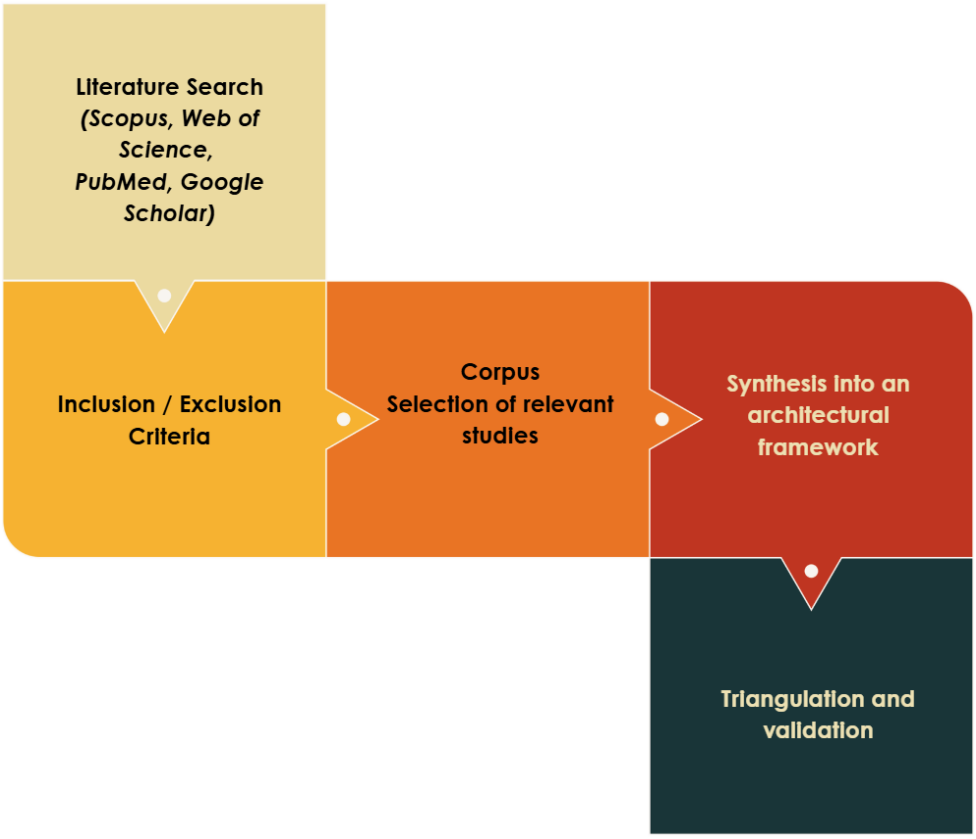

Figure 2. Review Methodology Diagram

The diagram illustrates the cyclical review process. The process begins with a structured literature search across major databases, followed by the application of inclusion and exclusion criteria. Evidence was then organized into four analytical categories—sources of infrasound, wave patterns, resonance mechanisms, and architectural implications. Finally, findings were synthesized into an architectural framework and validated through triangulation across acoustics, physiology, psychology, and architecture.

3.1. Conceptual Framework

This review adopts a stepwise conceptual framework linking infrasound to human experience in architectural space. First, natural infrasound sources are excluded, and anthropogenic sources such as compressors, appliances, ventilation systems, and others that generate low-frequency acoustic energy are defined. Second, this energy forms specific wave patterns that interact with rooms and structures, producing standing waves and spatially uneven low-frequency sound fields. Third, these fields can couple with known resonance ranges of the human body and brain, so that, under certain exposure conditions, infrasound may act as an underlying environmental factor influencing comfort, mood, and well-being rather than as an overtly audible sound.

4. Measurement Limitations in Architectural Context—Problem Statement

Due to the limited exploration of this topic from an architectural perspective, several issues arise. These include the lack of dimensional data for the architecturally defined spaces in which infrasound was measured, as well as the reliance on A-weighted measurements, which are not well suited to accurately assessing infrasound.

Naturally, industrialisation favoured progress and efficiency rather than inaudible soundwaves. Much of the available literature addresses low-frequency noise from roughly 20 to 200 Hz, rather than sub-20 Hz infrasound. The result is an architectural blind spot. Residential complaints may involve spectral content extending toward or into the infrasonic region, but if instruments, standards, and consultants are not tuned to detect it, the phenomenon effectively disappears from professional knowledge. This helps explain why the literature is richer on industrial sources, wind turbines, or laboratory exposures than on ordinary dwellings, even though domestic environments clearly contain persistent low-frequency sources and highly variable indoor transfer conditions.

Routine building-noise assessment still privileges the audible band and frequently relies on A-weighted indices, meaning low-frequency and infrasonic components are easily under-represented or missed entirely. A further consequence is interpretive fragmentation: because direct residential infrasound data are scarce, evidence tends to be split across separate domains — room acoustics without physiology, physiology without architecture, or complaint literature without detailed spectral documentation. One contribution of the present review is therefore to connect these partial literatures into a single explanatory frame centred on the dwelling as an acoustically active environment.

Two examples demonstrate the richness of the inaudible spectrum emitted by refrigerators and cooling compressors, which are commonly overlooked. Boabaid et al (2014) showed that a typical refrigerator does not produce merely a faint "hiss," but a broadband spectrum with pronounced tonal components around 50–60 Hz and significant measurable energy from about 10 Hz upwards (Figure 2). When such tonal low-frequency content is reinforced by room resonance, it can create local "hot spots" of pressure and vibration inside a dwelling, providing a physical basis for occupants' reports of heavy-headedness, headaches, or general discomfort when spending time in those specific zones. These local "hot spots," known as room modes, can amplify certain frequencies by 20–30 dB. When such recordings are compared to hearing thresholds, it becomes clear that specific infrasonic frequencies resonating within enclosed spaces may intrude into the audible range if they are already at a level close to the hearing threshold line.

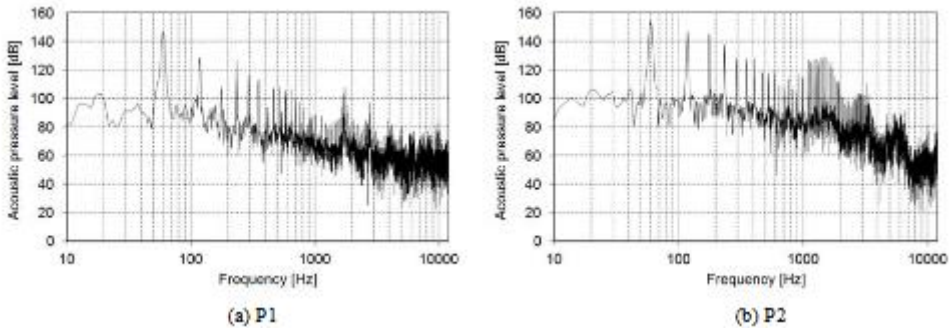

Figure 3. The acoustic pressure spectral density in narrow frequency bands (1.56 Hz), for a typical test under a compressor speed of 3500 rpm (58.3 Hz approximately), (Boabaid et al, 2014).

Pedersen et al (2017) provided a particularly useful spectrogram-based view of how low-frequency complaints manifest in real dwellings. Using an occupant-operated recording device, they documented three cases involving a restaurant cooling compressor, a residential heat pump, and nearby wind turbines. Figure 4 shows a spectrogram of the heat pump recording taken outside the house. The left image presents the full spectrum of the inaudible sound, demonstrating that it is a broadband signal with dominant low-frequency content. In contrast, the right image, weighted according to the hearing threshold, shows that much of this low-frequency energy falls below the range of conscious audibility.

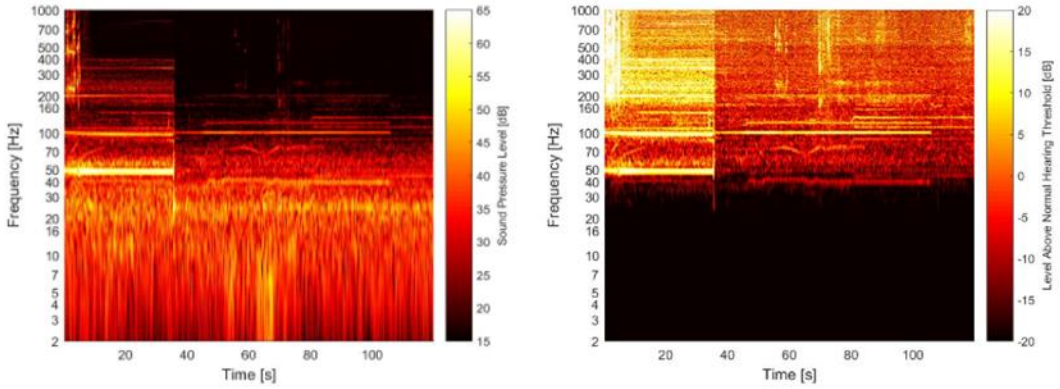

Figure 4. Left: Spectrogram of an outdoor recording. Right: a weighted according to the hearing threshold spectrogram of the same recording, (Pedersen et al., 2017).

5. Research gap and aim

In architecture, sound is omnipresent and routinely considered to ensure acoustic comfort. Standard architectural acoustics, however, primarily focus on the audible spectrum (20 Hz–20 kHz), leaving inaudible soundwaves—particularly infrasound—largely unaddressed. This omission creates a significant research gap: while acoustics and medicine have documented the physiological and psychological effects of infrasound, architecture has rarely treated it as a design concern.

Despite growing evidence that low-frequency and infrasonic sound can modulate perception, mood, and cognitive performance at levels encountered in everyday environments, these phenomena remain absent from architectural standards, design workflows, and post-occupancy evaluations. Existing studies are fragmented across acoustics, medicine, and environmental psychology, offering little guidance on how architects should recognise, anticipate, or mitigate infrasound within real buildings.

Low-level, continuous infrasound generated by household appliances, HVAC systems, and building services can interact with room resonance, producing localized "hot spots" that may incite occupant discomfort. Despite this evidence, architectural practice lacks systematic frameworks for recognizing, measuring, and mitigating such exposures.

This paper aims to raise awareness of infrasound as a legitimate architectural design concern. By synthesizing cross-disciplinary evidence from acoustics, physiology, and environmental psychology, the study develops an architectural framework that connects sources, resonance mechanisms, and occupant responses. In doing so, it advocates for integrating low-frequency awareness into design workflows, advancing salutogenic and evidence-based approaches to healthier built environments.

5.1. Research Significance and Contribution

The significance of this study lies in raising awareness of infrasound as an overlooked architectural factor. While acoustics, physiology, and psychology have documented its effects, architecture has rarely acknowledged infrasound as a design concern. By reframing it as a spatial and environmental variable, this paper contributes to salutogenic and evidence-based architecture. The framework developed here connects everyday sources, resonance mechanisms, and occupant responses, offering architects and researchers conceptual tools to recognise and anticipate low-frequency exposures. In doing so, the study encourages future standards, design workflows, and post-occupancy evaluations to integrate low-frequency awareness, ultimately promoting healthier and more responsive built environments.

6. Case studies

Due to the lack of definite architectural research dealing with the presence of infrasound in dwellings, below is presented only one study measuring both architectural space and infrasound, calculating the relationship of the space with the soundwaves. Pedersen et al.'s (2017) study moves away from A-weighted measurements and contains valuable spectrograms, which show the whole broadband of inaudible frequencies present in dwellings. Oliva et al.'s (2011) study experimentally proves and illustrates how furniture affects the 50 Hz frequency soundwaves. It is important to note that while 50 Hz is audible at appropriate SPL levels is not considered infrasound and is mentioned exclusively for its possible method of use for infrasound mitigation, which calls for further research.

6.1. Architecture as a Resonant System

As mentioned in the introduction, in 2000, Vic Tandy investigated a reported "haunted" space, a 14th-century cellar beneath the Coventry Tourist Information Centre. Visitors from different countries independently reported intense sensations in the Coventry cellar—chills, a strong "presence," pressure at the threshold, and even seeing a woman's face—despite no visible stimuli. This prompted Tandy to investigate a physical, rather than paranormal, cause. Building on these accounts, this section shifts the focus from physiological responses to spatial mechanisms, examining architecture itself as an active acoustic system that can unintentionally amplify, trap, or modulate low-frequency energy and thereby intensify such experiences.

The mathematical calculations based on Tandy's cellar geometry showed that its 7.7 m length would support a longitudinal standing wave at about 22 Hz, while the corridor connecting to it (10.95m in length, which would resonate at 16.3 Hz), with an effective straight-line length of roughly 9.5 m, would resonate close to 18 Hz. The plan of the cellar is depicted in Figure 5. Measurements of the space revealed a stable tone around 18.9 Hz with an amplitude of about 38 dB, together with slower 2–3 Hz fluctuations and an additional peak near 23 Hz, consistent with the predicted room modes. No mechanical source could be identified, but the standing wave persisted for several hours. This does not mean that the sound "appeared from nowhere"; rather, the room resonance may have been extracted by amplification of low-frequency components already present in the ambient noise field (Tandy, 2000).

The measured frequency of the recorded soundwave was almost identical to the one measured in the mentioned 1998 Laboratory case (Tandy, 1998). That frequency coincides with the natural frequency of the eyeball, and also falls into the spectrum of the head resonance that is documented to be at around 2-20 Hz (Kroemer, 2008; NASA, 1977). This frequency falls into the spectrum of beta (β) brainwave rhythm as well (15-30 Hz). In optimal conditions, beta waves facilitate logical thinking and conscious focus, yet their prominence triggers a state of high arousal, chronic anxiety, and an inability to relax (Abhang, Gawali, Mehrotra, 2016).

Tandy noted that the 19 Hz signal with a slow 2–4 Hz amplitude modulation and noted that it mirrors a principle relevant to acoustic disruption: temporally modulated low-frequency rhythms can be more difficult to habituate to than steady tones (Tandy, 2000; Thiel & Alexander, 2000). In animal communication research, nonlinear and acoustically unpredictable sounds such as fear screams and alarm calls are known to elicit stronger behavioural responses because their irregular structure signals urgency and threat (Blumstein et al., 2014). Military and security research on sonic and infrasonic weapons applies a comparable principle at far higher intensities, using pulsed or modulated acoustic fields to disturb vestibular function, cognition, or bodily comfort (Altmann, 2001; Li et al., 2026).

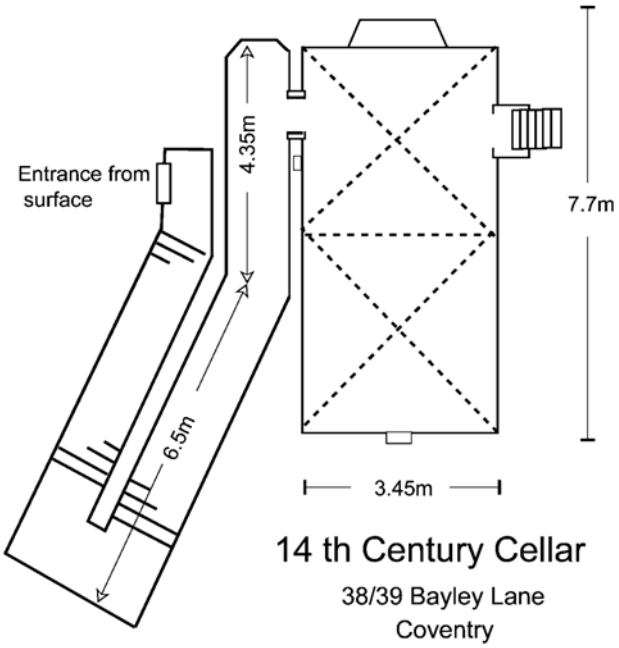

Figure 5. Plan of the cellar (Tandy, 2000).

While infrasound is widely investigated in the military and weapons field, this comparison must be treated carefully. Altmann's prospective assessment explicitly warns that the dramatic potential of infrasonic weapons has often been overstated, and that technically effective deployment at a distance is difficult (Altmann, 2001). The relevance of the weapon literature here is therefore not to suggest that buildings secretly function as weapons, but to underline that temporally modulated low-frequency sound can be physiologically meaningful. If similar waveform structures are present in residential buildings at much lower levels, their relevance to occupant well-being cannot be dismissed outright, even though the exposure context and intensity are entirely different.

As mentioned in the introduction and as observable in Figure 6, the aesthetic of the cellar is reminiscent of those viewed in horror movie scenes and, undoubtedly, might be perceived as 'eerie' itself, even without the presence of infrasound.

Figure 6. The cellar of Coventry Tourist Information Centre (Tandy, 2000).

6.2. Room Resonance: Basic Principles

Room resonance refers to the amplification of sound at specific frequencies, known as room modes (standing waves) within an enclosed space. These frequencies arise from the interaction between a radiating sound source and its reflections within an enclosed room, when the sound wavelengths bear specific proportional relationships to the room's dimensions. Under these conditions, the reflected waves form stable patterns of constructive and destructive interference, creating regions of maximum and minimum sound pressure (Năstașa et al., 2023).

The fundamental relationship between wavelength (λ), frequency (f), and the speed of sound (c) is expressed as:

$$\lambda = c/f$$

Where:

- c is the speed of sound in the medium (the speed of sound through air is approximately 343 m/s at 20°C),
- f is the frequency in Hz. (Leventhall et al., 2003)

To calculate the fundamental room mode along a single axis (e.g., length), the formula becomes:

$$f = c/2L$$

Here, L is the distance between two opposing walls. This expression yields the lowest frequency at which an axial resonance can occur. Higher-order resonances (harmonics) appear at integer multiples of this fundamental frequency (Everest, 2001).

6.3. Harmonics and room mode types

Harmonics are resonant frequencies that occur at integer multiples of the fundamental mode. If a room's fundamental axial mode is 43 Hz, its harmonics will appear at 86 Hz, 129 Hz, and so on. These harmonics interact with room geometry to produce complex acoustic patterns, especially in small or rectangular spaces (Mašović, 2021). Room modes are typically classified as:

- Axial modes: between two parallel surfaces (e.g. floor–ceiling, opposite walls)
- Tangential modes: involving four surfaces
- Oblique modes: involving all six surfaces (Everest et al., 2001)

Axial modes are strongest and most easily calculated, while tangential and oblique modes are weaker but still contribute to the overall sound field. Their harmonic relationships can lead to constructive or destructive interference, affecting clarity, warmth, and spatial perception (Everest, 2001)

In a box-shaped room, resonance frequencies can be estimated from the modal equation:

$$f_{lmn} = \frac{c_0}{2}\left[\left(\frac{l}{L_x}\right)^2 + \left(\frac{m}{L_y}\right)^2 + \left(\frac{n}{L_z}\right)^2\right]^{1/2} \quad l, m, n \geq 0$$

where Lx, Ly, and Lz are the three dimensions of the room; l, m, and n are mode numbers; and c0=344 [m/s] is the speed of sound in air in normal conditions of temperature and air pressure.

Room modes (standing waves) arise when sound reflections between room boundaries reinforce each other at specific frequencies, producing resonance (eigenfrequencies). At these frequencies, the room does not behave like a uniform container of sound: instead, fixed regions of high sound pressure (antinodes) and low sound pressure (nodes) form, so measured SPL depends strongly on microphone

and listener position. This effect is most pronounced at low frequencies, where only a few modes dominate and the modal spacing is wide, causing large spatial variations across a room. In rectangular rooms, modal families are commonly described as axial (involving one dimension), tangential (involving two dimensions), and oblique (involving three dimensions).

In 2011 research, Oliva et al. Claim that when the sound enters the room, the room modes are the strongest at low frequencies. Absorption of room boundaries is negligible at low frequencies, and as a consequence, even relatively modest levels of low-frequency noise outside a building may lead to significantly higher levels at particular positions inside a room. For architectural acoustics, this means that room geometry, boundary conditions (parallel surfaces), and absorption/furnishings can unintentionally amplify or suppress low-frequency components, which has direct implications for both measurement strategy and perceived indoor annoyance (Oliva et al., 2011).

6.4. Spectrogram-based complaint cases

Pedersen et al (2017) provide a detailed spectrogram-based view of how these sources behave in real dwellings by equipping occupants with a low-frequency recording device and analysing three complaint cases: a restaurant cooling compressor, a residential heat pump, and nearby wind turbines.

6.4.1. Cooling compressor case

The occupant lives next to a restaurant where cooling compressors vent through an outlet mounted on the wall near the occupant's window, and they made over 20 recordings across different times (day/evening/night) and locations (rooms, hallway, and outside by the restaurant). The worst-case spectrogram (Figure 7) shows speech at the start, followed by impulse sounds (footsteps and a closing door), and then a clear dominant tonal component around ~47–48 Hz that fluctuates in frequency and level.

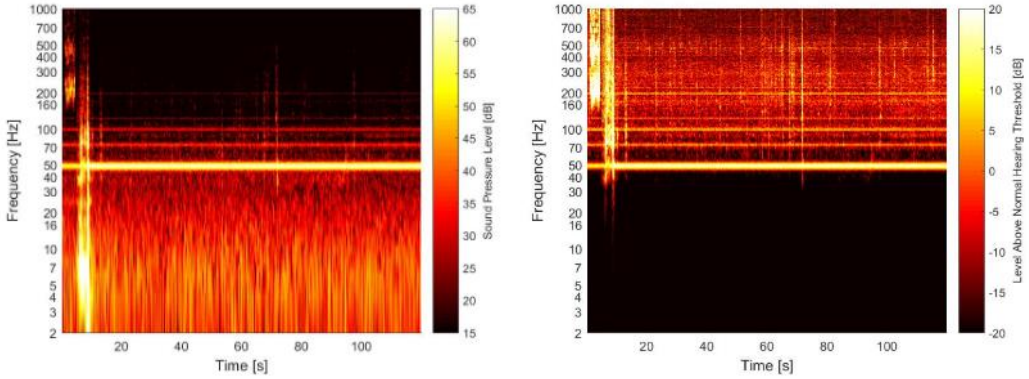

Figure 7. Left: spectrogram (logarithmic frequency axis) of a recording in a room in the apartment. Right: Same recording with a spectrogram where the level is weighted according to the normal hearing threshold (ISO389-7:2005) (Pedesen et al., 2017).

The 48 Hz tone becomes stronger after the door is closed, for which the authors argue that it is likely because the closed door changes reflections and the standing-wave pattern in the room. A threshold-weighted spectrogram (right) indicates that content below the tone is inaudible, while higher frequencies are audible but less prominent than the ~47–48 Hz component. In the left spectrogram, it is evident that the whole spectrum below the hearing threshold line exists at significant SPL levels (up to around 45 dB). The same spectrogram, as is observable, indicates a pulsating rhythm over the temporal dimension.

The spectrograms below (Figure 8) present recordings outside of the apartment. The left one is showing the recording in the hallway outside of the apartment, and the right one is showing a recording outside of the back door of the neighbouring restaurant.

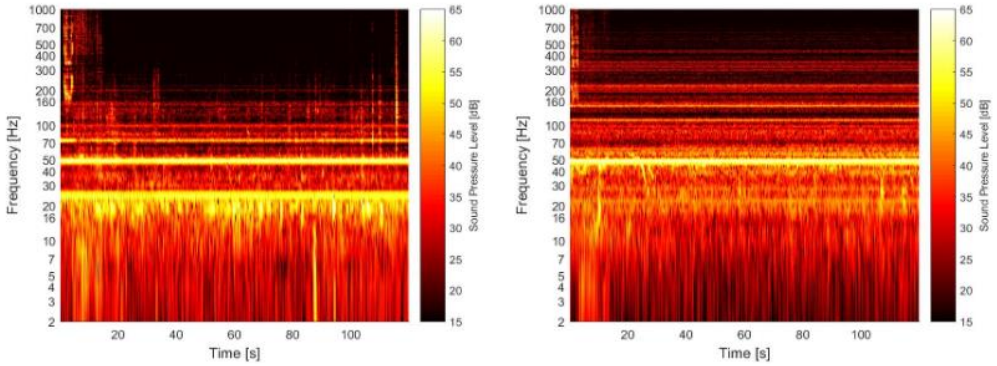

Figure 8. Left: Spectrogram of a recording in the hallway outside the apartment. Right: Spectrogram of a recording outside of the backdoor of the neighbouring restaurant (Pedersen et al., 2017).

It is observable that in both spectrograms the line of the frequency at around ~23 Hz is showing, but on the left one (the hallway outside of the apartment) it is significantly more prominent.

6.4.2. Heat pump case

In this case, a neighbouring heat pump is located close to the occupant's house, and the occupant made several recordings both indoors and outdoors (at the facade and at the property boundary). It is noted that because the noise is non-stationary, it was difficult to capture consistently. The indoor recordings did not show audible low-frequency noise; instead, they revealed some mid-frequency tones, confirming that the system can also detect mid-frequency components. When the occupant was presented with these results, it became clear that the main issue was outdoors, supported by multiple outdoor recordings showing a fundamental around 48 Hz that corresponds to the harmonic structure seen in the indoor data (Pedersen et al., 2017).

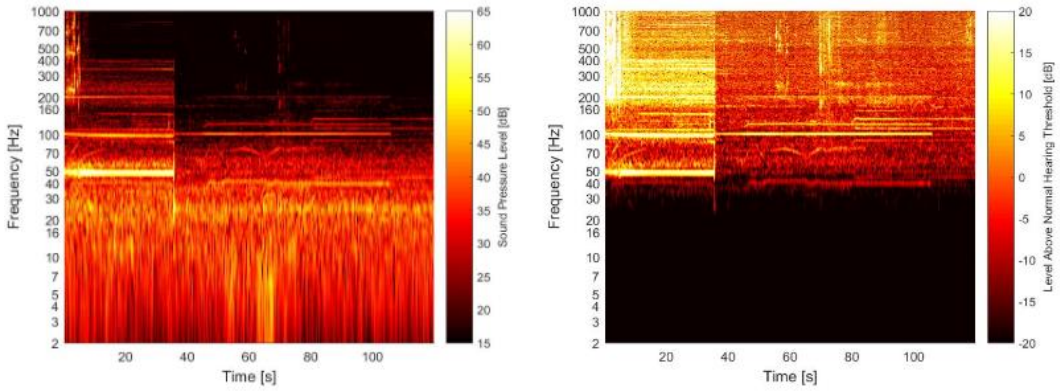

Figure 9. left: Spectrogram of an outdoor recording. Right: a threshold-weighted spectrogram of the same recording (Pedersen et al., 2017).

Again, the left, non-threshold-weighted, spectrogram is showing significant SPL levels of infrasound, which appear not to have a stable SPL through time, meaning that it may be a fast-pulsating sound,

which would align with the way of operating of these machines. There is, again, a faint, almost consistent with higher SPL, at around 23 Hz.

6.4.3. Wind turbine noise case

In this case, the occupant suspected nearby wind turbines as the source of low-frequency noise and therefore made recordings at different times and positions, including indoors, outdoors, and closer to the turbines. An indoor living-room recording shows a dominant tonal component around 68 Hz with higher harmonics that vary in level.

An outdoor recording taken about an hour later, roughly 190 m from the nearest turbine, contains the same tonal components, strengthening the source attribution. The time variation is consistent with wind turbine noise, since wind direction, wind speed profile, and turbulence change over time, and the findings are also in line with the official turbine measurement report, which reports a pronounced 68 Hz tone, especially at higher wind speeds.

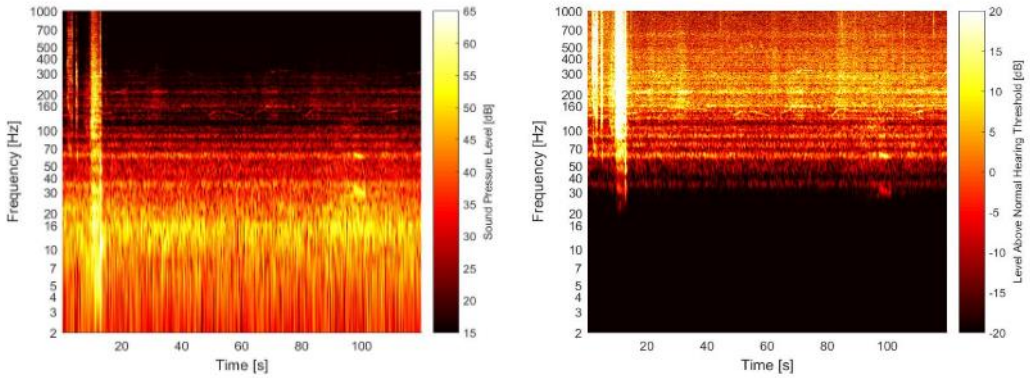

Figure 10. Left: Spectrogram of a recording in the living room. Right: a threshold-weighted spectrogram of the same recording, (Pedersen et al., 2017).

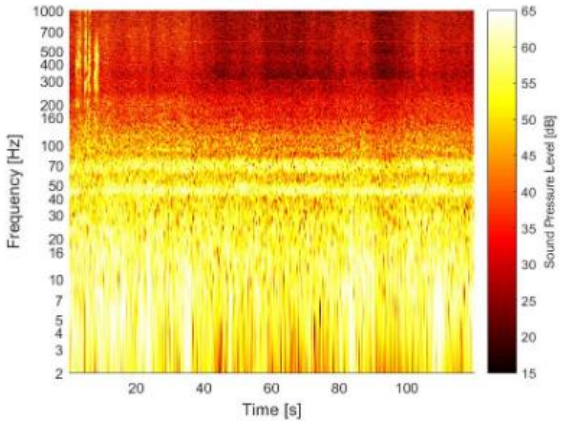

Figure 11. Spectrogram of an outdoor measurement 190 m from the nearest wind turbine (Pedersen et al., 2017).

The spectrogram in Figure 8 shows infrasound levels with an SPL value at around 35 dB, peaking at around 50 dB, especially around 8-17 Hz. Outside recording marks significantly high SPL level (around 55

dB), but the inside recording does not seem to peak at the same frequency, nor does the inside level peak at lower frequencies, which are up to 65 dB of SPL.

7. Furniture as a possible mitigator

Oliva et al (2006) modelled a simple rectangular room (6 × 4 × 2.5 m, ≈60 m³) to study how absorption panels and furniture influence the low-frequency sound field. In the reference case, the room was empty, and all boundaries were treated as perfectly reflecting (case 6a). A second case added three mineral-wool panels on the walls, and a third introduced typical furniture, with all items acoustically hard except for a porous wool sofa (case 6b). In the third case (6c), the room was excited by a small planar broadband source, chosen to minimise transmission-path effects and isolate how added absorption and furnishings reshape the indoor sound distribution. Below in Figure 12, cases 6a and 6c are depicted.

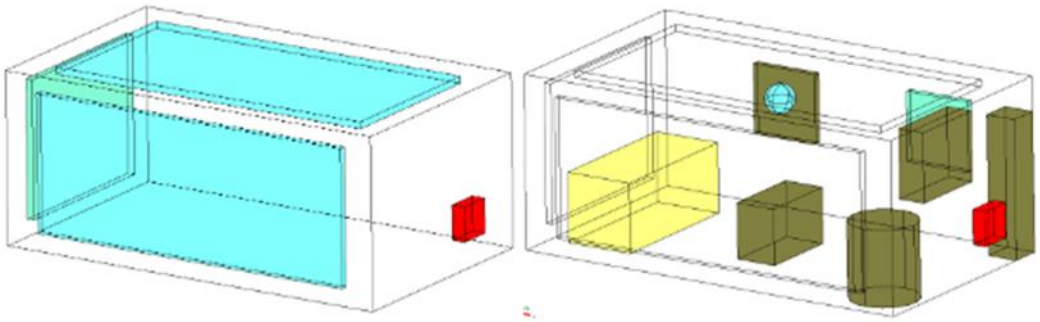

Figure 12. left: Case 6b (blue = absorbing panels; red = planar source). Right: Case 6c (green = furniture; yellow = sofa; panels not coloured) (Oliva et al., 2006).

In those models, two frequencies were played: a 50 Hz band and a 160 Hz band. At 50 Hz, the SPL distribution at 1.5 m height is presented for the empty room, Case 6A, and the furnished/absorptive room, Case 6C, in Figure 20. In the empty-room case, the spatial pattern is dominated by a clear modal structure. The authors identify a mode lmn = 010 around 49 Hz, and show that this modal behaviour is strongly disturbed once absorption and furniture are introduced.

The practical consequence is exactly what one would expect when a resonance is "broken": the maximum SPL decreases in Case 6C, primarily because overall absorption is higher and the resonance behaviour is less coherent. At the same time, the minimum SPL stays approximately the same.

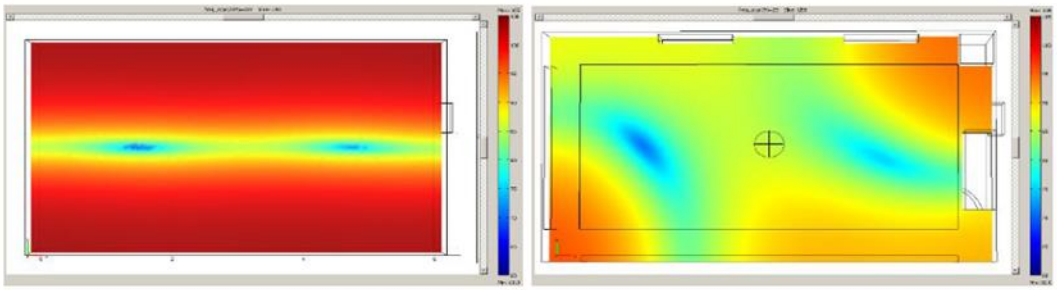

Figure 13. SPL at 1/3 octave 50 Hz. Left) Case 6A. Right) Case 6C. Both figures are at a height of 1.5 m. SPL scale is between 60 (blue) and 105 dB (red) (Oliva et al, 2006).

Using the modal relation, a 6 × 4 × 2.5 m room has first axial modes at approximately 28.6 Hz (length), 42.9 Hz (width), and 68.6 Hz (height). This places the 50 Hz band close to low-order modal behaviour, which is consistent with the strong spatial pattern observed in the empty-room case. This is evident from the figure 21 were undisturbed ~50 Hz component is near resonant, and may still experience noticeable reinforcement, due to proximity to the ideal theoretical modal resonant frequency. In this 6a case, the SPL peaks near the opposite walls at ~105 dB, and in the middle of the axis, it is ~75 dB.

In the case of 6c, it is evident that the furniture and fittings dampened the SPL levels to the range of ~75-85.

Although Oliva et al (2006) examined modes at 50 Hz rather than in the infrasonic band, their findings illustrate a general principle: adding furniture and limited porous absorption to an otherwise empty rectangular room reduced the strength and spatial contrast of low-frequency standing waves. By disturbing the coherence of the dominant mode, maximum sound pressure levels dropped by roughly 20–30 dB at some positions, while minima remained similar, making the room's response less "peaky". Given that room modes at slightly lower frequencies follow the same wave physics, this suggests that even ordinary furnishings can act as mild mitigators of low-frequency build-up, although dedicated low-frequency treatments would be required to affect true infrasound more substantially.

8. Discussion

The reviewed evidence demonstrates that infrasound is neither a purely paranormal curiosity nor a speculative military phenomenon, but a measurable acoustic factor that can interact with architectural space and human physiology. However, several limitations must be acknowledged before drawing architectural implications.

First, much of the empirical data originates from laboratory exposures or isolated case studies, where conditions differ substantially from everyday residential environments. Laboratory experiments often employ controlled intensities and frequencies, whereas domestic exposure is typically low-level, continuous, and embedded within complex noise spectra. This discrepancy cautions against direct transfer of laboratory findings to architectural practice without further validation.

Second, individual sensitivity to infrasound varies considerably. While ocular resonance at ~19 Hz or vestibular sensitivity at ~7 Hz has been documented, not all individuals exposed to these frequencies report perceptual anomalies. Psychological expectations, environmental co-factors, and personal susceptibility may modulate responses. This variability highlights the need for cautious interpretation and for design strategies that prioritize minimizing exposure rather than assuming uniform effects.

Third, contradictions among studies remain unresolved. Some research links infrasound to anxiety, stress markers, or cognitive modulation, while others report negligible or inconsistent outcomes. These discrepancies may reflect differences in measurement protocols, exposure levels, or analytical methods. Importantly, many residential complaints involve spectral content extending into the infrasonic range, yet conventional A-weighted measurements underrepresent or exclude these frequencies. This methodological blind spot contributes to interpretive fragmentation across acoustics, physiology, and architecture. The Coventry cellar is an example of where an environment could have influenced the perception of the space and the feelings of 'being haunted' that arose, which might have already been appearing from visual cues, rather than infrasound alone, which might have only been an amplifier. It is extremely important to take the whole environment into account while analysing such cases.

However, the documented effects of infrasound shall not be ignored or categorised as an overblown ghost story. With modern advances in technological appliances and infrastructure, the issue of infrasound is becoming more prevalent. It has been proven that infrasound does affect the body in various ways: subtly reshaping brain activity and connectivity, elevating stress hormones, increasing

irritability and negative appraisal, and elevating salivary cortisol, even when it is not consciously heard (Ascone et al., 2021, Forlim et al., 2024; Kasprzak, 2012, 2014; Scatterty et al., 2026; Stepanov et al., 2003; Weichenberger et al., 2015, 2017).

From an architectural perspective, the most relevant insight is that built space itself can act as a resonant system. Room modes, standing waves, and boundary conditions may amplify low-frequency components generated by household appliances or building services, producing localized "hot spots" of pressure and vibration. Such amplification does not require extreme intensities; even modest outputs from compressors or fans can become perceptually significant when reinforced by geometry. This recognition reframes infrasound as a spatial variable, instead of it being merely a technological by-product.

The cooling compressor case (Pedersen et al., 2017), the spectrogram shows clear amplification of the ~48 Hz frequency when the doors were closed, as the authors have claimed, assuming it happened due to reflections in the enclosed space. The outside of the backdoor of the neighboring restaurant recording showed the same dominant frequency (~48 Hz) and faint lines in the lower spectrum, including the ~23 Hz frequency. That implies that the ~23 Hz frequency was not dominant, but rather a part of the spectrum. What is interesting is that in the hallway outside of the apartment, as shown in Figure 6, the frequency is amplified up to ~55 dB.

The information about the dimensions of these apartments, or the hallway, is not presented, but if the geometry of the hallway is amplifying—resonating with—that specific frequency, it would be calculated with the already presented formula: $f = c/2L$, where L is the distance between two walls, c is the speed of sound, and f is the frequency.

If the speed of sound were taken as 334 m/s, at the temperature of 20 °C, the distance between two walls would, for the perfect resonance, have to be ~7,5 m. That length occurring is plausible, but unfortunately, the exact floor plans are not available, so this calculation is a speculation, not a fact. Furthermore, using the same formula, for amplification by resonance of the ~48 Hz frequency, one dimension of the room in which the sound was measured would need to be ~3,6 m, which is also a plausible occurrence.

The wind turbine case (Pedersen et al., 2017) shows, in the spectrogram recorded 190 m, away from the turbine (figure 7), a vast spectrum of soundwaves below 60 Hz, at high intensities, but the inside-of-the-apartment recorded spectrogram (figure 8, left) does not seem to have that same frequency spectrum as excited, but rather the ones between 10-16 Hz seem to be more prominent. Knowing that lower-frequency sound waves travel long distances and around obstacles without losing energy quickly, it is safe to assume that they have all arrived at the apartment with a similar SPL. That may imply natural enclosed space resonance amplifying, however, without available dimensions of the living room, it is impossible to conclude if the reason for the excitement of these specific frequencies is the room geometry.

The possible room dimensions remain speculations due to the lack of data; however, the spectrograms shed light on a broader problem—standard A-weighted measurements ignore a significant portion of inaudible soundwaves, which may affect humans through the body, avoiding the

Although the frequency analysed is clearly not infrasound and is audible, research by Oliva et al (2006) provides valuable insight into how low-frequency sound waves could be mitigated by furniture positioning.

Despite this still being an under-researched field, it is of utmost importance to continue research in this direction, since architecture itself should never be divided from the comfort of its users, and if it makes even a slight difference in the quality of their lives, it needs to be explored.

9. Sick Building Syndrome

Constant exposure to low-frequency and infrasonic components has been described as a background stressor, which must be coped with continuously and can therefore contribute to chronic stress symptoms when individuals cannot "switch off" the demand to cope (Benton & Leventhall, 1994; Leventhall et al., 2003; Gregorio et al., 2001). Frequency noise centred around ~7 Hz was identified in several investigated office rooms, and many occupants in those spaces reported symptoms commonly grouped under "sick building syndrome" (e.g., fatigue, headaches, nausea, dizziness, and concentration difficulties). Frequency noise centred around ~7 Hz was identified in several investigated office rooms, and many occupants in those spaces reported symptoms commonly grouped under "sick building syndrome" (e.g., fatigue, headaches, nausea, dizziness, and concentration difficulties).

10. Salutogenic Approach—Design Workflow

From a salutogenic architectural perspective, integrating infrasound awareness into the design workflow can be understood not as the creation of a separate specialist discipline, but as a structured extension of existing design and evaluation procedures aimed at supporting healthier and less stressful living environments. At the earliest concept and planning stage, potentially relevant low-frequency sources—such as compressors, heat pumps, split air-conditioning units, lift machinery, chillers and large ventilation fans—should be identified and, where possible, located at a distance from bedrooms, living rooms and other restorative dwelling spaces, with consideration of both airborne and structure-borne transmission paths. During spatial and structural design, the expected spectral content of such sources should be assessed using full-spectrum or Z-weighted data rather than A-weighted indices alone, so that low-frequency and infrasonic components are not excluded at the outset. On that basis, basic room-acoustic calculations, including room-mode and resonance analysis, can be applied to spaces most likely to be occupied for long durations, while simple three-dimensional modelling may help visualise potential low-frequency pressure maxima or spatial "hot spots." The resulting acoustic knowledge can then be fed back into the project through adjustments in room proportions, service placement, enclosure design, and the positioning of sensitive functions away from predicted zones of amplification. Finally, where complaints arise after occupation, post-occupancy evaluation should include measurements extending below 20 Hz alongside conventional audible-band assessment, so that infrasonic components and room-gain effects can be identified rather than remaining invisible within standard practice.

11. Conclusion

This review has demonstrated that infrasound, though inaudible to most occupants, represents a measurable environmental factor with potential implications for health, comfort, and perception in built spaces. Evidence from acoustics, physiology, and environmental psychology confirms that low frequency fields generated by everyday building services can interact with architectural geometry, producing localized resonance zones that overlap with human resonance ranges. While findings remain heterogeneous and individual sensitivity varies, the architectural significance lies in recognizing buildings as resonant systems that can unintentionally sustain infrasonic fields.

Measurements in occupied dwellings show that everyday sources such as HVAC systems, refrigerators, ventilation fans and distant wind turbines can, under specific spatial and structural conditions, generate localised "hot spots" where room modes amplify particular frequencies by tens of decibels. In these situations, architecture functions not as a neutral backdrop but as an active acoustic filter and amplifier, shaping how residents experience low-frequency sound. The point is not that household appliances are malicious or equivalent to acoustic weapons, but that overlooked interactions between mechanical systems and enclosure geometry can reproduce some of the perceptual patterns described in laboratory research.

These findings suggest that infrasound in buildings should be understood less as an isolated hazard and more as an amplifier within a broader sensory and psychological ecology. Achieving healthy rather than "sick" buildings therefore requires integrating low-frequency acoustics into design and diagnostic practice alongside light, thermal comfort and air quality. At the same time, the existence of therapeutic uses of low-frequency sound reinforces a broader ethical point: the same physical phenomena can support healing or harm, depending on context, control and exposure. Future work should combine detailed room-acoustic modelling, in-situ measurements and longitudinal occupant feedback to establish practical low-frequency design guidelines and to clarify when architectural interventions can meaningfully improve residents' quality of life.

By reframing infrasound as a spatial and environmental variable, this study contributes to salutogenic and evidence-based architecture. Practical implications include service placement and isolation, careful room proportioning, and the integration of low-frequency monitoring into post-occupancy evaluations. Limitations of current measurement practices, particularly reliance on A-weighted indices, highlight the need for more comprehensive standards below 20 Hz.

11.1. Further Investigations

This paper calls for further investigations to move beyond isolated case reports and controlled laboratory studies towards integrated, real-world assessments of infrasound in dwellings from an interdisciplinary perspective. Future work should ideally combine long-term low-frequency measurements in occupied homes with detailed information on room geometry, source characteristics and occupant experiences, including sleep quality, mood and stress markers. Experimental studies could systematically vary both frequency and temporal modulation of low-frequency fields at realistic levels, to clarify which patterns of exposure are most relevant for background stress and annoyance. Finally, closer collaboration between architects, acousticians, structural and mechanical engineers, psychologists and health researchers is needed to test how design decisions—such as room proportions, placement of compressor-based systems and furnishing strategies—alter the low-frequency sound field and whether targeted architectural interventions can measurably improve occupant well-being.

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Conflicts of Interest
The authors declare no conflict of interest.

Data Availability Statement
The study is based on previously published literature and case studies; no new experimental or survey data were collected. All sources used are cited in the reference list, and no additional datasets were generated or analysed.

Institutional Review Board Statement
This research did not involve new experiments on humans or animals, nor the collection of personal data, and, therefore, did not require approval by an institutional review board or ethics committee.

Contribution to the Field Statement
This paper argues that infrasound should be integrated into architectural thinking, rather than limiting acoustical relevance to A-weighted sound levels that privilege only the audible spectrum. It synthesizes

evidence from acoustics, physiology, and environmental psychology to show that household appliances and building services, both independently and in interaction with architectural geometry, generate a full spectrum of low-frequency sound waves, including components below the threshold of hearing. The paper analyses how these sources interact with architectural space and, coupled, affect dwellers. It explicitly calls for further research and encourages architects to embed infrasonic awareness into design workflows, standards, and post-occupancy evaluation.

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Dovecotes: From Rural Tradition to Modern Architectural Vision

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ABSTRACT

Dovecotes are among the most distinctive expressions of rural architecture in many European and non-European landscapes, precious evidence of the centuries-old intertwining of architecture, landscape and agricultural traditions. This proposal aims to investigate this architectural typology in the Euro-Mediterranean and Middle Eastern areas, in order to highlight its main characteristics, the materials used and the most common building types. The methodology adopted is based on the study of historical and literary sources, architectural and agricultural treatises, and pigeon protection regulations. The ultimate aim is to understand the role that these structures can still play in the contemporary world. Through the analysis of a number of contemporary projects inspired by dovecotes, the contribution prompts critical reflection on the potential contribution of these structures to the development of a vision of architecture in dialogue with the local ecosystem.

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1. Introduction

A dovecote is a typically rural agricultural structure used for raising pigeons, found in many regions both within and outside Europe. The presence of these structures in such diverse geographical contexts attests to the variety of functions and values they have served over the centuries: valuable economic resources within the agricultural system, defensive outposts for controlling the territory, and expressions of the owner's power and prestige.

Pigeon breeding, documented since ancient times, was, in fact, a fundamental component of the economic system in many regions because it ensured an abundant supply of meat with unique nutritional benefits and the production of palombino, an excellent fertilizer derived from pigeon droppings and used to improve soil fertility. For these reasons, ownership of a dovecote was among the feudal rights reserved for the aristocratic elite, a prerogative that remained unchanged over time.Peasants, on the other hand, were permitted to raise only a few dozen pigeons in small, makeshift

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enclosures set up inside stables, attics, and barns.

This paper aims to examine the architectural manifestations of this phenomenon in the Euro-Mediterranean and Middle Eastern contexts, proposing a classification of the main architectural types and comparing them to highlight recurring formal and structural elements as well as local specificities.

In an effort to reconstruct the typological evolution of these structures and to understand the design choices made, this study began with an analysis of both historical sources and treatises in the field (treatises on agriculture and architecture, with particular attention to the sections on vernacular architecture): from Varro and Columella in antiquity, to Pietro de' Crescenzi in the Middle Ages, up to Palladio, Tanara, and Viollet-le-Duc.

After a long period during which this model was widely adopted, beginning in the 19th century, the evolution of agricultural techniques, the advent of chemical fertilizers, and the abolition of feudal rights led to the gradual abandonment of these structures. Some have been lost, and many others remain in a state of neglect and disrepair, forgotten in the landscape.

Long considered obsolete structures, the recent proliferation of studies - especially at the local level - has contributed to a general reevaluation of these architectural assets. To date, however, there has been no wide-ranging study capable of analyzing the phenomenon in its entirety, across various regions. The aim of this paper is to fill this gap by first presenting an analysis of historical sources and scholarly treatises in the field and, finally, a classification of the main architectural typologies within the Euro-Mediterranean and Middle Eastern contexts, comparing them to highlight recurring formal and structural elements as well as local specificities.

2. The Dovecote in Architectural Treatises

The study of historical and literary sources is essential for a thorough understanding of the evolution of dovecote designs and the various functions to which these buildings were adapted according to the economic, social, and productive needs of each era.

The most significant accounts from the Roman world are found in Varro's De re rustica(116–27 B.C.). The scholar from Rieti provides a description of two types of dovecotes: a tower-like structure, built atop the roofs of dwellings, and another with a circular plan, constructed as a freestanding building capable of housing up to five thousand birds (Varro, 1846/trans. Canal).

> It is confined to a kind of building that some call a peristeona and others a peristerotropheion. Often, as many as 5,000 are kept in one of these places. Such buildings must be covered like a large dome; they must have only one narrow door and windows in the Carthaginian style—or wider ones with grilles on both the inside and outside—so that the entire space is well-lit and no snake or other harmful animal can enter. All the interior walls and vaults are plastered with crushed marble; this plaster is made as smooth as possible. The same is done externally around the windows to prevent mice or lizards from clinging to the "eyes" of the dovecote, for there is no animal more timid than the dove. For each pair of pigeons, round, thick "eyes" (nests) are arranged in orderly rows: there can be many such rows, starting from the floor all the way up to the vault. Each "eye" must be three palms wide internally in every direction, and its entrance must be such that the pigeon can enter and exit. Beneath each row of nests, small platforms two palms wide are attached to the walls; these serve as a vestibule where the pigeons can rest before entering the nests (Ghigi, 1950, pp. 257–259).

The same architectural solutions can be found in Lucius Columella's De re rustica (4–70 CE) and in the Opus agriculturae by Rutilius Palladius, an agronomist of the 4th–5th centuries CE. These authors do not provide further details but merely suggest the optimal layout of the rooms and emphasize hygiene and protection against predators.

During the Middle Ages, reconstructing a clear picture of the typological evolution of dovecotes proved to be a difficult and problematic task due to the scarcity of surviving documents. It is possible that pigeon breeding during these centuries continued using the structures and techniques developed in Roman times.

In the Italian countryside, the model of the rural tower-dovecote house became established—a multi-story structure designed to serve multiple functions: residence, defense, manure production, and tool storage.

The only medieval source on this subject comes from Pietro de' Crescenzi (1233–1321), who updated the Latin agronomic tradition with elements of feudal practice and offered practical advice for building a dovecote.

> Dovecotes can be built in two ways: either atop columns with walls made of timber, masonry, or rounded stones, or atop a tower with thick masonry walls, and each may have nests both inside and outside in holes. (De Crescenzi, 1805, pp. 156–157)

During the same period, the house-tower-dovecote type coexisted with single-purpose dovecote towers—found in some Cistercian grange complexes—and with defensive towers, located either inside or outside the walls of urban centers, whose top floor was used for raising pigeons.

Some references to dovecotes are found in municipal statutes, which at times reveal significant previously unknown details. The regulations were aimed at combating illegal hunting, preserving game, and ensuring its abundance. In some cases, this protection extended even to buildings used for breeding, partly because the term "dovecote" found in these archival documents is often very generic and refers to various types of structures.

For example, in certain documents from 1445, the Countess of Lecce, Maria d'Enghien, decreed "that no person shall dare to kill or hunt with a crossbow or bow the pigeons of a dovecote, nor capture said pigeons with traps or snares, unless they are the owner" (Muratore, 1991, p. 113).

Starting in the sixteenth century, sources become significantly more numerous and offer much richer information. The topic is given ample attention in both architectural treatises and agricultural literature, and the dovecote began to be increasingly identified with the isolated tower.

On the international scene, the Parisian physician and printer Charles Estienne, in Predium Rusticum, explains that these buildings are towers constructed above the facade of the villa's main structure and that, in France, ownership of such structures is the exclusive prerogative of feudal lords (Estienne, 1554).

The Spanish agronomist Alonso de Herrera describes a tower model "built like a house at the top of it" or "above pillars with wooden or stone columns" (Herrera, 1583). This latter type, raised on stilts, is particularly widespread in certain southern regions of France and in Catalonia, and provides insulation from moisture and greater protection from predators.

No less important are the references made by Italian Renaissance treatise writers. Andrea Palladio also addresses the topic of dovecotes, specifying: "The quarters for livestock, such as pigs, sheep, pigeons, poultry, and the like, should be arranged according to their qualities and natures, and in this regard, one must take into account the customs of different regions" (Magagnato & Marini, 1980, p. 145).

In Palladian villas—busy centers of agricultural production—dovecotes are positioned at the ends of or along the barchesse, that is, the side wings branching off from the central body.

This recommendation is echoed by Vincenzo Scamozzi, architect and intellectual heir to Palladio, who suggests placing dovecotes in a location set apart and secluded from the villa, in more isolated and quiet spots. Vincenzo Tanara, too, in his treatise L'economia del Cittadino in Villa, recommends situating the dovecote at a distance from the rest of the dwelling to preserve the tranquility of the surroundings (Tanara, 1651).

In this brief overview of sources related to dovecotes, it is finally worth mentioning Eugène Viollet-le-Duc, who devotes an extensive section to this topic in his Encyclopédie Médiévale. The French architect documents several surviving examples built during the 14th and 15th centuries and analyzes the main architectural differences between dovecotes in northern France and those found in the southern regions (Viollet-le-Duc, 1854).

3. Main Architectural Types of Dovecotes

In the area under consideration—the Euro-Mediterranean and Middle Eastern region—three main types of structures used for raising pigeons have been identified: rock-cut dovecotes, isolated tower dovecotes and those attached to or integrated into other buildings.

3.1. Rock-cut dovecotes

Even before the construction of specific structures for raising pigeons, natural cavities served as a primitive solution for spaces dedicated to this practice. By taking advantage of the ethology of this bird—which, in the wild, nests inside rocky crevices—humans have sought to recreate an environment as faithful as possible to its natural habitat. These cavities are generally found near a populated area or at the foot of a rocky slope. In many cases, they are located in the immediate vicinity of a watercourse, which ensures an independent water supply for the birds. The interior walls have been carved out to create niches for laying eggs, and appropriate functional measures have been taken for the collection of guano.

This type is widespread in various parts of the world and exhibits a wide range of variations depending on the geomorphological characteristics of each region. The rural area of Tuscia, in northern Lazio, Italy, is among the regions with the highest concentration of rock-cut dovecotes (fig. 1). These structures, carved into very friable tuff and often connected by tunnels, feature nearly square niches arranged in multiple rows (Grano & Di Giuseppe, 2022). The presence of this type of structure is also widely documented in another Italian region, Puglia, specifically in the provinces of Lecce and Taranto, as well as in the Matera area, where these structures were integrated into the daily life of rock-cut villages (Foschino & Paolicelli, 2019).

In Sicily, there are no documented cases in the literature of artificial cavities used exclusively for pigeon breeding. However, some recent studies have identified the presence of quadrangular or rectangular chambers distributed across multiple levels in the rock-cut environments of Calascibetta and Enna, in central Sicily, which, in terms of shape and size, are comparable to the niches of rock-cut dovecotes found in other areas of the Italian Peninsula (Bonanno & Cugno, 2022).

A region particularly rich in rock-cut structures is Cappadocia, in central Turkey, where the shape of the niches in some dovecotes bears striking similarities to those in Tuscia (fig. 1) (Bixio et al., 2023a). In this area, known worldwide for its extraordinary natural landforms, thousands of dovecotes (Güvercinlik) have been built into the characteristic tabular rock outcrops and soft tuff pinnacles.

These sites were excavated during the Byzantine period and later altered during the Seljuk and Ottoman eras, in an area of approximately 20,000 square kilometers of volcanic rock at an elevation of 1,000–1,500 meters above sea level (Bixio et al., 2023a).

Although they are still recognizable today by the openings along the walls of pinnacles and cliffs, a significant portion has now collapsed as a result of thermoclastic and erosive processes. The niches are shaped like round arches, stilted arches (or extended arches)or lunettes. Quadrangular niches—whether flat or with semicircular vaults—are also very common (Bixio et al., 2023b). In some cases, the entrances to the dovecotes are painted with depictions of animals, plants, human figures, geometric patterns, or are simply whitewashed. Local artists created these symbolic decorations using naturally derived colors, such as yaşa, and other plant-based pigments (Amirkhani et al., 2010).

In Maresha, Israel—a famous archaeological site that is now part of the Beit-Gruvin-Maresha National Park—there is also evidence of numerous underground dovecotes, which are conceptually very similar to those found in Turkey and date to the 3rd–2nd centuries B.C. (fig. 1).

In this area, pigeon breeding not only provided a supply of fresh meat for consumption but also ensured a supply for sacrifices at the Holy Temple in nearby Jerusalem. The National Park currently comprises 85 dovecote caves, with a total of 50,000–60,000 niches (quadrangular, trapezoidal, or triangular in shape), and it is possible that many more existed in the past.

Figure 1. On the left, an example of a rock-cut dovecote in Lazio (Italy). Source: https://www.iluoghidelsilenzio.it/grotta-delle-monache-vasanello-vt/; in the center, rock structures used for raising pigeons near the cultivated areas of Uçhisar, Nevşehir, Cappadocia (Source: A. Bixio et al., Rock-cut Dovecotes in Cappadocia: Elements in Comparison, Genoa 2023, p. 3); on the right, rock-cut dovecote at the archaeological site of Beit Guvrin–Maresha, a UNESCO World Heritage Site (Source: Wikimedia Commons)

3.1.1. Rock-cut dovecotes surmounted by a tower

A particularly rare variation of the first type consists of dovecotes divided into two distinct sections: an underground chamber, with niches carved into the rock, surmounted by a masonry structure, typically a tower. The most numerous examples of this hybrid type are documented in the vicinity of Gesi, in Central Anatolia, where the unique topography of the area necessitated the adoption of these mixed structures (Fig. 2) (Özen, 2012).

The underground section, with a square, rectangular, or circular floor plan, contains hundreds of carved niches of various sizes (Amirkhani et al., 2010). The towers (burç), built above the central space, are between 1.5 m and 4.5 m wide and sometimes reach a height of 4 meters. They are all constructed of cut stone or rubble stone. The opening at the top allows pigeons to enter and provides light and ventilation to the compartment below. The opening has a diameter ranging from 100 cm to 150 cm (İmamoğlu et al., 2005).

Figure 2. Pigeon coops in the vicinity of Gesi, Kayseri, Turkey. Source: Türkiye Kültür Portalı, Kayseri Provincial Directorate of Culture and Tourism, https://www.kulturportali.gov.tr/turkiye/kayseri/gezilecekyer/gesi-baglari-ve-guvercinlikler

The distinctive nature of this characteristic yet complex mixed system of the Gesi dovecotes is virtually unique within the broader context under consideration. A similar example can be found in the dovecote at Masseria Pinta, in the countryside around Otranto (Lecce, Italy). The underground section features a distinctive cruciform plan, and at the intersection of the arms—above a large central opening—there is a domed roof supported by a low drum and surmounted by a circular crenellated structure (Rossi, 2012, p. 162). The underground structure, discovered only in 1976, was most likely originally a Messapian settlement used for funerary purposes. In the 17th century, after part of the vault collapsed, a tower was built, which was also used for raising pigeons.

3.2. Isolated tower dovecotes

Tower-style dovecotes, standing alone in agricultural settings, are the most common architectural type among buildings used for raising pigeons. In line with the recommendations of ancient treatise writers, particular attention was paid to selecting the most suitable site to ensure easy access for the pigeons and to limit their exposure to predator attacks. For these reasons, dovecotes were built in open areas, on slopes, sheltered from strong winds, and, whenever possible, near water sources. The south-facing orientation allowed the sun to penetrate and warm the interior on colder days, thus ensuring a warm and dry environment, which is essential for the pigeons' health.

In Italy, this type of dovecote is found primarily in the Salento region, in the south of the country, where the practice became extremely widespread beginning in the 15th century. There are two types of designs: the more common circular plan and the quadrangular plan. The construction method is similar in both: the niches are carved into the thickness of the walls, making use of the empty space—about 22–25 cm—created by the staggered arrangement of the ashlars.

The openings face east in most cases; in a few instances, they face north or south, but never west. With the exception of a few examples from a later period, these structures are always open-air. The absence of a roof is a unique feature of Salento dovecotes, not found in any other context. This design ensured better ventilation of the structure and facilitated the pigeons' entry, though it also exposed them to attacks by predators. It is therefore possible that the presence of such predators in these areas was relatively scarce, to the point that a system of protection from above was not required.

Furthermore, there is little attention paid to the care and finishing of the interiors: there are no plastered sections, no protective systems for the nesting cavities, no specific measures for collecting bird droppings, and no perches for the birds.

The materials used are of local origin: tuff and Lecce stone, the latter used primarily for decorative elements. Finally, polychromatic effects are completely absent. The only chromatic variation is created by the alternation of stone blocks which, although made of the same material, often came from different quarries or from different layers of the same quarry. The decorative elements are concentrated at the top, along the cornices or above them, in the crowning elements. These come in numerous variations: from simple battlements, based on medieval curtain walls, to more elaborate battlements connected by an upper cornice or arranged in a stepped pattern, to simple spires, truncated pyramids, pointed arches, and arched structures, all the way to systems of spires and pinnacles topped by spheres or pointed elements (Rossi, 2012).

Although the freestanding tower dovecote is a phenomenon typical of the Salento region, other similar structures belonging to this typology can be found throughout the rest of Italy. This is the case, for example, with the dovecotes incorporated into the "villas of delight" along the coast of the Gulf of Naples, dating from the late 18th century and designed by renowned architects (such as Muzio Nauclerio and Luigi Vanvitelli). In this context, the dovecotes are conceived more as elements of decoration and prestige than for practical use, reflecting a desire for a spectacular and refined display (Robotti, 2009).

Figure 3. Dove towers in the province of Lecce, Italy. Source: Author's archive, 2025

In France, the wide variety of local laws governing pigeon ownership led to a varied distribution across the country. The significant presence of dovecotes in the southern regions, particularly in Provence, is due, for example, to the lack of specific building restrictions and the freedom granted to local residents to erect these structures as they pleased.

The marked dependence on wheat cultivation—a free source of sustenance for pigeons—explains the abundance of dovecotes in grain-growing regions: they are rare in Brittany, a very arid region; numerous in the fertile Normandy; relatively few in Central France; and found in large numbers in Languedoc and the Périgord. In the valleys and on the plateaus of Provence, where the fields were devoted to wheat cultivation, the number of dovecotes was very high. This varied geographical distribution is matched by a remarkable variety of architectural and decorative styles, with numerous regional variations.

The circular shape is the most common and best suited to accommodate the potence system, a rotating mechanism attached to a central shaft to which circular rotating ladders are hooked (Fig. 4). This particular system, developed in France and later adopted in England and Scotland, allowed the caretaker to easily reach all the nests in the dovecote (Levillain-Hubert, 2001). The largest structures have a diameter ranging from 8 to 10 meters and a height exceeding 8 meters. The quadrangular shape, very common in Provence, has a more understated appearance and is generally shorter in height. Some dovecotes have a polygonal floor plan, with a hexagonal or octagonal base, and are highly prized for their aesthetic appeal. The materials used for construction were sourced locally or nearby and were rarely imported from other regions. Stone was used either in its raw form or cut for arches and pillars. Wood (from oak, chestnut, beech, walnut and elm trees) was used for doors, window frames, and floors.

Some half-timbered dovecotes were filled using the torchis method, consisting of wood and a mixture of straw and clay, the latter highly valued for its thermal and acoustic properties. Pigeons entered through flight grilles, made of wood, plaster, stone or brick and set slightly back from the facade (Fig. 4). The holes take various shapes (round, diamond-shaped, star-shaped) for purely decorative purposes. In Provence, the grilles are often framed by glazed tiles in red, yellow, green, and blue (Chausserie-Laprée, 1983).

In some dovecotes, particularly in Normandy and Brittany, the nests are not carved directly into the walls; instead, nest boxes are inserted into the masonry. In Haute-Provence and neighboring regions, some nests consist of terracotta pots (toupines) stacked one on top of the other. Nests made of woven wicker baskets, hung on the wall with nails on wooden beams, are less common.

The exterior walls of many dovecotes are encircled, at various levels, by projecting brick or stone cornices—called randière—that run along the perimeter. These bands consist of a row of flat stones or small glazed tiles, secured with cement or iron rivets. In addition to their ornamental function, they served as a barrier against predators attempting to climb the walls.

To provide insulation from ground moisture and ensure greater protection from predators, many dovecotes were built on pillars, columns, and arches: veritable monuments, ranging from 10 to 12 meters in height (fig. 5). They are very common in the Midi-Pyrenees and Aquitaine and are supported by four, six, eight, or nine stone columns, topped with Doric capitals arranged upside down. Because of its characteristic shape, this element is called a "mushroom" or "hat" (Rossi, 2012). The floor plan is quadrangular, and in the most elaborate examples, hexagonal or octagonal in base. The upper quadrangular enclosure, known as the "aviary," is constructed of masonry (sandstone, brick or limestone) or wood. The infill consists of wattle and daub, rammed earth, or fired bricks.

Figure 4. On the left, a circular brick dovecote with a triple randière, topped by a lantern with a flight grille, Château Rouge, Haute-Garonne (France). Source: https://www.alaingillodes.fr/; in the center: various examples of flight grilles. Source: https://pigeonniers-et-colombiers-de-france.webador.fr/; on the right: a spiral staircase in the Villesavin dovecote, restored in 2019. Source: Wikimedia Commons

Arched dovecotes are supported by four pillars and feature a pyramidal roof, often crowned by a lantern. Among the main local variations, the mule's foot dovecote is very common in the Toulouse and Montauban areas and is therefore also known as the Toulouse-style dovecote. It is characterized by the distinctive shape of its roof, featuring two offset roofs (with a low pitch, stepped or with opposing slopes) that resemble the animal's foot.

In the Tarn region of Occitania, the Gaillacois-style dovecote is distinguished by its square floor plan and a very steep, four-sided pyramidal roof, known as the cow's tail style. Castrais-style dovecotes have a slate, bell-shaped roof resting on a wooden frame with holes for the pigeons to pass through. Finally, the Saint-Suplice or Albigeois style features an almost flat roof with four slopes.

Figure 5: Dovehouses on pilotis, France. Source: www.alaingillodes.fr

In England, the oldest dovecotes have a circular floor plan, very thick walls, a domed roof, and a small entrance door at ground level. They are most common in the central region of rural England, where

feudal control was strongest. Between the 15th and the mid-17th centuries, square and rectangular floor plans were predominant. Dovecotes built between the mid-17th century and the 19th century, on the other hand, have rectangular or octagonal floor plans (Beacham, 1990).

The roof design is determined by the floor plan: square or rectangular dovecotes have a pyramidal roof, while octagonal or circular dovecotes feature a domed or conical roof. In some regions, ingenious square-shaped variations can be found, with four- or six-sloped roofs. The birds entered through a turret on the roof, called a louver, or through openings in the walls (wall louvers) (McCann, 1991, p. 152).

The outer perimeter is encircled, at various heights, by a series of moldings known as rat-courses. Although interpreted as a deterrent against rats, these ledges were actually intended simply as resting places for the birds (McCann, 1991). Moreover, according to English historical sources, rats were not considered a threat to pigeons, at least until the mid-18th century. However, certain measures were adopted with the arrival, toward the end of the century, of a new species—Rattus norvegicus—which posed a real threat to dovecotes. It thus became customary to protect the central opening with a board or a tin grate and to position the niches several meters above the ground to shield the nests from possible intrusion by these predators. In some later-period dovecotes, which had thinner walls, it was difficult to carve niches deep into the masonry; therefore, a separate structure of nesting boxes was built using clay bricks, wood, or a combination of wood and stucco. Often, there are ledges (alighting ledges) beneath the rows of nests where pigeons could perch comfortably. In some structures, to increase the interior space for the birds, central pillars with niches or a partition wall—with nests on both sides—were introduced.

In England as well, some dovecotes were equipped with a potence system for cleaning the nests, to which one or two ladders were attached. In Scotland, the earliest doocots date back to the 16th century and are found mainly in the eastern part of the country, in the regions of Fife and East Lothian (IHBC). There are two main types:

- Beehive or tun-bellied: It has a circular plan, with tapered walls culminating in a flat-domed roof featuring a circular opening at the top (Fig. 6) (IHBC). This type is one of the oldest forms in Scotland and is also found in some examples in northern England.
- Lectern type: rectangular in shape, with a single-sloped roof facing south (Fig. 6). Typically, the interior is divided into several separate chambers. In stately settings, they are often decorated with engravings, coats of arms, or commemorative stones. This type became common from the late 16th century onward.

Beginning in the 17th century, when aesthetic considerations took precedence over practical ones, numerous towers were built with circular cross-sections or polygonal floor plans (hexagonal or octagonal). Almost all Scottish dovecotes were built with local stone and the number of nesting boxes ranges from about 500 in the smallest dovecotes to over 2,000 in the largest ones. The potence system, which appeared in England in the late 16th century, was not introduced in Scotland until the following century.

Figure 6. Left: A beehive-type dovecote (Source: https://www.findlatercastle.com/the-doocot/); Right: a lectern-type dovecote (Source: https://en.wikipedia.org/wiki/File:Doocot_in_Caiplie_-_geograph.org.uk_-_6087120.jpg)

Spanish palomares are simple, functional structures, typically circular in shape, with a few square or rectangular exceptions. Dovecotes with a polygonal floor plan are the rarest, but at the same time also the most striking. Some feature an inner courtyard.

Clay, in its two basic forms—rammed earth and adobe—was the primary building material because it was inexpensive and readily available. The use of stone, a rarer and more expensive material, was reserved for strictly structural purposes, such as for the foundation plinths, at the corners of the building, or in the renovation of openings, shutters and lintels. The use of brick was also rather limited and reserved for finishing overhanging eaves or certain decorative elements.

Nest boxes, carved into the clay, were built starting at a height of about 60 cm above the ground. The roofing solutions, inspired by rural civil architecture, vary: single-sloped or multi-sloped roofs, hipped roofs, or—in the absence of an interior patio—flat or stepped roofs. In all cases, the roof is covered with Arabic tiles.

To shield against the wind, some dovecotes are equipped with masonry windbreaks (guardiaventos), where decorative elements are often concentrated. Some tiles are interrupted at regular intervals by red brick pillars, and at these points, ceramic or stone-carved pinnacles are inserted.

Egyptian dovecotes, whose presence has been documented in local history since Ancient Egypt, have entirely unique characteristics (fig. 7). They are large conical towers, built with sun-dried mud bricks, consisting of multiple cylinders stacked on top of one another in four or more levels. Sometimes they have a cylindrical shape, tapering at the top, and are pierced by thin columns arranged in geometric patterns, often in a pyramidal layout (Robotti, 2009, p. 167).

In the Siwa Oasis, on the border with Libya, the presence of salt lakes—fed by underground aquifers—has made it possible to extract small, irregularly shaped blocks of salt mud, which are then cut into smaller bricks and molded using certain types of clay, such as tafla or tiin. This mixture, known as kershef, was the primary material used in the construction of dovecotes in this region and has become a distinctive feature of the area's architectural identity.

Numerous crosswise wooden poles allow the pigeons to perch before taking flight or to seek shelter from predators. The interior is designed with great care, and numerous nesting compartments create an ideal environment for thousands of pigeons to nest.

Figure 7. Examples of dovecotes in Egypt. Source: https://egyptianstreets.com/2022/04/24/dovecotes-a-signature-of-the-egyptian-landscape/

In the heart of the Aegean, the dovecotes of the Cyclades islands, known as peristeriònes (from the Greek word peristeri, meaning "dove"), feature unique decorative elements (Fig. 8). They are small structures with square, rectangular, or "L"-shaped floor plans, divided into two levels: the upper level (anoi) was intended for the pigeons, while the lower level (katoi) was used for agricultural activities. The building's orientation was designed with particular attention to the Meltemi, the strong north wind that blows through this area. In fact, the dovecotes are situated on sheltered slopes and, in some cases, feature projecting wall sections to protect the entrances from the wind. The exterior is, without a doubt, the most striking part. The facades display a vast array of decorative motifs, ranging from square, triangular, circular, fishbone, and wheel patterns to more elaborate designs such as cypress-triangle, wheel-triangle, or wheel-cypress patterns. This variety of decorations was achieved using slabs of schist, a local fissile rock. The roof is flat and made of clay. Small turrets are situated at the corners, featuring protruding slate slabs that made it easier for pigeons to land and served as scarecrows for crows (Grano, 2024).

Figure 8. Dovehouses in the Cyclades Islands, Greece. Sources: Wikimedia Commons

In southeastern Anatolia, in what is now the province of Diyarbakir, there are a significant number of dovecotes—called boranhane in the local dialect—that have a truly unique appearance (fig. 9). Before chemical fertilizers became widely available, local farmers used pigeon droppings to improve soil fertility and boost watermelon production—the region's flagship crop.

Various types can be observed: with one, two, three, four, or five compartments (lüle). The walls are built of sun-dried adobe bricks and are about four meters high. The roof has a flat surface formed by thin

branches resting on poplar beams placed against the walls, covered with a layer of clay and fine mud. The birds entered through small openings measuring 25x30 cm located in the walls facing sunlight or water sources (Bekleyen, 2009).

Wooden poles are attached to the interior walls at various heights (145–160 cm and 250–300 cm) to support baskets made of woven willow branches, where the pigeons rest or lay their eggs (Bekleyen, 2009, p. 455). A single-block dovecote contains about 200 baskets, while a three-compartment dovecote holds over 1,500 (Dasdag & Işik, 2011).

Iranian dovecotes (kabutar khÿneh or borj-e kabutar in Persian) are majestic and fascinating structures (fig. 9). In past centuries, they captured the attention of numerous European travelers, who documented them in their travel journals. Although there are examples dating back to the 10th century, it was between the 16th and 18th centuries that these structures underwent significant development.

During the Safavid period (1501–1736), agriculture remained the cornerstone of the empire's economy. The key to this success was the use of fertilizers, and dovecotes played a decisive role. The geographical and climatic conditions of Isfahan Province proved, in fact, to be ideal for the breeding and rearing of pigeons. The temperate climate, low humidity levels, and abundant availability of farmland and water resources—the Zayandeh River in the Isfahan Plain makes this region the most water-rich in central Iran—created a comfortable environment for these birds.

Ownership of a dovecote was not subject to explicit restrictions, but the high costs of construction and maintenance were affordable only to wealthy individuals, typically Muslims. The only requirement was the mandatory payment of a dung tax (Sarrami, 2024).

The dovecotes of Isfahan are predominantly circular in plan and range in height from 11 to 16 meters. In the Khunsar-Gulpayagan area, northwest of Isfahan, the towers are rectangular in shape, resembling small fortresses. Some have a polygonal plan with 8, 10, or 12 sides and a height of about 10 meters. They are built of mud bricks (adobe) that are plastered and mixed with straw. Each tower consists of an outer drum—lobed, flared, and reinforced internally—supported on the sides by a second, smaller inner drum that extends to half the tower's height.

The niches are evenly distributed along the interior walls; they have a cubic cross-section and vary in size: 20x20x27 cm, 30x25x20 cm, or 20x25x30 cm (El Gemaiey, 2016). The perforated domes at the top provide light to the interior, allow for air circulation, and serve as the only point of entry for pigeons. Their shape resembles that of a pepper shaker, hence the name "pepper pot." The vaults and domes, with their alternating solid and hollow sections, are often embellished with muqarnas decorative elements, typical of Islamic tradition.

The exterior, clad in pisè, is often surrounded by a band of smooth plaster (gach), colored with lime or red ochre, which was intended to deter reptiles (Sarrami, 2024, p. 109). Some structures were also decorated with poetic inscriptions and pictorial motifs.

Figure 9. Left: dovecote near the village of Şükürlü, Turkey, (source: Bekleyen, A.,2009, "The Dovecotes of Diyarbakır: the Surviving Examples of a Fading Tradition," The Journal of Architecture, 14(4), p. 457); right: dovecote towers around Isfahan, Iran, (source: Rosati, D., & Saeidi Anaraki, F. (2018). Borj-e Kabotar: Architecture and Anthropology of the Pigeon Towers in Isfahan Province https://borjekabotar.com/)

3.3. Pigeon coops attached to agricultural, residential, or multifunctional buildings

Another type identified does not involve dovecotes as standalone structures, but rather as an integral part of agricultural-residential complexes or multifunctional buildings. Whether located on upper floors, attached to farmhouses, incorporated into monastic complexes, situated at the front of a church, or in a room above the presbytery, each case confirms the extreme versatility of these structures, which are capable of meeting diverse needs and adapting to the functional and architectural characteristics of the complex.

In central Italy, for example, the tower-house-dovecote combines defensive and residential functions, with spaces dedicated to agricultural work, tool storage, and pigeon breeding. It is a building with a quadrangular floor plan, characterized by a predominantly vertical design and organized across multiple stories. Its height allowed for surveillance of the valleys and the signaling of potential threats. The width of the floor plan is almost always constant: 6 or 7 meters per side; this measurement is replicated in the diameter of circular structures. The ground floor served as a tool storage area or was reserved for livestock. The middle floor was used for residential purposes, and the attic was intended for raising birds (Volpe, 1981).

The Marche-style structure is always built of masonry, using locally sourced materials (stone, river pebbles and brick), and rises directly from the ground. The roof comes in several variations: single-pitched (very rare), double-pitched or hipped (Volpe, 1982).

In the Umbrian examples, the architectural elements do not strictly belong to rural construction, but rather draw on the style of military towers and urban residences, creating a unique and functional blend. The craftsmen entrusted with the work are, in fact, the same. The dovecote serves as the dividing element between the residential and livestock areas. It is constructed from simple stone slabs set into the wall or from bricks of various sizes.

"Eyes"—access holes for the pigeons—are cut into the exterior walls. Specific measures were taken to prevent the intrusion of other animals: inverted terracotta pots, with the opening facing downward, or smooth-surfaced iron corner brackets were placed at the corners of the building (Sperandio, 1991).

In France, several types of pigeon lofts can be distinguished that are attached to or integrated into a building:

- The portico-style dovecote (pigeonniers porche): quadrangular in shape, built into the entrance portico, within the perimeter wall, of larger farms (fig. 10).
- The balèt dovecote (from the Occitan word balèt, meaning canopy, balcony, or veranda) is a characteristic architectural type of southwestern France, especially in the Quercy region. The term balèt denotes the external timber gallery, supported by wooden posts, which protects the entrance to the dwelling and provides access to the dovecote located on the upper floor.
- Tower-style dovecotes, either single or in pairs, are located on the facade or at the corners of the house (fig. 10). They are small in size and can accommodate only a few dozen nests (Chausserie-Laprée, 1983).

Across the Channel as well, there are dovecotes built into the walls of farm buildings or attached to the main body of the house. Starting in the 18th century, restrictions on keeping pigeons were relaxed, and small enclosures were created inside stables and barns.

A structure designed for multiple functions, in which the upper level was reserved for pigeons, was known as a "pigeon tower." When the pigeon chamber was built on the roof of another building, it was called a "pigeon loft" (McCann, 1991).

In Scotland, beginning in the 19th century, many dovecotes were built to be incorporated into farms or the gables of country houses (fig. 10). Access to the chamber was through hatches located on the floor or walls. In several cases, housing for pigeons was created in parts of a church, such as the bell tower.

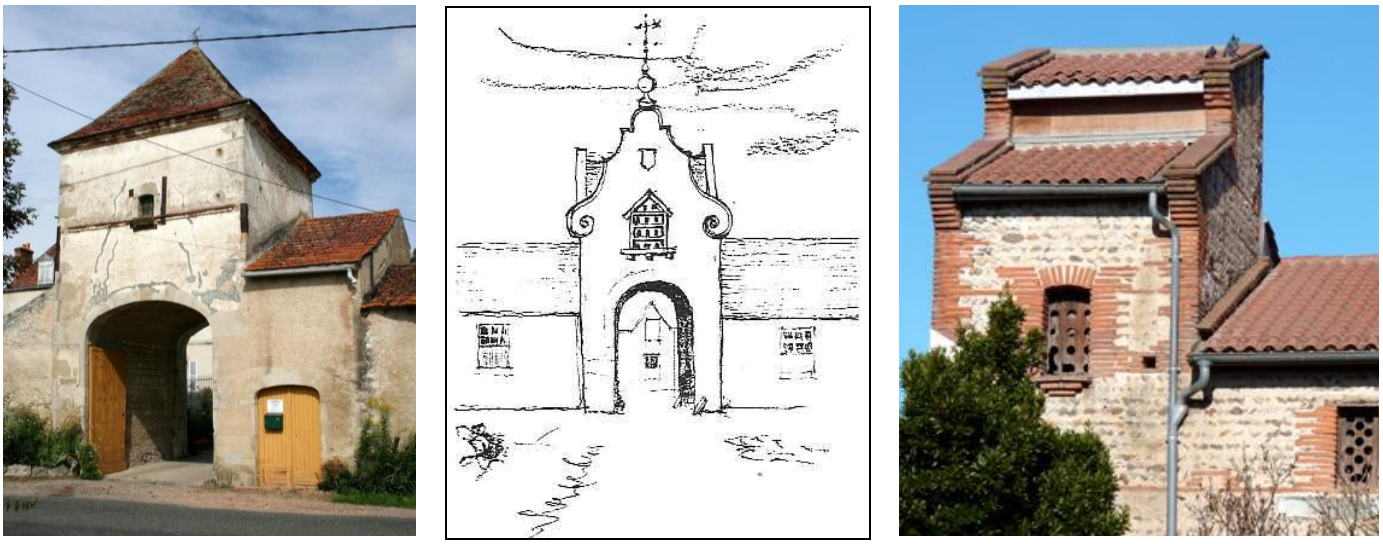

Figure 10. Portico-style dovecote, on the left, France (source: pigeonniers-et-colombiers-de-france.webador.fr); center: Edrom, Scottish Borders, a 19th-century dovecote above the entrance arch of a farmhouse, Scotland, source: Institute of Historic Building Conservation (IHBC), Doocots in Scotland, https://web.archive.org/web/20150924033320/http://www.ihbc.org.uk/context_archive/57/doocots/scotland.html; right: a tower-style dovecote with a "mule's foot" base at the corner of a house, France (source: www.alaingillodes.fr)

3.4. Comparative analysis

The research identified three main architectural types of structures designed for pigeon breeding, from which certain characteristic features and the major differences between the analyzed geographic areas can be identified.

The construction of rock-cut dovecotes was most common in areas where the geomorphological characteristics of the terrain were ideal for excavating artificial cavities, such as Cappadocia, Israel, and certain distinctive regions of Italy (the rural area of Tuscia and southern Italy). These structures have sometimes been misinterpreted, partly due to the hybrid meaning of the Latin term colombarium, which refers both to rock-cut dovecotes and to underground collective burial chambers characterized by small niches (similar to those in a dovecote) that contained urns with the ashes of the deceased. Over time, these spaces have also been used as stables, granaries, storage areas, water cisterns, and above all as olive oil mills.

However, the most common architectural type is the tower-style dovecote, which stands separate from the building complex to which it belongs. While in the Euro-Mediterranean context the floor plans adopted are very simple and usually circular or quadrangular in shape (more complex polygonal plans belong to more recent periods), in the Middle Eastern context, on the other hand, there is a tendency toward truncated conical shapes and multi-level designs, with cylindrical volumes that are either stacked or adjacent. The same difference is evident in terms of decoration. In the Mediterranean region, the construction is sober and very simple (only the date of construction or the owners' coats of arms are visible on the exterior walls), unlike Egyptian and Iranian dovecotes, which are characterized by a rich repertoire of decorative solutions featuring geometric motifs. The distinctive dovecotes of the Cyclades islands, among the most elaborately decorated, are an exception to this rule.

In all the regions under consideration, the materials used are locally sourced, readily available and affordable. A defining feature is the presence of a projecting cornice made of brick or stone, positioned at various heights. Whether single or multiple, with a rectangular, toric, or complex, curvilinear cross-section, it encircles the tower along its entire circumference or is interrupted at several points. In addition to protecting the facade from rain, it served as a deterrent to animals attempting to climb the walls to reach the interior.

Roofing systems vary widely and are largely determined by the basic floor plan. Circular dovecotes are, in most cases, topped by a dome. Dovecotes with a quadrangular base, on the other hand, feature a flat roof, a stepped roof, a single- or double-pitched roof, or a roof with a variable number of slopes. The open-air dovecotes of Salento are a unique and exceptional case.

The interior was designed specifically to provide a comfortable environment for the birds. In most cases, the walls were left unfinished, and niches were carved out of the wall thickness, making use of the empty space created by the staggered arrangement of the masonry units.

The potence system for the periodic cleaning of nests is common in the Anglo-French region, but has not been found in other regions, where wooden ladders, resting directly against the walls, were likely used instead.

The final category examined includes dovecotes that are not architecturally independent structures but are integrated into manor houses, rural complexes, churches, or castles. The variety of examples in this category attests to the importance attributed to pigeon breeding, to the point of incorporating these structures into pre-existing agricultural, residential, or multifunctional complexes.

For greater clarity, Tables 1 and 2 provide a summary of the main characteristics of each type.

Table 1. Rock-cut dovecotes. Source: Authors'elaboration

Territory	Location	Geomorphological context	Dating	Niches	Characteristic features
Italy	Northern Lazio (Tuscia); Apulia, Basilicata, Sicily	Rooms carved out of very crumbly tuff	Varies by region	Typically quadrangular in shape, arranged on multiple levels	Spaces often connected by passageways
Turkey	Cappadocia, Central Turkey	Cavities formed in the characteristic tabular rock outcrops and soft tuff pinnacles	Byzantine origin, with subsequent alterations during the Seljuk and Ottoman periods	Round-arched, raised-arched, lunette-shaped, quadrangular, flat, or half-barrel vaulted	Symbolic decorations made with natural pigments at the entrance to some dovecotes
Israel	A prime example at the Beit-Gruvin-Maresha site	Underground dovecotes carved into the rock	3rd–2nd centuries B.C.	Thousands of regular niches on the walls, typically rectangular, trapezoidal, or triangular in shape	Subsequent repurposing of these spaces as stables, barns, warehouses and underground oil mills

Table 2. Isolated dovecote towers and dovecotes attached to other buildings. Source: Authors'elaboration

Region	Type	Floor Plan	Material	Coverage	Roofing Material	Openings for pigeons	Nests	Decorations	Distinctive Features
Salento	Isolated Dovecote Tower	Circular (most common); quadrangular, octagonal or supported by arches (more recent)	Tuff, Lecce stone	Absent	-	Access from above is made possible by the absence of roofing	Created in the masonry by the staggered arrangement of the blocks	No decorations or polychromatic effects	Outer intermediate frame, decorated cornices, base plinth
France	Isolated Dovecote Tower; dovehouses attached to other buildings	Circular (most common), quadrangular, polygonal, on *pilotis* or arches, portico-style, turret-style or bâlet-style	Stone (rough or cut), wood, earth, clay	Conical roof; single- or double-pitched; with 1, 2, 4, 6, or 8 slopes; domed; stepped; "mule's foot"	Slate, straw, flat or interlocking roof tiles, granite, wood	Perforated flight grids (made of wood, plaster, brick or stone)	Hollows in the masonry; nesting boxes; wicker baskets; *toupines*	Limited and varying by region	*Randière*, decorated cornices, pinnacles, lanterns, *potence*
England	Isolated Dovecote Tower; dovehouses attached to other buildings	Circular (75% of cases), quadrangular, octagonal	Local stone and bricks	Dome-shaped; with a conical roof; pyramidal; with 4 or 6 slopes	Slate, stone, straw, wood	*Louver* or *wall louver*	Recessed into the masonry; nest boxes	Generally understated appearance	*Rat-courses, potence, alighting-ledges*, central pillars with internal cavities, partition wall
Scotland	Isolated Dovecote Tower; dovehouses attached to other buildings	Beehive-type, lectern type-circular, polygonal	Local stone	Flat dome; single-sloped roof	Slate, Local stone	An opening in the roof; beneath the sloped roof or side openings in the walls	Dig into the masonry; wooden nest boxes	In stately estates, often decorated with engravings, coats of arms, or decorative stones	*Rat-courses, potence*, interior walls that are unfinished or finished with paint or plaster
Spain	Isolated Dovecote Tower	Circular, square, rectangular, polygonal; with or without an interior patio	Compacted earth and adobe. Stone and brick for certain elements	Single- or multi-sloped; hipped; flat or stepped roof	Arabic roof tiles, flat roof tiles	Made in the roof planes (slits below the gutter)	Dug into fresh clay; adobe brick nest boxes	Extremely simple and unadorned. Few examples feature elaborate decorations.	Masonry windbreaks (tapial or adobe)
Egypt	Isolated Dovecote Tower	Conical towers consisting of several stacked cylinders; cylindrical in shape, tapering at the top	Mud bricks; *kershef*	Conical summit	Mud bricks; *kershef*	Openings in exterior walls	Dig into the masonry	Geometric decorations	Thin, cylindrical, transverse logs arranged in geometric patterns
Greece (Cyclades)	Isolated Dovecote Tower	With a square, rectangular, or "L"-shaped floor plan, consisting of 1 or 2 stories	Local slate. Slate slabs for decorative purposes	Flat roof	Clay	Small holes in the facades sheltered from the wind	Openings in the masonry	A wide variety of geometric designs	Small towers placed at the corners to help birds land
Diyarbakir (Turkey)	Isolated Dovecote Tower	With one, two, three, four, or five compartments (lüle)	Sun-dried adobe bricks	Flat roof	Thin branches, resting on poplar beams, covered with a layer of clay and mud up to	Openings in walls facing the sun	Baskets made from willow branches and hung from wooden poles	Limited or absent	Internal support pillars to provide greater stability to the structure
Iran	Isolated Dovecote Tower	Circular, square or polygonal	Mud bricks (adobe), often mixed with straw	Dome-shaped	Mud bricks (adobe)	Openwork domes on top	Openings in the masonry	Decorative paint on exterior walls	Central band of smooth plaster (*gach*), *muqarnas* elements in the domes

4. What does the future hold for dovecotes? Contemporary projects

Recognizing these structures—long considered obsolete and belonging to an architectural culture deemed "minor"—as among the most distinctive expressions of rural architectural heritage requires careful reflection on the challenges associated with preserving these assets and on the strategies for their enhancement. To date, many dovecotes—particularly those belonging to major rural complexes or public parks—have undergone significant restoration work and been converted for new uses: lodging facilities, luxury residences, agritourism properties, or public spaces for meetings and cultural activities.

A substantial number of "minor" dovecotes, scattered throughout the most remote countryside, have, however, been excluded from restoration efforts and left to deteriorate inexorably over time. Many have collapsed and others remain in a state of neglect and disrepair.

In this sense, surveys, censuses and mapping efforts using new technologies have proven to be essential resources for bringing attention and visibility back to even the most marginal structures, saving them from oblivion. The protection of this heritage goes beyond mere—albeit complex—physical conservation; it is of strategic importance for reflecting on current human practices. Far more than mere reminders of the past, dovecotes are, in fact, living entities that continue to exert an enchanting charm. As silent guardians of the centuries-old intertwining of architecture, landscape, and agricultural traditions, they prove to be valuable tools for rethinking our present in terms of sustainability and the balance between humanity and nature. The inexhaustible vitality of these structures is confirmed by a series of contemporary projects inspired by traditional dovecotes or the figure of the dove.

A prime example is the Nativity Façade of the Sagrada Familia, brought to life by doves carved in stone and perfectly integrated into the architectural composition. Gaudí weaves into the stone the intricate narrative of the harmony of life and nature as a divine creation, in which the doves symbolize peace and spiritual elevation.

From a decorative and symbolic element, this bird becomes, in itself, a natural element that can be integrated into architecture. In The City of Tomorrow and Its Planning, Le Corbusier describes the scene of St. Mark's Square teeming with pigeons (Le Corbusier, 1929).

> "The uniformity of the countless windows on this vast wall facing St. Mark's Square creates the same visual effect as the smooth surface of a room. The repetition of the same unit lends the wall a boundless yet readily appreciable grandeur; the result is a clear and simple archetype. The pigeons of St. Mark's add their own uniform pattern, providing a varied and effective touch to the composition." (Le Corbusier, 1929, p. 69)

In contrast, Salvador Dalí's unusual dovecote at his eccentric residence in Port Lligat, in the province of Girona—a labyrinthine structure furnished with extravagant furniture and objects (fig. 11)—takes on a symbolic dimension, bordering on the dreamlike. In the outer courtyard, a huge stone egg sits atop a white dovecote whose wall openings, on days when the tramontana wind blows, produce a sound resembling a howl. The Spanish artist's home-studio is considered, to all intents and purposes, a true biological structure, a living architecture in harmonious relationship with the picturesque landscape of the Catalan coast.

Figure 11. Pigeon coop at Dalí's cottage in Port Lligat, left, (source: Soul Studio, "Casa Dalí – Coco Capitán"); Capsule, a project by Matali Crasset, Caudry, France, 2003 (center) (source: https://www.matalicrasset.com/en/project/capsule-caudry); Dovecote Studio – Haworth Tompkins, right (source: Cilento, K. ,2010, Dovecote Studio / Haworth Tompkins. ArchDaily. https://www.archdaily.com/89980/dovecote-studio-haworth-tompkins)

O Pombal, the monument erected in 1960 by architect Oscar Niemeyer in the Brazilian capital, also has profound symbolic significance. The monument, shaped like an obelisk, features several openings designed for pigeons to perch on. The name of the work is a play on words that refers both to the Portuguese term "os pombos" (pigeons) and to Minister Marquis of Pombal, a historical figure associated with colonial reforms in Brazil. The dovecote, in this case, serves no productive purpose. The pigeons symbolize a people free from labor: they are not exploited for their eggs or meat, but gather for the sole pleasure of flight (Gissen, 2009).

The Lampione Ravello project by Italian architect and designer Filippo Alison—commissioned in the early 2000s by the town of Ravello, in the province of Salerno—is part of an approach aimed at fostering a harmonious coexistence between the urban landscape and these birds, which are now largely regarded as pests in city squares. The streetlights were conceived as delicate structures with plump bronze pigeons perched on their arms, in the act of taking flight (De Iuliis, 2021). From a simple and functional element of urban furniture, the streetlight becomes an urban sculpture, engaging in a dialogue with the surrounding landscape, populated by flocks of real pigeons.

Alongside these interpretations, however, some projects revive the dovecote's original function—that of raising pigeons. Capsule, by designer Matali Crasset, is, for example, a prototype of a contemporary dovecote designed to pass on the centuries-old practice of pigeon-keeping to new generations (fig. 11). The work, inaugurated in 2003 in Caudry, in northern France, was commissioned by the Beauvios Pigeon Fanciers' Association. The structure, painted a bright yellow, resembles a capsule, modeled after the dovecotes of ancient Egypt. The interior evokes the shape of a tree—a natural resting place for these birds—and is designed to collect guano, which local farmers use as fertilizer (Crasset, 2003).

Figure 12. Pigeon Tower on Dam Square—Arne Hendrik's imagined pigeon tower standing on Dam Square, rendering by Dominik Einfalt and Andy Cartier (left), source: https://www.mediamatic.net/en/page/379633/mycelium-pigeon-towers; Pigeon Tower, Venice Architecture Biennale, Italy, 2021 (center), source: https://www.studio-ossidiana.com/pigeon-tower-la-biennale-di-venezia; Mourning Dovecote by Schwartz and Architecture, Sonoma, California, United States (right), source: https://www.archdaily.com/1026709/a-mourning-dovecote-schwartz-and-architecture

One example of a conversion is The Dovecote Studio, a project by the London-based firm Haworth Tompkins (fig. 11). Set within the ruins of a Victorian dovecote and clad in Corten steel, the new studio—built on site—was designed as a space for contemporary performances and exhibitions. Out of respect for the existing building, the intervention was limited to the bare minimum, and even the vegetation growing on the dovecote was preserved. (Cilento, 2010).

The experiments by artist Arne Hendrinks, which use mycelium as a building material for modern pigeon towers, represent a more innovative approach. Beginning in the summer of 2020, blocks of live mycelium—derived from oyster mushroom cultivation waste—were used to create spaces where Amsterdam's pigeons have found shelter to nest (Fig. 12). These towers are not meant to last forever but are merely part of the mycelium's life cycle. After about a year, the organic material decomposes,

leaving behind only fertile soil enriched by the guano deposited by the pigeons, which is then distributed to local farms and urban gardens, where the cycle begins anew. These structures are, by their very nature, living architectures and represent only one phase of this life cycle. As the mushrooms sprout, mature, and decompose, the towers shrink, bending under their own weight until they collapse. At the same time, the Mycelium Pigeon Towers bear witness to the relentless search for new forms of coexistence with these birds in urban environments (Mediamatic, 2020).

In the same vein, Studio Ossidiana's Pigeon Tower, presented at the 2021 Venice Biennale, explores the relationship between humans and birds as it addresses the exhibition's central theme "How will we live together?" (fig. 12). In the Giardino delle Vergini, the dovecote tower with its metallic feathers becomes an urban refuge for pigeons and other bird species, offering them shelter from the elements and predators. The structure's form is inspired by the bell towers that rise above the lagoon city (Studio Ossidiana, 2021).

Among the most recent projects inspired by traditional rural dovecotes is the Mourning Dovecote by Schwartz and Architecture (fig. 12). Nestled in nature, the home of the owner-architect in Sonoma, California, incorporates twelve artificial nests into its exterior facade, modeled after the typical niches found on farms or in barns. Particular attention was paid to the orientation, proportions, and ventilation best suited to encourage nesting by mourning doves. This species, widespread in North America and belonging to the Columbidae family, owes its name to its characteristic call, which resembles a funeral dirge. A window on the lower level allows visitors to observe the birds as they feed and to hear their sweet call. The roof, constructed of sheet metal, takes on a distinctive "feather-like" shape. The project, built entirely with sustainable materials, aims to promote coexistence between humans and the natural environment, fostering a respectful and balanced relationship (ArchDaily, 2025).

5. Conclusion

The research has shown that architectural analysis alone is not sufficient to fully understand the value of a dovecote. The study of the architectural typologies presented confirms both the close connection between dovecotes and the local territory and the decisive impact - on design choices - of climatic, environmental, and agricultural factors.

For these reasons, the approach to the research was oriented toward a comparative method involving multiple cross-cutting factors:

- The combined analysis of architectural treatises and agronomic literature;
- The parallel analysis of the various design choices made across multiple geographical contexts examined:
    - Euro-Mediterranean context: Central and Southern Italy; Israel; Turkey; Greece; Spain; England and Scotland; France; Egypt;
    - Middle Eastern context: Iran.

The literature has shown that it is not possible to identify a single, well-defined model of a dovecote that can be attributed to a specific historical period. Every era, from the Roman period onward, has been familiar with and experimented with the main construction models.

With the exception of structures in the Middle East - which exhibit specific construction characteristics related to both the materials and the architectural forms used - a survey of the main design solutions adopted in the Mediterranean context has made it possible to identify a common architectural language (albeit with minor local variations and the use of different materials depending on the area), in which the tower-style dovecote - conceived as an architecturally autonomous building - is the most widespread type of structure.

The digression on the contemporary reception of this phenomenon - included at the end of this article - aims precisely to highlight how current and spontaneous the recognition of these structures is as among the most emblematic and identity-defining expressions of vernacular architecture, capable of suggesting new ways of conceiving architecture based on a renewed relationship between humans and nature.

Following this initial phase of systematic study of the territory, future research prospects call for continuing along this path of comparison to further clarify the link between design choices, architectural form and aspects that lie outside architecture but are firmly intertwined with it (climate, agricultural economy, biodiversity, local traditions)—both to provide a comprehensive picture of these complex structures, precious gems of rural architectural heritage, and to conceive and design strategies aimed at their effective adaptive reuse and contextual enhancement within the broader framework of the cultural landscape.

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The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

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Studies involving animal subjects: No animal studies are presented in this manuscript.

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The author declares no conflict of interest.

Contribution to the Field Statement
This manuscript examines the phenomenon of dovecotes—typically rural agricultural structures used for raising pigeons—in the Euro-Mediterranean and Middle Eastern contexts. The research is conceived as a wide-ranging study that, starting from an analysis of historical sources and scholarly treatises in the field, aims to understand the phenomenon in its entirety and, to that purpose, proposes a classification of the main architectural types identified. The discussion of the contemporary reception of this heritage highlights the current and spontaneous recognition of these structures as among the most emblematic and identity-defining expressions of vernacular architecture—capable of suggesting new ways of conceiving architecture based on a renewed relationship between humans and nature—and, at the same time, underscores the need for the protection, conservation, and enhancement of this important heritage.

Authors' Contributions
Paragraphs 2 and 3 are by Francesco Del Sole; paragraphs 1 and 4 are by Lorenzo Paiano. Paragraph 5 is by both authors.

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Architectural Design and the Relationship Between Architecture and Landscape: Relevant Cases in Modern and Contemporary Portuguese Architecture

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ABSTRACT

Modern and contemporary Portuguese architecture tends to establish an intentional dynamic relationship between the building, the landscape, and the territory, with the latter constituting a central pillar of its architectural culture. However, the design strategies that give shape to this relationship remain scientifically under-systematized, even within the broader context of Mediterranean cultural landscapes. This article aims to analyze architectural practice based on an understanding of the design process and architectural design choices, taking into account intervention strategies and their implementation on-site, as well as their relationship with the landscape. Based on a selection of architectural works by five Portuguese architects of recognized merit—who demonstrate shared sensibilities in their approach to place and landscape—an integrated analysis was conducted that included the interpretation of drawings, photographs, and project documents. The results highlight common strategies for integration into the site, reinforcing a persistent cultural approach to designing with the landscape. The study contributes to architectural theory by systematizing place-oriented design principles relevant to contemporary practices in architecture and urban design.

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1. Introduction

The relationship between architecture and landscape has been widely recognized as a defining element of Portuguese architectural culture. However, despite the extensive theoretical literature on place, identities, and memory, little research has been conducted into how Portuguese architects operationalize this relationship during the design process, particularly through drawing as a tool for interpreting and constructing place. This gap becomes even more significant when viewed within the context of Mediterranean cultural landscapes, where the interaction between topography, climate, and building traditions shapes the ways in which people inhabit and build the territory.

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The landscape has always played a fundamental role in shaping local, regional, and national identity. Human beings, as an integral part of it, continually intervene and add utilitarian, symbolic, and artistic dimensions, transforming it over time, whilst also recording memories and defining identities. The landscape is in constant motion and transformation; "it is an expression of existence and a form of representation (...). It is not simply an expression of a single era, but a manifestation of all eras" (Carapinha, 2015, p. 14), which makes it complex. This relationship between human beings and the landscape, as well as the way in which they relate to it, is the result of an emotional connection, of feelings, which creates a bond with the place.

Just like the landscape, architectural works are also complex, stemming from an interpretation of the ways in which the landscape is used and occupied, giving rise to unique places where landscape and architecture complement each other harmoniously. This emotional connection to the landscape finds expression not only in contemporary architecture but also in architectural structures that shape the territory, notably the Renaissance-style suburban villas and the Portuguese "Quintas de Recreio".

These typologies, deeply rooted in Mediterranean culture, represent some of the earliest models in which architecture and landscape are integrated. The "Quintas de Recreio", in particular, embody "a spatial program for vacation living, characterized by an intentionally direct relationship with the landscape" and reveal "a rationalized organization of space, where leisure and production share the same territory" (Pires & Frutuoso, 2024:2). Their layout on terraces, the use of topography as a compositional structure, the presence of gardens, orchards, woodlands, and paths, and the interplay between house, water, vegetation, and views constitute a cultural legacy. This has profoundly shaped the way the relationship between architecture and place is conceived in Portugal.

Thus, contemporary Portuguese architecture does not emerge from a conceptual vacuum: it inherits and reinterprets principles that span centuries—adaptation to the terrain, continuity between interior and exterior, the emphasis on local materials, the creation of pathways, and the integration of the landscape as a structuring element. These principles, present in Portuguese "Quintas de Recreio" and Renaissance-style suburban villas, reappear in a transformed form in the works of architects Fernando Távora, Álvaro Siza Vieira, Eduardo Souto de Moura, João Lus Carrilho da Graça, and João Alvaro Rocha. This reveals a cultural continuity that fits within the broader context of Mediterranean landscapes.

Over the years, concepts such as genius loci (Norberg-Schulz), the phenomenology of space (J. Pallasmaa, M. Heidegger), critical regionalism (K. Frampton), and landscape urbanism (Corner, Waldheim) have been explored. These concepts and contributions are rarely discussed hastily with regard to Portuguese architectural practices. These practices exhibit a unique relationship with the territory, characterized by topographical adaptation, the selection of local materials, and the creation of spatial sequences that intensify the experience of the landscape. Thus, this study aims to provide a cross-sectional analysis that identifies common principles and recurring strategies among different generations of architects. It seeks to answer the question: What spatial, material, and conceptual strategies emerge from the selected case studies to articulate a specific cultural relationship between architecture, place, and landscape?

To this end, we analyze drawings, photographs, descriptive accounts, and project documents by five contemporary Portuguese architects—Fernando Távora, Álvaro Siza Vieira, Eduardo Souto de Moura, Joo Lus Carrilho da Graça, and Joo Álvaro Rocha—whose works highlight the strategies employed in the design process. These stem from an interpretation of and relationship with the site, demonstrating respect for nature—whether through layout and articulation or even through the use of materials. Through a comparative analysis, the study seeks to identify patterns of landscape integration, understand how design guides conceptual and constructive decisions, and situate these practices within the framework of Mediterranean architectural cultures.

This paper aims, on the one hand, to systematize place-oriented design principles that characterize contemporary Portuguese architecture. On the other hand, it proposes a comparative analysis that allows for an understanding of continuities, differences, and evolutions, offering relevant insights for contemporary practices in architecture and urban design.

The paper is organized as follows: the second section provides the theoretical framework; the third section describes the method and analytical framework adopted; the fourth section presents the results of the comparative analysis; the fifth section discusses the contributions and implications; and the final section summarizes the conclusions and suggests avenues for future research.

2. Methodology

Given that the creative process of architectural design can be based on the perspective that the landscape comprises a set of dimensions and memories created by human beings—whether through the interpretation of visible and invisible traces over time. It is possible to establish a sense of continuity between the past and the present when designing a particular space. This places the concept of the character of the place at the heart of the project's development.

An architectural project draws on both theoretical and practical aspects, which help to develop methods and references for shaping a concept. The drawings indicate design intentions, thoughts, and ideas, fundamental from the earliest sketches right through to the construction details. They are a representation of the gaze, a means of expression, and a means of conveying thought, which, according to Siza Vieira, "The project is to the architect as the character in a novel is to the author: it constantly surpasses him. One must not lose sight of it. The drawing pursues it. But the project is a character with many authors, and it becomes intelligent only when this is acknowledged; otherwise, it is obsessive and impertinent. The drawing is the desire for intelligence" (Siza, 2019, p. 21). A process in which the body participates in the construction of thought and ideas. Drawing thus becomes an extension of perception; it does not merely record what is seen in the present but also translates what the body has already experienced and recognizes, with memory being inseparable from this process. A synthesis between the architect's external and internal worlds.

Here, drawing is not merely a tool for representation but a means of reconstructing the experience—of re-inscribing on paper the way the body inhabits space, how light was perceived, and how the place was experienced.

The selected works go beyond the pursuit of their own ideal of landscape; they are not merely structures that sculpt the territory, but rather structures that organize a space, creating conditions for inhabiting it, defining its character and spatiality, without negating the character of that place. To this end, a qualitative, interpretive approach was adopted, centered on the comparative analysis of the case studies.

2.1. Selection of Architects and Case Studies

Five contemporary Portuguese architects—Fernando Távora, Álvaro Siza Vieira, Eduardo Souto de Moura, João Luís Carrilho da Graça, and João Álvaro Rocha—were selected due to the recognized significance of their work in exploring the relationship between architecture, place, and landscape. The selection was based on three criteria:

1. Consistency in their approach to the territory and contexts;
2. Availability of graphic and written documentation;
3. Representativeness within the landscape of contemporary Portuguese architecture.

The selected case studies correspond to emblematic works in which integration with the landscape constitutes a structuring element of the entire design process.

2.2. Sources and Materials Analyzed

The analysis focused primarily on drawings, plans, sections, perspectives, and sketches, as well as photographs of the construction site, descriptive accounts, texts by the authors, and supplementary documentation. These sources were treated as records that reveal design intentions, spatial decisions, and the relationships established with the site.

2.3. Comparative Analysis

A framework consisting of five dimensions was developed, drawn from the literature on landscape, place, and architectural design:

1. Strategies for topographic integration and adaptation—methods of site placement and relationship with the terrain;
2. Interior–exterior relationship—openings, transitions, and spatial sequences;
3. Materiality and its integration—use of natural materials, textures, and structural continuity;
4. Visual relationships—frames, views, orientation, and light;
5. Cultural identity and memory—cultural references, building traditions (craftsmanship), and interpretation of the territory.

These dimensions made it possible to structure a cross-cutting analysis of the cases, linking phenomenological and constructive aspects. The analysis took place in three stages: the first involved an individual review of each case study to identify relevant elements within each dimension; the second involved grouping recurring patterns among works and architects; and finally, a comparative synthesis highlighted convergences, differences, and developments.

The validity of the analysis was reinforced by cross-referencing different types of sources (drawings, photographs, and texts). The interpretive nature of the study, however, entails limitations inherent to qualitative analysis, namely reliance on available documentation and the inability to make statistical generalizations. Nevertheless, the consistency of the identified patterns supports conclusions relevant to the debate on architecture, landscape, and territory.

3. Case Studies

The analysis of case studies begins with the works of architects Fernando Távora and Álvaro Siza Vieira, focusing on the reinterpretation of their contemporary architectural concepts, which place great emphasis on place, tradition, and culture.

The Santa Maria da Feira Municipal Market (1953–1959) and the Dr. Ribeiro da Silva House (1956–1958) in Ofir, Esposende, are examples of projects by the architect Fernando Távora. Here, a fully modern understanding of space is evident, incorporating distinctive aspects of the landscape and local tradition. This heralds a new way of understanding architecture. It embraces various architectural influences, trends, and concerns, such as the functional and the organic, but primarily Portuguese vernacular architecture. The connection with the place and the landscape is clear.

In these architectural design projects, the relationship with the landscape is evident: the clean, simple lines do not detract from the view of the landscape. The choice of materials, the colors, and the way the house is integrated into its surroundings are all aspects that contribute to a design approach that works in harmony with the landscape.

A disciple of the architect Fernando Távora, the architect Alvaro Siza Vieira's career is also characterized by and evidenced through a focus on and relationship with nature and on integration and dialogue with the site and the landscape. He never loses sight of his commitment to modernity. For Siza, '(…) architecture has no meaning unless it relates to nature' (Siza, 2019, p.34).

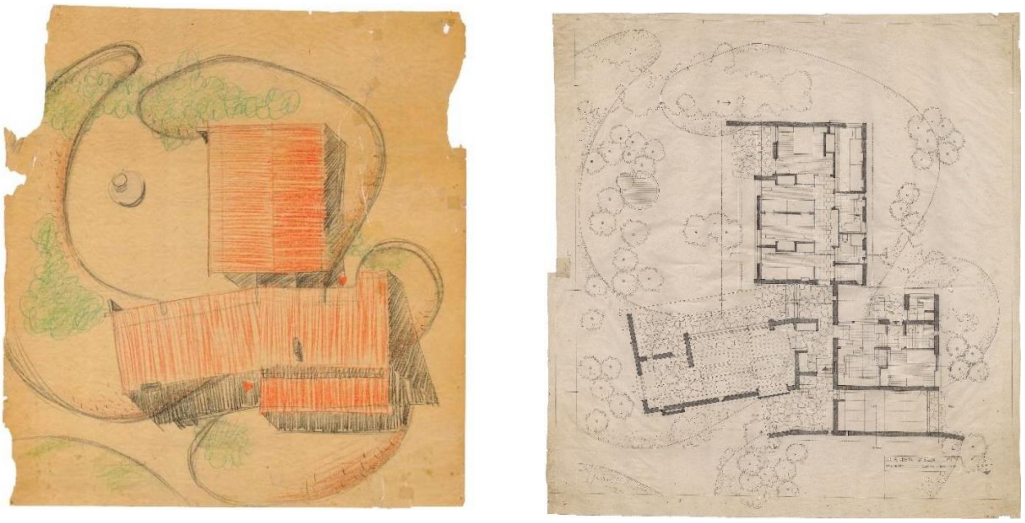

Figure 1. Dr Ribeiro da Silva House, Fernando Távora – drawings (roof plan and ground floor plan) showing the importance attached to the existing natural features. Source: Távora100 (2023)

Figure 2. Dr Ribeiro da Silva House, Fernando Távora – the house's relationship with the surrounding landscape. Source: Távora100 (2023)

The Boa Nova Tea House (1958–1963) in Leça da Palmeira is in harmony with its natural and cultural surroundings, blending various elements that straddle the rational and the organic. Respect for nature is evident; the rock is recognized as an integral part of the structure, the building being "like a great rock, partly clad, partly exposed, rising from the land, the sea, and the beach" (Távora, 1958, p.125). Designed to reward those who enjoy the space with carefully studied views from each level, all the way to the entrance. The project was influenced "(…) by the extreme attention paid to the existing and

tangible balance between nature, a chapel, and, a little further away, a lighthouse. It is no coincidence that the restaurant is low-rise: it could not tower over the chapel for sentimental reasons, but also because the building's design itself would not allow it. The main objective was, therefore, to allow the chapel to take precedence, without the restaurant becoming a building devoid of character: it was necessary to reconcile the building's autonomy with what already existed." (Siza, 2012, p.23).

Figure 3. Boa Nova Tea House, Álvaro Siza Vieira – a structure facing the beach.
Source: V. Frutuoso (2022)

The Piscinas de Marés [Tidal Pools] (1961–1966), on Leça beach, are situated to the south of the Tea House. As with the Tea House, the architect explores a profound sensitivity and a strict '(…) symbiotic relationship with the natural characteristics of the site, articulating a geometric layout with the irregularity of the rocky elements upon which they rest.' (Silva, 2011, p.33). The pools blend into the landscape, the building's presence being diluted as it sinks to the level of the walkway, thus not becoming a physical or visual obstacle in the landscape. The building is nothing more than the transition between the human scale and the immensity of the ocean.

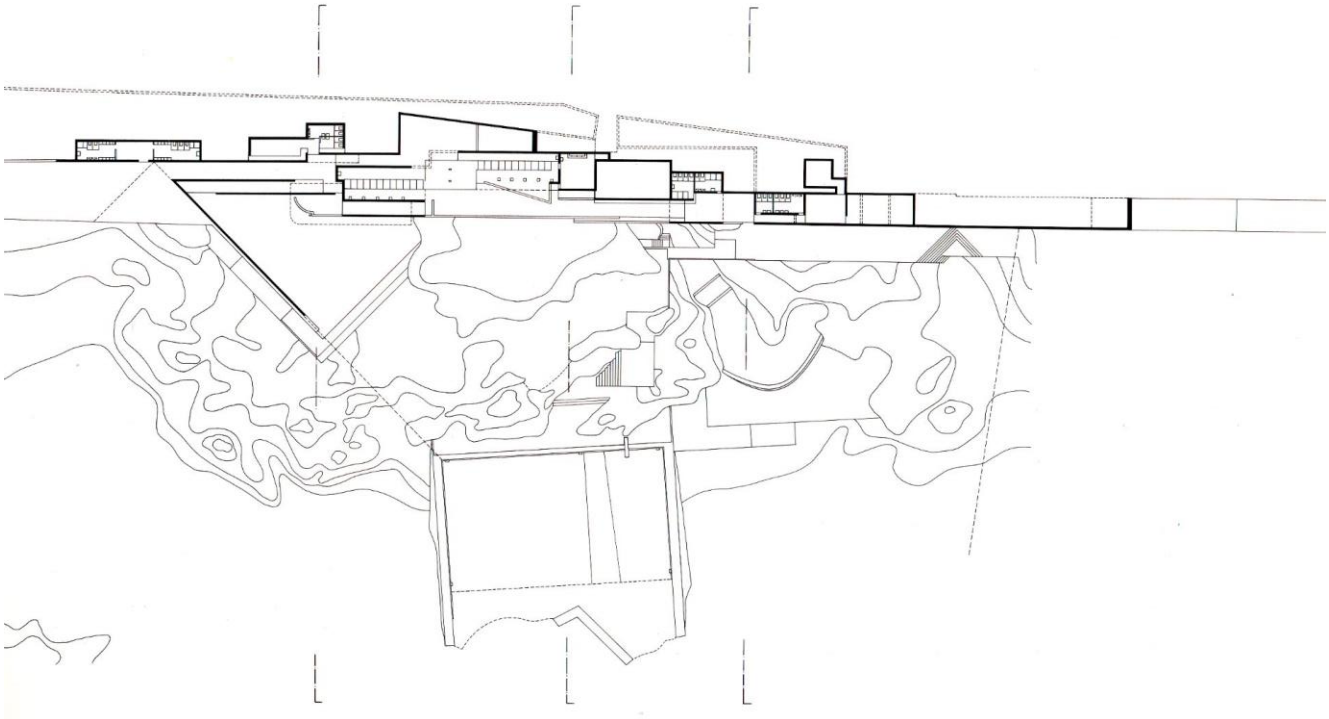

Figure 4. *Piscinas de Marés* [Tidal Pools], Álvaro Siza Vieira – floor plan.
Source: Fundación Docomomo Ibérico

Rooted in a deep appreciation of the landscape, this is a prime example of the balance and harmony achieved with the site, as well as of the proportions of the architecture. It serves as a model of cultural heritage and the continuity of the landscape. It was within this context of respect for and connection with the site that, in the 1980s, the architect Eduardo Souto de Moura began his own architectural projects.

For the Casa de Moledo (1991–1997) in Viana do Castelo, the starting point was the intention to integrate the house into the existing terraced landscape, making the most of the site's topography. As it was not possible to make use of the terraces due to their narrow width, he began designing based on the topographical reorganization and the granite walls; the site layout solution involved excavating the slope, removing some terraces, thereby creating a larger space with the necessary elevation for construction. In addition to adapting the house's construction to the site's characteristics, priority was also given to visual connections with the surrounding area.

The building is immersed in nature; the use of natural materials in its construction and its integration with the landscape create a sense of continuity in which there is virtually no distinction between inside and outside—only landscape.

Figure 5. Moledo House – Set in the Landscape. Source: Divisare

Another striking project designed by Souto de Moura, due to its seamless integration into the landscape, was the Braga Municipal Stadium (1997–2004), where he made use of the existing undulations in the terrain to ensure the landscape's continuity (Souto de Moura, 2008, p. 45). Situated on the site of a disused quarry, it was designed to blend harmoniously into the landscape, occupying the slope of Monte Crasto. The natural amphitheater formed by the slope was cleverly utilized, opening out onto the landscape.

Methodologically, the architect critically engages with the brief and the site; although the project is successful, the solution often involves reconstructing both. Drawing is his way of thinking, an essential working tool, not so much as a graphic exercise but as a study of proportions (Correia, 2016, pp. 10–11). "Portuguese cities seek out very rugged sites so that the very characteristics of the terrain can aid in the construction. Thus, it is the layout that must adapt to the topography, whilst the architecture, which is quite simple, finds itself in a difficult relationship with the terrain and its extraordinary character (…)" (Siza, 2012, p. 89).

Figure 6. Braga Municipal Stadium, Eduardo Souto de Moura – built on the site of a former quarry. Source: A. G. Pires (2004)

Another leading figure in the field of contemporary Portuguese architecture, João Luís Carrilho da Graça, "(…) embraces the legacy of the modern movement, not in a uniform, narrow, and dogmatic sense, but in its diverse expressions—critical, fragmentary, and open to new meanings—in the empirical process through which he seeks, for each project, its internal coherence in the essence of the respective program and in the construction of relationships with the site" (Byrne, 1995, p.8).

Figure 7. School of Media Studies, Lisbon, J. L. Carrilho da Graça – relationship with the landscape. Source: A. G. Pires (2019)

Carrilho da Graça, whilst its design is strongly characterized by formal aesthetics, manages at the same time to demonstrate a deep sensitivity to the site and to break down barriers between popular and high culture. The architect regards the site as a starting point, for it is from the existing material that he begins his intervention, and it is within this that he constructs the guiding principles of the project's concept. Analyzing the particularities of the territory, "The simple observation of the imagined stark relief, revealed by the contour lines, allows us to create a space for contemplation. It allows us to think of the territory as an initial supporting skeletal structure (…)" (Graça, 2002, p.9), establishing a methodology of intervention based on reading the site, identifying its natural and built characteristics, and articulating a program and its functional and constructive singularities. These are organized according to an idea capable of intensifying the experience and relationship with the place (Byrne, 1995, p.8).

Among his early works, the Campo Maior Municipal Swimming Pools (1985–1990) exemplify the interplay between interior and exterior. Organized around a courtyard—a recurring feature in his work—a pergola defines the boundaries of the space, where one can both observe and be observed. "The buildings (…) stand out as landmarks in the landscape. As places of convergence or absorption, they invite contemplation. The belvedere becomes the object of contemplation in a duality that is now merely a remnant of the relationship that Palladian towns establish with the territory—simultaneously the dominant center and the structuring core of the territorial system." (Byrne, 1995, p. 10).

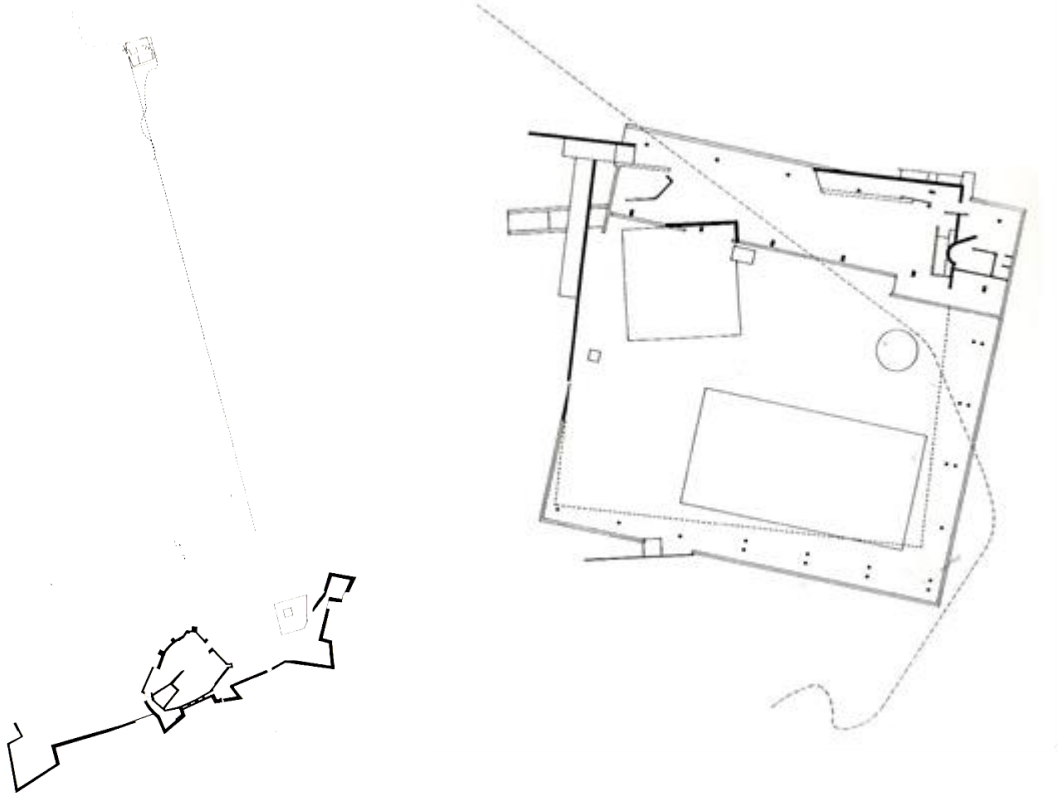

Figure 8. Campo Maior Swimming Pools, J. L. Carrilho da Graça – site plans and concept drawings. Source: Graça (1995:26)

His reflections on the landscape are revealed in his designs: "The buildings (…) stand as landmarks in the landscape. Places of convergence or absorption invite contemplation. The belvedere becomes the object of contemplation in a duality that is now merely a remnant of the relationship that Palladian towns establish with the territory, simultaneously the dominant center and the structuring nucleus of the territorial system." (Byrne, 1995, p.10).

João Álvaro Rocha (1959–2014), another prominent contemporary architect, used drawing as a tool for conceptual research and as a fundamental element in the realization of his projects. Proof of this can be seen in his projects; one such example is the design and construction of Quinta da Gruta (1998–2001) in Castêlo da Maia, Maia. This site saw the estate's grounds adapted and expanded into an urban park, involving various interventions, from the renovation of the mansion to the construction of the environmental school and landscaped areas, "(…) as well as representing an attempt to preserve the perception of the extent of the agricultural land still in existence, it seeks to position itself within the defined strategy as a fundamental and indispensable agent in the transformation of the territory of which it forms part." (João Álvaro Rocha, Arquitectos, S.A., 2010).

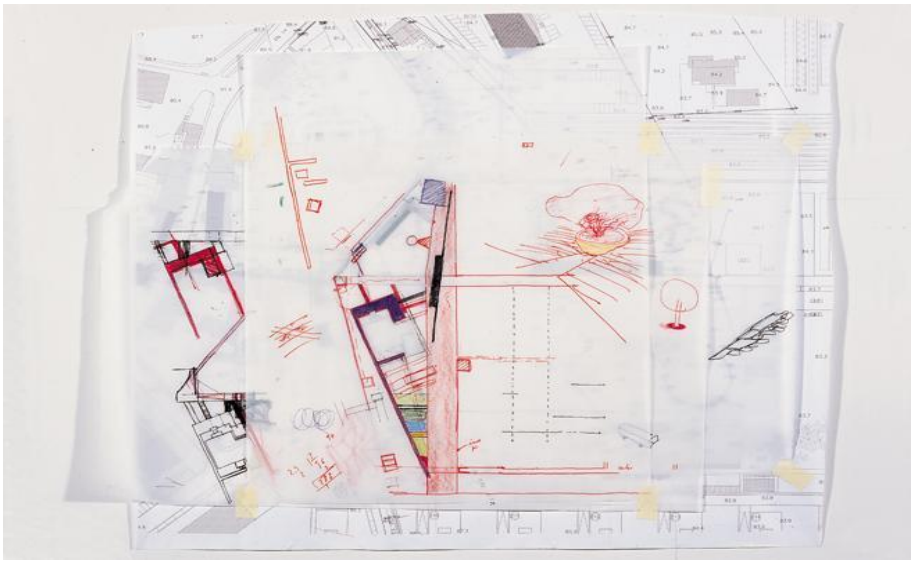

Figure 9. Quinta da Gruta, João Álvaro Rocha – conceptual drawings.
Source: João Álvaro Rocha, Arquitectos, S.A. (2010)

"To transform, in this case, means having the ability to look further back, to go back to the origin to find foundations and reasons, so that everything can be established in the wake of a memory. Memory is relevant here both as an affirmation of contemporaneity and as an unmistakable sign of the connection between past and present." (João Álvaro Rocha, Arquitectos, S.A., 2010).

4. Results

A comparative analysis of the case studies identified a set of strategies that characterize this relationship between architecture and landscape in the work of the five selected contemporary Portuguese architects. In all the cases analyzed, topography is not treated as a constraint but as an active element of the design. Topographical adaptation emerges as a cross-cutting principle that guides spatial and structural decisions.

The relationship between interior and exterior spaces is another common element, reinforcing the idea that architecture does not close in on itself; it goes beyond its interior and expands outward into the landscape.

The choice of natural materials reveals a shared concern for continuity between the building and the landscape. The creation of visual frames and pathways is central to all the works, which allows us to affirm that the landscape is an active element of the composition.

The memory of place emerges as a cross-cutting dimension, in which Portuguese cultural identity manifests itself through strategies that reconcile modernity and tradition.

This analysis reveals five common principles:

1. Topography as a generator of form and space;
2. Spatial continuity between interior and exterior;
3. Materiality as an extension of the landscape;
4. The creation of pathways and visual frames;

5. Memory and identity as the foundations of the project.

These principles shape an architectural culture that designs in harmony with the place, reinforcing the continuity between architecture, territory, and landscape. An analysis of the works of the five architects revealed common patterns and significant differences in the way each one articulates the relationship between architecture, place, and landscape. A comparative matrix is presented below:

Table 1. Table 1. Comparative matrix. Source: Authors, 2026

Analytical Dimension	Fernando Távora	Álvaro Siza Vieira	E. Souto de Moura	J. L. Carrilho da Graça	João Álvaro Rocha
1. Strategies for integration and topographical adaptation	- Integration with the existing landscape; - Preservation of existing natural features; - Site-specific layout.	- A layout that adapts to the irregularities of the terrain; - interaction with natural elements (e.g., rock) and the topography.	- Uses the topography as infrastructure; - cuts, slopes, and platforms as form-generating elements.	- Interpreting the landscape as a foundational structure - Morphology-guided planning.	- Coordination of elevations, routes, and platforms; - preservation of the existing landscape view.
2. Relationship between interior and exterior	- Direct connection to the outdoors through patios, balconies, and windows;	- Alternating spatial sequences; - Carefully designed views and openings.	- Horizontal planes and continuous materials that extend the living space outward.	- Courtyards and galleries as mediating devices.	- Pathways that gradually reveal the site; - Subtle transitions between interior and exterior.
3. Materiality and its integration	- Use of local materials while drawing on vernacular tradition;	- Materials that interact with the site, sometimes contrasting with it, sometimes blending into it.	- Use of stone and concrete as structural elements.	- Materiality that interacts with the interpretation of the territory.	- Materials associated with the site's memory and identity.
4. Visual relationships	- Framing and orientation that reinforce the connection to the place;	- The creation of views and pathways that enhance the experience of the landscape.	- Structures that reveal different depths within and toward the landscape.	- Territory used as a setting and a framework for contemplatio n.	- Pathways that reveal the site in a sequential and sensory way.
5. Cultural identity and memory	- Reinterpretation of vernacular tradition.	- Cultural continuity through contemporary design elements rooted in the site.	- The permanence and transformation of the built landscape.	- Territory as a historical and cultural framework.	- Memory as the foundation of the contemporary intervention.

5. Discussion

The results confirm that the relationship between architecture and landscape in Portugal has historically been shaped by a particular sensitivity to place. This sensitivity manifests itself both in the interpretation of the territory's natural and cultural conditions and in the way architects translate that interpretation into their designs, seeking continuity, respect, and dialogue with the landscape and the place.

This exercise allows us to deepen the dialogue with international literature and situate these practices within the broader context of Mediterranean cultural landscapes, where topography, climate, and building traditions have historically shaped ways of living.

The analysis confirms, first and foremost, the centrality of place as the foundation of the project, in line with the phenomenology of Norberg-Schulz (1984), for whom the genius loci emerges from the interaction between built form, memory, and experience. This relationship is clearly evident in Fernando Távora's Casa de Ofir, where the site layout respects the existing vegetation and the building's volume adapts to the topography, revealing a sensitive interpretation of the site. Similarly, in the Boa Nova Tea House, architect Siza Vieira shapes the building around the rocky outcrop, allowing the architecture to become an extension of the landscape. These examples demonstrate how design functions as a tool for interpreting the territory, as advocated by architect Siza Vieira (2019), who views the act of designing as a way of thinking and of building relationships with the place.

Topographic adaptation, identified as one of the cross-cutting principles, takes on different forms among architects. At the Braga Municipal Stadium, architect Souto de Moura transforms the former quarry into a monumental structure, using cuts and slopes as architectural elements. This approach contrasts with that of architect Carrilho da Graça, whose School of Media Studies is designed as a volume that interacts with the slope through platforms and horizontal planes, revealing a more abstract interpretation of the terrain. At Quinta da Gruta, architect João Álvaro Rocha demonstrates a simultaneous focus on both the memory and the transformation of the site. These differences show that, although topography is a defining element, each architect has their own interpretation, guided by their own logic.

Another significant finding concerns the spatial continuity between interior and exterior, which is consistently evident in the work of the five architects discussed here. In the works of architect Fernando Távora, courtyards and balconies extend the living space outward, as seen in the Santa Maria da Feira Market. In the work of architect Siza Vieira, the sequence of spaces in the Casa de Chá—from the narrow entrance to the opening overlooking the sea—creates a spatial narrative that intensifies the experience of the landscape. Architect Souto de Moura employs continuous horizontal planes, as in the Casa de Moledo, where the interior extends to the terrace and the terrace to the valley, dissolving boundaries. Architect Carrilho da Graça uses courtyards and galleries as mediating devices, while João Álvaro Rocha constructs pathways that gradually reveal the site, alternating moments of compression and expansion. This spatial continuity, combined with the temperate climate and the Mediterranean tradition of outdoor living, reinforces the relevance of situating these practices within the context of the cultural landscapes of southern Europe.

Materiality also serves as a tool for integrating into the landscape. Architect Fernando Távora uses local materials that engage with vernacular tradition, while architect Siza Vieira combines wood, stone, and concrete to establish subtle connections with the site. Architect Souto de Moura explores the rough texture of stone and the neutrality of concrete as extensions of the topography—as seen in the Braga Stadium. Architect Carrilho da Graça, on the other hand, uses materials that reinforce the geometric reading of the territory, and architect João Álvaro Rocha articulates materials that evoke the memory of the place. This diversity confirms Frampton's (1983) idea that critical regionalism is not limited to the reproduction of tradition but rather to its critical reinterpretation through materiality. In this sense, these architects do not seek a nostalgic return to the vernacular but rather construct a modernity rooted in the territory, where technique—understood as a material and constructive expression—plays a central role between local culture and contemporary language. Examples such as the Boa Nova Tea House, where concrete conforms to the rocks, or the Moledo House, where stone extends the topography, demonstrate how materiality becomes a vehicle for cultural and landscape continuity. Thus, Portuguese architecture adopts a stance of critical resistance, integrating climate, territory, and tradition without relinquishing the formal and conceptual autonomy of modernity.

Visual relationships are another fundamental element. At the Casa de Chá, architect Siza Viera creates carefully studied views that frame the sea; at the Piscinas de Marés, the horizon line becomes a compositional element; with architect Souto de Moura, the cross-sections of the Braga Stadium reveal

different depths of the landscape; with architect Carrilho da Graça, the territory is treated as a backdrop; and, with architect João Álvaro Rocha, the pathways reveal the site in a sequential and sensory manner. These examples show that the landscape is not merely a backdrop but an active element of the project.

Finally, memory and identity emerge as defining dimensions. Architect Fernando Távora reinterprets vernacular tradition; architect Siza Vieira articulates modernity and cultural continuity; architect Souto de Moura explores the permanence and transformation of the built landscape; architect Carrilho da Graça draws on a historical reading of the territory; and architect João Álvaro Rocha integrates memory and contemporaneity as driving forces of the project. This diversity confirms that Portuguese architecture designs with the landscape, rather than over it, articulating tradition and modernity.

In summary, the results reveal that, although significant differences exist, there is a shared culture of place-oriented design that is linked to broader Mediterranean practices. They demonstrate how essential it is to understand the territory and the dynamics intrinsic to the space, with the concepts of landscape and nature in Portuguese culture being an integral part of the process. This culture values topography, spatial continuity, natural materiality, the creation of pathways, and memory as the fundamental foundations of design. These principles offer relevant insights for contemporary practice, suggesting that sustainability can be understood as continuity with the territory and not merely as technology.

6. Conclusions

This study identified a set of principles that characterize the relationship between architecture and place, as well as the landscape, in contemporary Portuguese architectural culture. A comparative analysis of the five selected architects demonstrated that, despite their differences, there is a common approach to designing in harmony with the site, integrating topography, materials, pathways, and memory as the foundations of the design process. This approach confirms the continuity of a tradition in Portuguese architectural culture, whose origins can be traced back to the Renaissance-style suburban villas and "Quintas de Recreio". The relationship between architecture, gardens, territory, and landscape was already established as a defining element.

The research question—What spatial, material, and conceptual strategies emerge from the selected case studies to articulate a specific cultural relationship between architecture, place, and landscape?—can be answered through the following five cross-cutting principles: (1) topography as a structure that generates form; (2) spatial continuity between interior and exterior; (3) materiality as an extension of the landscape; (4) the creation of pathways and visual frames; (5) memory and identity as the foundation of the project.

These principles reveal an architectural culture that values the interpretation of the territory and its continuity with the landscape, critically articulating tradition and modernity. A comparison of specific works—the Boa Nova Tea House, the Braga Municipal Stadium, the School of Media Studies, and Quinta da Gruta—shows that the landscape is treated as an active element of the project. Just as was the case with Renaissance-style suburban villas and recreational estates—spaces where architecture, gardens, water, vegetation, and the landscape came together in a unified composition—contemporary architects also critically reinterpret this heritage, adapting it to the languages, programs, and challenges of the present.

The findings contribute to architectural theory by systematizing place-oriented design strategies, offering a conceptual framework applicable to other Mediterranean regions where climate, topography, and building traditions play fundamental roles. For contemporary practice, the study reinforces the importance of drawing as a research tool and of landscape integration as an essential component of a sustainable and culturally rooted approach. A historical analysis of suburban villas and recreational

estates reinforces this perspective, demonstrating that landscape integration is not merely a contemporary concern but a persistent defining feature of Portuguese and Mediterranean architectural culture.

The study does, however, have limitations inherent to its qualitative nature: its reliance on available documentation, its focus on five architects, and the absence of interviews or direct observation. Future research could extend to other Mediterranean regions, explore participatory methodologies, or delve deeper into the role of drawing as a research method in architecture.

In summary, the study demonstrates that contemporary Portuguese architecture forges a unique relationship with the landscape, based on a sensitive reading of the territory, cultural continuity, and the capacity of drawing to transform a place. These contributions reinforce the importance of understanding architecture as a territorial and cultural practice, capable of generating new ways of inhabiting that are rooted in the landscape.

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Ethics statements
Studies involving animal subjects: No animal studies are presented in this manuscript.

Studies involving human subjects: No human studies are presented in this manuscript.

Inclusion of identifiable human data: No potentially identifiable human images or data is presented in this study.

Conflict of Interests
The author declares no conflict of interest.

Contribution to the Field statement
This research explores, from both theoretical and methodological perspectives, the relationship between architecture, place, and landscape in the Portuguese and Mediterranean contexts, systematizing place-oriented design principles. It demonstrates how different generations of architects construct cultural continuities through design, materiality, and the interpretation of the territory. An analysis of works by Fernando Távora, Álvaro Siza, Souto de Moura, Carrilho da Graça, and João Álvaro Rocha reveals cultural continuities that trace back to the Quintas de Recreio, the Renaissance-style suburban villas, and Mediterranean practices, where architecture, gardens, water, and topography interplay. Five common principles are identified: topographical adaptation, interior-exterior continuity, integrated materiality, pathways, visual frames, and memory as the basis of the design.

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Linear Cultural Heritage and Public Space: Urban Walls Between Conservation and Collective Appropriation

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ABSTRACT

The present contribution addresses the issue of heritage-led urban regeneration through a qualitative analysis of Rome's fortification system, examined as a paradigmatic instance of the transformation of historic defensive infrastructure into a strategic resource for the contemporary city (Connolly, 2015). Three complementary regeneration strategies: promoting of physical accessibility and walkability along the wall circuit; the integrating the fortification system into a network of linear parks; and the supporting of cultural and identity-based appropriation of the surrounding public spaces. From this analytical sequence, a five-principle methodological framework is derived: systemic interpretation of linear heritage, context-sensitive diversification, prioritisation of everyday over touristic use, long-term management sustainability, and participatory governance. Its transferability is understood in analogical rather than statistical terms: Rome compresses within a single continuous structure a range of urban conditions that other European walled cities typically present only in isolated, non-comparable cases; its applicability elsewhere remains an interpretive hypothesis for future comparative research rather than a validated result. Similarly, the observed instances of spontaneous appropriation and community attachment to specific wall sections are read, on the basis of repeated observation, as indicative of a potential for collective identity formation, rather than as an empirically demonstrated outcome, given the study's qualitative and observational scope. The Roman case thus suggests that linear heritage, when supported by contextually informed valorisation processes, holds significant potential for the regeneration of marginal urban areas and the construction of collective urban identity (Ricci, Mariano 2018).

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1. Introduction

Urban regeneration and heritage-based approaches: context and theoretical framework The recent debate on the new urban issue has led to a redefinition of the characteristics of widespread socioeconomic, urban, and cultural marginalization, social inequality, and poverty, which is leading to the obsolescence of the very concept of the "periphery, understood as physical distance and in

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contrast to central areas" (Ricci et al. 2026). Climate change, territorial imbalances, and the depletion of ecological and energy resources highlight, more than ever, a worsening of the structural deficiencies that have characterized the development of Italian and European cities since the early 20th century (Ricci, Mariano, 2004). These fundamental changes, resulting from processes of metropolisation (Indovina, 2009; Oliva, 2010), are bringing about profound shifts in the meaning and practices of urban planning and environmental management, and highlight the urgent need to implement policies, strategies and tools capable of providing integrated and multi-level responses to the physical, social, cultural and economic regeneration needs of the contemporary city (Ricci et al. 2026).

A regeneration strategy, aimed in general terms at "revitalizing problem areas—by addressing issues related to the restoration of natural and man-made environments, heritage conservation, social integration, employment, and economic activities—in urban, peri-urban, and rural contexts" (CE, 2007) and, specifically, to play a leading role based on an awareness of the collective and symbolic value of cultural heritage. The issue of managing urban cultural heritage has made significant progress in recent decades. The theoretical framework adopted refers to the concept of heritage-led regeneration, which has established itself in international urban planning literature as an approach capable of overcoming the traditional dichotomy between conservation and development (Pendlebury and Townshend, 1999; Pendlebury, 2009). In its most recent developments, this approach no longer views heritage as a constraint on urban transformation, but as an active resource capable of guiding regeneration processes that produce positive effects on cities—both physically and economically and socially. In this context, linear cultural heritage is regarded as a multidimensional resource able to contribute simultaneously to cultural identity, environmental quality, social cohesion and economic attractiveness (Gravagnuolo et al., 2019). The Recommendation on the Historic Urban Landscape (UNESCO, 2011) introduced an approach that conceives of urban heritage not as a collection of isolated monuments, but as a layer of meanings accumulated over time, interwoven with the cultural practices of the communities that inhabit and transform the urban space. This theoretical framework recognizes the need to manage change so that new transformations integrate with the values of existing heritage, without denying its historicity or impeding its evolution (Bandarin, van Oers, 2012).

This theoretical premise makes it necessary to clarify, from the outset, how the concepts mobilised throughout this article relate to one another, since their relationship is not self-evident and has rarely been made explicit in the literature on heritage-led regeneration. Linear heritage is here understood as a physical structure that, by traversing and structuring the urban fabric, holds the potential to function as public space: not merely open or accessible space, but space whose meaning is produced through everyday practices of use. When such practices are recurrent, situated and community-driven, they constitute what this article refers to as collective appropriation: the process through which inhabitants make a heritage structure their own, inscribing it with contemporary meanings that coexist with its historical stratification. The appropriation, in turn, is the mechanism through which linear heritage contributes to collective identity, understood as the shared sense of belonging that a community derives from its relationship with a recognisable, shared spatial reference. Heritage-led regeneration, finally, is the strategic and design framework through which public authorities and communities can intentionally support this chain – from physical structure to public space, to appropriation, to identity – rather than leaving it to spontaneous and often precarious dynamics. It is this conceptual chain, rather than any single concept in isolation, that structures the analysis developed in the remainder of this article.

1.1. Linear heritage, research gaps, and objectives

City walls can be classified as linear heritage, a category with specific characteristics that distinguish it from isolated monuments or defined historic districts. Their nature as continuous structures, traversing the urban fabric, conceptually links them to other historical linear infrastructures (e.g., consular roads, navigable canals, abandoned railway lines, etc.), whose conversion into public spaces has seen

growing interest in recent decades, both in design practice and theoretical reflection. In the specific case of historic walls, the heritage dimension adds a further layer of complexity: the wall structure is not merely a disused infrastructure to be repurposed, but a 'document' of exceptional value, requiring intervention approaches that respect its materiality and stratification. It is precisely this dual condition – structures still capable of evoking, in Choay's (1992) terms, the historic landscape of European cities, yet also subject to the practical constraints of contemporary urban life – that makes city walls a critical case for interrogating how linear heritage can be transformed into identity-forming public space without eroding its material and historical integrity.

Structures designed to defend, demarcate, and define the ancient city continue to shape its physical form and collective identity long after they have outlived their original purpose. Yet, by the end of the 20th century, much of this heritage has been progressively marginalized (Xu, Cheng and Li, 2025): relegated to a residual fragment, incorporated into the infrastructural logic of modern mobility, or simply abandoned to silent decay. The tension between the historical and monumental value of the walls and the functional need of the contemporary city constitutes the central problem around which this contribution revolves. This tension raises a question that existing studies have so far addressed only implicitly: whether and under what conditions the same structure that once separated and defended the city can be repositioned as a device of connection and collective use, without this repositioning being read as a loss of its historical authenticity. Addressing this question requires moving beyond a descriptive account of the walls' evocative value, toward an explicit analytical comparison of the strategies through which such repositioning has been attempted.

The scientific literature on urban regeneration guided by linear heritage, while growing, remains fragmented along at least three dimensions, rather than constituting a unified body of knowledge. A first group of contributions addresses linear heritage primarily at the scale of the single monumental segment, with limited attention to its relationship with the surrounding urban contexts it traverses. A second group focuses on comparative or typological classification of enhancement experiences across cities, but without a shared methodological framework linking historical stratification, contextual typology and design strategy within a single analytical model. A third group engages with the theoretical relationship between heritage conservation and adaptive reuse but rarely translates this reflection into operational tools applicable across the highly heterogeneous urban contexts that a single wall system can traverse within one city (Ricci, Imbesi and Perrone, 2025; Vandesande and Van Balen, 2023). This fragmentation is confirmed, rather than merely asserted, by the enhancement initiatives carried out in major European cities with historic wall systems which have produced significant but difficult-to-compare results, due to the diversity of contexts, approaches adopted, and resources mobilized: to date, no systematic comparative framework has been applied across these cases capable of relating the type of urban context traversed (dense historic centre, peripheral fringe, infrastructural corridor) to the enhancement strategy adopted and to its outcomes in terms of public use. It is precisely this methodological gap that this article aims to address.

The case of Rome stands out for the extraordinary complexity of its wall system, the variety of urban contexts it traverses, and the wealth of enhancement initiatives already implemented, but also for the persistence of situations of decay and neglect that make a systematic reflection on the most effective strategies urgent (D'Elia et al., 2022). This richness is what qualifies Rome as a paradigmatic rather than a merely convenient case: the Roman wall system traverses, within a single continuous structure, the same range of contextual conditions – dense historic fabric, consolidated residential districts, peripheral and infrastructural corridors – that other European cities with historic walls typically present only in isolation, distributed across different, non-comparable cases. The transferability sought in this article is therefore not statistical but analogical: Rome is treated as a case in which the diversity of urban conditions relevant to linear heritage regeneration is compressed into a single, internally comparable system, allowing strategies to be tested and compared across contexts under otherwise similar institutional and historical conditions

The built heritage constitutes a system of key territorial reference points that provide a framework, capable of guiding regeneration strategies in urban contexts characterised by physical and socio-economic marginalisation. From this perspective, cultural heritage becomes a key factor in the processes of sustainable and resilient regeneration of the city and the territory (Rotondo, 2016): no longer a constraint or a remnant of the past, but an active resource capable of generating sustainable economic development, innovation, social inclusion, and an enhancement of the residents' quality of life, with particular reference to peri-urban and extra-urban areas traditionally excluded from revitalization policies. This gives rise to the need to develop regeneration strategies on a broader territorial scale, which consider not only urban cultural heritage (which is more layered and recognized) but also its geographical, historical, and landscape-based extension into the surrounding territory, restoring coherence and identity to contexts that are currently fragmented and heterogeneous (Ricci et al., 2023; Ricci et al., 2024).

This article aims to explore the relationship between linear cultural heritage, public space and urban regeneration, analysing Rome's walls as a paradigmatic example of a broader process: the transformation of a historic defensive structure into the central hub of a system of public spaces that contribute to the construction of contemporary urban identity. The specific objective is to identify the most effective integration strategies in the various urban contexts traversed by the wall system and to construct a methodological framework transferable to other contexts.

The research is guided by three main questions: (i) How can historic walls transition from obsolete infrastructure to identity-forming public spaces, while maintaining their historical and material integrity? (ii) Which integration strategies prove most effective in the various urban contexts traversed by the Roman wall system? (iii) To what extent can the Roman case offer insights transferable to other European and global urban contexts? To these is added a theoretical question: in what way does linear heritage differ, in terms of enhancement approaches, from point monuments and delimited historic areas?

1.2. Relevance and structure of the paper

The relevance of this topic can be found at the intersection of several pressing challenges facing the contemporary city: the need to create high-quality public spaces in densely populated urban contexts; the need to promote cultural heritage as a driver of social cohesion and economic development; and the challenge of ensuring the sustainable management of regeneration projects. Cultural heritage assumes a structuring value as a network of historical and documentary landmarks that serves as a benchmark and constitutes a marker for the stratification of the territory, from which regeneration dynamics can radiate out to surrounding contexts as well.

The structure of this paper is as follows: § 2 outlines the methodological framework adopted; §3 presents the results of the analysis of the Roman case study, organised by historical stratification, contextual typology, characteristics of the monumental nodes and patterns of use; § 4 discusses the regeneration strategies identified and compares them with the international literature; § 5 presents the conclusions, including a transferable methodological framework and recommendations for the future implementation of the research.

2. Methodology

The proposed methodological framework is the result of a synthesis process that integrated the findings of empirical field analysis and the documentary analysis with insights derived from a review of the international literature (Clark, 2003; De la Torre, 2002; Liu et al, 2026; Pendlebury, 2009; Wang et al., 2019).

2.1. Case study, research design, and methodological approach

The case study selected is Rome's historic wall system, with its extraordinary complexity and stratigraphic continuity, from the traces of the Servian Wall of the 4th century BCE to the Aurelian Walls of the 3rd century CE, through the subsequent medieval, Renaissance, and papal interventions that progressively modified, reinforced, and reinterpreted the original defensive wall. The choice of Rome as a laboratory for analysis is driven by four converging factors: the exceptional richness and variety of the wall heritage, which offers a nearly complete sample of the diverse relationships between historical infrastructure and the contemporary urban fabric; the complexity and variety of the contexts involved, which allow for the analysis of conflicts and opportunities for enhancement under conditions of maximum heterogeneity; the availability of established enhancement initiatives, some of which have already been subject to critical evaluation in the scientific literature (D'Elia et al., 2022; Perrone, Imbesi, Ricci, 2025); and the persistence, in other sections, of situations of deterioration and neglect that make a systematic reflection on the most effective intervention strategies both urgent and timely.

2.2. Analytical tools and comparative analysis

The analysis of the spatial and formal relationships between the walls and the surrounding urban context was carried out through a typological classification process based on the systematic observation and evaluation of available documentary sources concerning of four dimensions (Table 1): (i) the physical characteristics of the wall sections, understood as state of preservation, residual height, and continuity of the curtain wall; (ii) accessibility and usability conditions, namely the presence and quality of pedestrian paths, street furniture, and nighttime lighting; (iii) the quality of adjacent spaces, assessed in terms of the presence and maintenance of greenery, the quality of paving, and the absence of conflicting uses; (iv) the intensity and variety of observed usage patterns, with attention to user types, frequency of use, and the presence of forms of informal appropriation (Do, Fassari et al. 2025). The indicators used across the four dimensions were recorded through direct inspection of sections of the wall, following protocols adapted to the nature of the data: physical indicators were measured or estimated on-site according to specified thresholds; qualitative indicators were classified using an observation form with predefined descriptors; usage indicators were derived from repeated observations carried out at different times of the day and on different days of the week.

The proposed was based on direct field observation and on an evaluative analysis of the available documentary sources – including historical and current cartography, photographic documentation, and prior studies concerning the different wall sections – consistent with the predominantly qualitative and historical-critical approach adopted in this research. This typological classification has been supplemented by a comparative analysis of international case studies on the enhancement of linear historical heritage, selected on the basis of criteria of typological similarity (fortified city wall systems), the presence of established enhancement processes, and their representativeness of different models of physical, functional and symbolic integration within the contemporary urban context, as well as their relevance to the Roman case: these include, amongst others, the Renaissance walls of Lucca and the Roman walls of York.

The walls of Lucca were converted into a pedestrian walkway in the early 19th century at the behest of Marie Louise of Bourbon. Today, with the renovation of the elevated walkway (which runs at a height of approximately 12 meters above the embankments) accessible along its entire length by foot and by bicycle, they represent one of the most interesting examples in Italy of a linear urban park (Aveta, C., Sabatini, P., 2025). The walls of York have been made almost entirely accessible by creating a 3.4 km elevated route that encircles the city center; this is accessible free of charge all year round and is deeply integrated into the city's civic and cultural identity (Wilson, Mee, 2005).

A comparison of the approaches adopted in these different contexts has made it possible to identify recurring principles in regeneration projects and to highlight the specific characteristics (and unresolved challenges) of the Roman case.

Table 1. The four analytical dimensions used to assess linear historical infrastructure, applied here to the Aurelian Walls (compiled by the authors)

Dimension	Indicator	Wall typology
Physical characteristics	State of conservation	*Excellent / Good / Deteriorated / Fragmentary*
	Residual height	*High (>3m) / Medium (1–3m) / Low (<1m)*
	Continuity of the curtain wall	*Continuous / Discontinuous / Isolated*
Accessibility and usability	Pedestrian pathways	*Present and equipped / Present but inadequate / Absent*
	Street furniture	*Adequate / Partial / Absent*
	Night-time lighting	*Present / Partial / Absent*
Quality of adjacent spaces	Presence and upkeep of greenery	*Well-maintained / Present but neglected / Absent*
	Quality of paving surfaces	*Good / Poor / Deteriorated*
	Conflicting uses	*Absent / Occasional / Widespread*
Observed use practices	User typologies	*Tourists / Residents / Mixed / None*
	Frequency of use	*High / Medium / Low / None*
	Informal appropriation	*Present and structured / Sporadic / Absent*

3. Results

3.1. The Roman wall system: historical stratification

Rome preserves traces of multiple overlapping wall systems, built in different eras and for different purposes, which together form a historical and documentary record of extraordinary richness (Esposito et al., 2017).

The Servian Wall, traditionally attributed to King Servius Tullius but likely dating to the 4th century BCE following the Gallic sack of 390 BCE, is the oldest of the preserved Roman walls. The structure visible today is the result of a reconstruction carried out during the Republican period along the same route (García-Hernández et al. 2017), built using blocks of Grotta Oscura tuff quarried north of Prima Porta on the Via Tiberina, after the original defenses had proven insufficient to contain the Gallic invasion. It ran across the seven hills of Rome for about eleven kilometers, defining the perimeter of the Republican city. Significant fragments remain today in several parts of the city: at Termini Station, where a long section has been incorporated into a modern public space; in Cinquecento Square; in the Villa Mellini Park; and in the Viminale area. The visibility of these fragments within the contemporary urban fabric varies greatly: some are highlighted and signposted, while others are practically invisible to the uninformed passerby.

The Aurelian Walls undoubtedly represent the most imposing and best-preserved wall system (Esposito et al., 2017). Built between 271 and 282 AD at the behest of Emperor Aurelian, in response to growing external threats that endangered the capital of the empire, the walls encircled the city for about nineteen kilometers, forming a continuous rampart punctuated by square towers at regular intervals of about thirty meters and by monumental gates at the entry points of the main consular roads. Built of brick with a concrete core, the walls originally reached a height of about six and a half meters, which was subsequently nearly doubled by the work of Honorius (or more precisely, his general Stilicho) carried out between 401 and 403 AD, transforming the previous parapet walk into a covered gallery and

creating a new crenelated walkway at the top. They have survived to the present day with remarkable continuity, serving as a perfectly preserved example of late antique defensive architecture. Their construction systematically incorporated pre-existing structures (aqueducts, tombs and suburban villas) into the wall system, creating a built environment of extraordinary complexity (Figure 1).

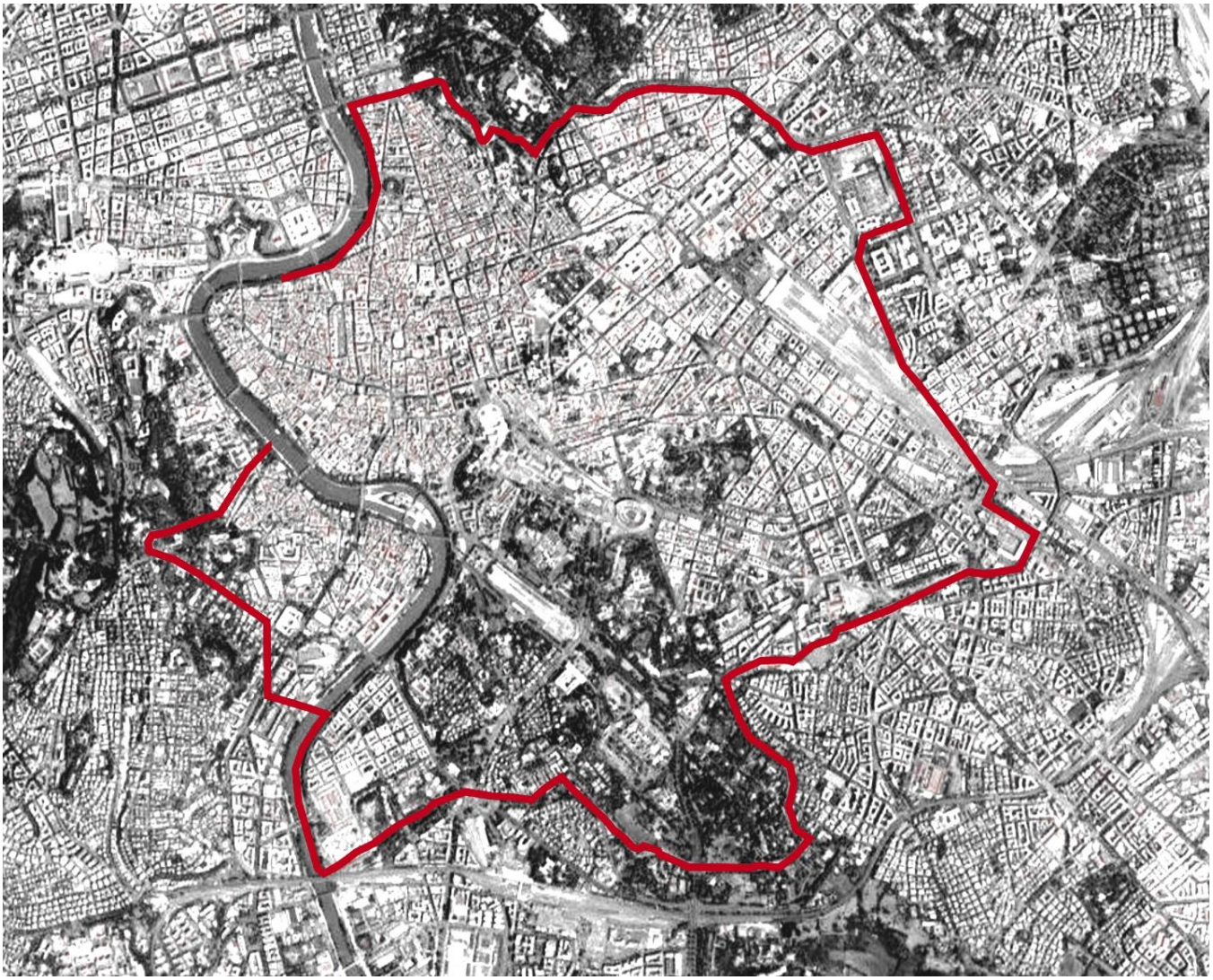

Figure 1. The Aurelian Walls (271–282 AD) traced over the modern urban fabric, showing how the historic perimeter now runs through the contemporary city (authors' elaboration based on aerial photographs)

The Roman wall system also includes elements built in later periods (Molinari and Spera, 2023): the medieval walls that reinforced and modified the Aurelian Wall in some places, adapting it to the defensive needs of a city whose population had declined compared to its imperial heyday; the imposing Leonine Walls, built by Leo IV in 847 AD to enclose the Civitas Leonina around the Vatican in response to Saracen raids, which still constitute a wall system of great significance in the landscape of Borgo and Vatican City; and the Gianicolense Walls, constructed in the 17th century to protect the Gianicolo neighbourhood and subsequently expanded and reinforced in the 19th century.

This layered system cuts through the contemporary urban fabric, creating a sequence of architectural and landscape features of great variety, each with its own characteristics in terms of preservation, context and accessibility. This historical stratification is not merely of antiquarian interest: as the following sections show, the differential preservation, integration and social use of these wall segments today can be read as the cumulative outcome of layered planning decisions, infrastructural pressures and informal practices, and constitutes the empirical basis for the typological classification developed in § 3.2.

3.2. Typological classification of urban contexts

An analysis of Rome's walled infrastructure has led to the identification of four main types of urban context (Horan, Rotondo, 2023).

Table 2. Typological classification of city wall contexts (analytical dimensions from Table 1) and identification of the four types (Barrier, Isolation, Integration and Appropriation). (compiled by the authors)

Type	Physical characteristics	Accessibility and usability	Quality of adjacent space	Observed use practices
Barrier	Walls visible but inaccessible; continuous curtain wall, not passable	Pedestrian discontinuity; difficult or dangerous crossings; absence of dedicated pathways	Illegal parking, unauthorised dumping, inadequate lighting	Marginal use; negative perception by residents
Isolation	Physically intact walls but separated from context; reduced visibility	Accessibility compromised by road infrastructure or surrounding disused areas	Residual spaces, urban voids, abandoned areas lacking quality	Near-total absence of uses; the walls as an invisible element within the context
Integration	Walls enhanced as a structuring element of public space	Equipped pedestrian and cycling paths; adequate lighting; signage	Well-maintained greenery, quality street furniture, adequate paving	Regular and varied footfall; everyday uses by residents and tourists
Appropriation	Walls as physical and symbolic backdrop to informal everyday practices	Variable accessibility; often without formal enhancement interventions	Spaces spontaneously transformed as an extension of domestic space	Informal user communities; jogging, play, etc.; recurrent and identity-forming uses

The first type, defined as the "barrier," includes sections where the walls still function today as a dividing element between different urban areas, creating discontinuities in the pedestrian network and making it difficult to cross. In these areas, the walls are mainly perceived as an obstacle to the movement of pedestrians and cyclists, and the surrounding area often shows signs of neglect (for example, unauthorised parking, unauthorised storage, and inadequate lighting).

The second type, the "isolation" type, includes sections where the walls are physically separated from the surrounding urban fabric by vacant lots, abandoned areas, or large-scale road infrastructure, which drastically reduce their visibility and accessibility. In these cases, the walls exist as isolated objects in a context lacking in urban quality.

The third type, "integration", encompasses sections where the walls have been incorporated into a system of high-quality public spaces, featuring well-equipped pedestrian and bicycle paths, well-maintained green spaces, adequate lighting, and quality street furniture. In these sections, the presence of the walls positively contributes to the quality of public space, offering a highly evocative architectural backdrop for residents' daily activities.

The fourth type, "appropriation", includes sections where the local community has developed informal uses and practices of spontaneous appropriation, even in the absence of formalised initiatives to enhance the area. In such instances, the evocative power and physical presence of the walls have given rise to a process of informal appropriation by residents, who have transformed the adjacent spaces into extensions of their everyday living spaces.

"Barrier" and "isolation" are defined primarily by physical-spatial criteria – respectively, the disruption of pedestrian connectivity and the physical detachment of the wall from the surrounding urban fabric – whereas "integration" and "appropriation" describe two analytically distinct dimensions of the relationship between the walls and public space (Figure 2): integration denotes a formal, design-driven condition, in which planned interventions (paths, lighting, green space, furniture) have produced a high-quality public space; appropriation denotes an informal, bottom-up condition, in which use and attachment emerge from residents' spontaneous practices, independently of (and at times despite) the absence of formal design interventions. The two categories are therefore not mutually exclusive: a well-integrated section may also display appropriation practices, and appropriation can occur even in physically unenhanced (barrier or isolation) contexts. Table 2 reports the classification adopted together with the indicators supporting it.

3.3. Spatial distribution and analysis of nodes

Based on the observational protocol described above, the distribution of the four contextual types along the perimeter of the Aurelian Walls shows a markedly uneven pattern, reflecting the layering of enhancement projects carried out over time and the varying degrees of urban pressure exerted by the surrounding neighbourhoods. The best-integrated sections are concentrated in the area of the Gianicolensi Walls Park and in certain sectors of the Celio and the Appia Antica, where the walls are surrounded by high-quality urban green spaces and well-equipped pedestrian paths that allow for continuous and varied use, with a mix of residents, athletes, and visitors attesting to its vitality as a public space. The most critical sections, on the other hand, are located in the eastern areas of the city, between Nomentano and Tiburtina, where the walls are often reduced to a backdrop for industrial or degraded residential areas, lacking any enhancement of the adjacent public space: the direct contact between the built environment and the wall system appears associated, on the basis of the observational evidence collected, with situations of physical compression and perceptual degradation that may compromise both the legibility and the usability of the walls.

Figure 2. The four types of relationship between the Aurelian Walls and their surrounding urban context: Barrier, Isolation, Integration, and Appropriation (developed by the authors)

The monumental nodes (gates and towers) constitute the points of greatest architectural quality and highest identity recognition within the entire wall system. The main gates – the most significant of which are Porta San Sebastiano, Porta San Paolo, Porta Maggiore, Porta Pia, Porta del Popolo and Porta San Giovanni – have generally undergone more systematic restoration and improvement work and are now the points of greatest tourist influx and most intensive social use. The towers, distributed at regular intervals along the walls, represent, on the other hand, an architectural heritage of remarkable quality but one whose enhancement remains largely incomplete: many have been incorporated over time into residential or private buildings, rendering them effectively inaccessible to the public; some are undergoing restoration and controlled opening, such as those along the route of the Museum of the Walls at Porta San Sebastiano; many others remain visible from the outside but inaccessible, presenting themselves as a heritage site with potential for activation through controlled access programs and uses compatible with conservation (Figure 3).

The Museum of the Walls, housed in the Porta San Sebastiano building and along a long stretch of the top walkway of the Aurelian Walls, represents the most successful attempt to open the wall structures to public use in their three-dimensional form. The walkway route offers a unique perspective on the city, allowing visitors to experience Rome from atop the city walls in a spatial relationship that reverses the

usual viewpoint and reveals the urban topography with extraordinary clarity. This mode of vertical exploration – which allows visitors to experience the structure from within and from above, revealing the defensive logic and scale of the work – is among the most promising approaches for enhancing the walls as a public space, as it combines the museum experience with experiential and landscape elements in a way that is difficult to replicate through other means.

Figure 3. Two of the most significant gates along Walls: Porta San Sebastiano (275 AD) and Porta San Giovanni, added later (16th century) (illustration by the authors)

3.4. Practices of use and spontaneous appropriations

Systematic observation of practices of use along the Roman walls s has revealed a rich and varied picture, encompassing both planned and formal uses and the spontaneous appropriations generated

by the evocative power and physicality of the walled heritage. The former includes visits to the Museum of the Walls, cultural events organised along or near the walls (concerts, theatre performances, film screenings, temporary exhibitions) and sporting activities in the adjacent parks. The latter include jogging and cycling along the footpaths, climbing on certain sections of the towers, informal use of the adjacent lawns for picnics and play, and street art on some of the less- monitored parts of the city walls.

In the parts that can be safely accessed, the greenery is well-maintained and the perceived safety is adequate, there is regular and socially diverse use, with the simultaneous presence of children, the elderly, sports enthusiasts and tourists: a density and variety of uses that Whyte (1980) would have recognised as reliable indicators of the quality of public space.

In run-down or underserved areas, however, the walls are ignored by the vast majority of passers-by or only marginally frequented by specific groups of users, which is consistent with the argument that the physical quality of the adjacent spaces is crucial to unlocking the heritage's potential to foster a sense of identity (Labadi, Logan 2015).

One element of particular interest is the presence, in certain sections, of informal communities of users who appear to have developed a strong sense of belonging to the spaces adjacent to the walls: joggers who regularly gather under a particular arch, children who consistently play on a certain lawn, elderly people who meet every afternoon on a bench in front of a section of the curtain wall. These communities of practice, often invisible to planners and administrators, represent the deepest connective tissue between heritage and everyday urban life: this recurrence suggests that the walls may have already generated, spontaneously and in the absence of any formal intervention, processes of collective appropriation potentially conductive to identity and a sense of community. Recognising, supporting and enhancing these informal practices therefore constitutes one of the most significant (and most promising) challenges for any strategy to regenerate the wall system.

The identification of informal communities of users, their sense of belonging and the associated identity-building processes should therefore be understood as an interpretive reading grounded in repeated observation, rather than as findings verified through resident testimony. Triangulating the observational findings with qualitative interviews and/or user surveys represents an important direction for future research and would allow the hypotheses on identity formation and social appropriation advanced here to be tested more robustly.

4. Discussion

4.1. Interpretation of the results: regeneration strategies

The results of the case study carried out on Rome walls enable us to identify three general strategies (which are complementary and not mutually exclusive) for the regeneration of linear heritage: these operate on different scales and with different tools, but all contribute to the same aim of transforming the walls from residual infrastructure into a system of public spaces that define a sense of identity. Their effectiveness is, however, conditioned in each case by specific contextual factors – the quality of the surrounding urban fabric, the availability of management resources, the degree of local community involvement – which determine their applicability and sustainability over time (Table 3). It should be stressed that these contextual factors are treated here as conditions associated with differential effectiveness, as observed within a single, non-experimental case study; the qualitative design of the research allows such associations to be identified and interpreted, but does not permit the demonstration of causal mechanisms in a statistical sense. Where a causal link is proposed in what follows, it is offered as an interpretive hypothesis to be tested through further comparative research, rather than as an established causal relationship.

Table 3. Strategies for the regeneration (physical accessibility, integration into the landscape and cultural programming) and their respective objectives, tools, case studies and implementation challenges (compiled by the authors)

Strategy	Main Objective	Tools and Actions	Exemplary Case	Key Challenges
Physical Accessibility	*Ensure continuous walkability of the wall system as a unified itinerary*	*Pedestrian and cycling paths; lighting; signage; traffic calming*	*Ostiense-Aventino stretch (Lungotevere — Porta San Paolo)*	*Discontinuities caused by road traffic; fragmented governance among institutions*
Landscape Integration	*Connect the built heritage with the urban public green network*	*Linear parks; equipped green spaces; shared management with local communities*	*Parco delle Mura Gianicolensi*	*High maintenance costs; risk of degradation due to lack of stable resources*
Cultural Programming	*Build a shared cultural identity and animate the wall spaces over time*	*Events, installations, temporary uses compatible with conservation*	*Estate Romana (concerts, screenings, performances along the walls)*	*Seasonality of interventions; difficulty in building continuous year-round programming*

The first strategy concerns physical accessibility and the uninterrupted connectivity of the entire wall system. The construction of a network of footpaths and cycle paths capable of overcoming physical discontinuities and gaps in connectivity represents the most urgent priority from a structural perspective, with a dual purpose: functional, by improving soft mobility in dense urban areas; and experiential, by allowing the walls to be enjoyed as a unified route and enabling visitors to appreciate their richness and variety across the different contexts they pass through. The Ostiense-Aventino section of the Aurelian Walls offers a successful example of this strategy: the pedestrian route running alongside the walls from the Lungotevere to Porta San Paolo has been upgraded with improvements to the road surface, night-time lighting, signage and street furniture, creating a continuous and safe route used daily by residents and tourists; integration with the Piramide-Ostiense underground station also ensures accessibility from other parts of the city. However, the problem of discontinuities caused by road traffic remains unresolved; at various points, roads cut across the wall route, creating dangerous crossings, the solution to which requires traffic calming measures and, in some cases, a more fundamental reorganisation of the local road network. This pattern suggests, more specifically, that continuity of the physical route functions as a precondition for the other two strategies discussed below to succeed: without a minimum threshold of walkable continuity, neither landscape integration nor cultural programming appear able to generate regular, non-episodic use, an interpretive link that future research should test explicitly rather than assume.

The second strategy involves integrating the wall system into the landscape through the creation of linear parks that link the built heritage with the network of public green spaces, transforming the adjacent areas into a series of landscaped green spaces. The Gianicolensi Walls Park serves as a prime example of this strategy: stretching along the route of the 17th-19th century papal walls, it offers a varied sequence of spaces of different qualities and characters – formal sections with tree-lined avenues and flowerbeds alternate with more natural areas featuring wild vegetation and open views of the city – and is now one of Rome's most popular urban parks, with a daily presence of residents who have made it an extension of their own domestic space. This strategy, however, presents significant management challenges: maintaining the quality of the green spaces requires continuous and substantial financial resources, which local authorities often struggle to guarantee on a stable basis, with the risk that ambitious projects will gradually deteriorate due to a lack of routine maintenance.

Management sustainability must therefore be considered a design constraint from the very outset, guiding decisions towards low-maintenance solutions and forms of management shared with local communities. The Gianicolensi case indicates that where dedicated management resources are lacking from the outset, the initial quality of design does not appear sufficient on its own to guarantee durable public use, an association that, again, should be read as a pattern to be verified rather than as a proven causal relationship within the scope of this study.

The third strategy concerns cultural planning and temporary activation of spaces through events, art installations and programmes of use that are compatible with heritage conservation. Unlike the previous strategies, this one does not require large-scale permanent physical interventions but has a significant impact on revitalisation of spaces, public visibility of heritage and redevelopment of a shared cultural identity sense (Connolly, 2015). The 'Estate Romana' programme has repeatedly used the city walls as a backdrop for various types of events (concerts, theatre performances, film screenings) with positive results in terms of attendance and the collective perception of the heritage. The main challenge, however, lies in overcoming the seasonal nature of these initiatives by establishing a continuous and diverse programme capable of generating regular use throughout the year, transforming the exceptional event into an ordinary practice of heritage enjoyment. This suggests that the perceived value of city walls as public space is not solely a function of their physical or landscape qualities, but also of the intensity and continuity of programmed activity though, again, isolating an independent effect of programming from that of accessibility and landscape quality would require a research design capable of disentangling these variables individually, which lies beyond the scope of the present study.

4.2. The case of Rome: theoretical validation and empirical specificities

The findings of the case study on Rome confirm and expand upon certain key insights that have emerged from the literature on heritage-led regeneration. The data collected on regeneration practices relating to the Walls and their urban context are consistent with the approach outlined in the Recommendation on the Historic Urban Landscape – HUL (UNESCO, 2011), which conceives of urban heritage as a layer of meanings accumulated over time and interwoven with the cultural practices of the communities that inhabit and transform the urban space. The typological analysis and the patterns of use documented in section 3 show that the walls function, in several of the contexts examined, as a structure that connects rather than separates different eras, neighbourhoods and practices of use, an indication compatible with Choay's (1992) reading of heritage as a living sediment of urban history. However, this evidence remains illustrative: a genuinely critical test of the HUL approach would require assessing whether the layering of meanings it describes is also perceived and valued as such by residents themselves, rather than inferred by the researchers from spatial and functional analysis alone, an assessment that this study, lacking a dedicated perceptual survey (see § 4.3), is not in a position to provide.

The analysis highlights the conceptual and theoretical shift from the enhancement of individual monuments to linear heritage, understood as a continuous sequence. This aspect requires a systemic approach and the planning of interventions that take account of the relationships between its parts and the potential for connectivity along the entire length of the wall (Tiesdell et al., 1996; Madanipour, 2010; Do, Fassari, et al., 2025), thereby fostering processes that reinforce physical and functional continuity to create high-quality public spaces.

A comparison with similar international cases of linear heritage enhancement supports this argument. The case of the walls of Lucca currently represents the finest Italian example of a modern fortification that is fully preserved and freely accessible, frequented daily by residents and tourists for walks, physical activity and cultural events of international appeal. The walls of Lucca benefit from a long-established management model coordinated directly by the local council, unlike the Roman system, where the walls fall within the jurisdiction of multiple authorities (see § 4.4). The case of York's city walls confirms

that the enhancement of linear heritage requires a city-wide strategy and a systemic vision, rather than a series of isolated interventions, and must be managed in a similar manner by a single conservation body with a uniform system of public access, without any discontinuity in ownership. These comparisons suggest that institutional and managerial simplicity, rather than the value of the heritage or the quality of the landscape itself, may constitute a key differentiating factor between the more comprehensive enhancement seen in Lucca and York and the more fragmented situation in Rome. The comparison, however, remains largely qualitative and based on secondary sources rather than on a common, structured set of indicators applied consistently: it will need to be developed in future phases of the research by defining a cross-sectional analysis that systematically links the Roman case to the international framework.

The importance of daily use emerges clearly from international comparisons as a key factor distinguishing successful regeneration projects from disappointing ones. Gehl (2010) has shown that the quality of public space depends first and foremost on its ability to meet the everyday needs of residents (strolling, sport, play, socialising) rather than on its appeal to tourists or its monumental significance. This resident-centred framework, however, is not uncontested: other scholars have argued that an exclusive focus on everyday, informal use can underestimate the economic and symbolic value generated by tourism-oriented and monumental uses of heritage (du Cros, McKercher, Ee Ong, 2026), and can obscure how access to 'everyday' quality public space is often unevenly distributed across neighbourhoods with different socio-economic profiles a concern this study, based on qualitative observation rather than a social survey (see § 4.3), is not able to fully address. This lesson is clearly borne out in the case of Rome: the sections of the walls most frequented and most appreciated by the local population are invariably those that integrate best with the daily life of the neighbourhood (due to the quality of the routes, the presence of greenery, and perceived safety) and not necessarily those of the greatest architectural or historical value. Within the limits of this study's qualitative and observational scope, daily use by residents appears as an important indicator of the success of heritage enhancement, consistent with Gehl's framework, and as a condition that helps make walled heritage a resource for the everyday city rather than solely a backdrop for tourism though the other value dimensions of heritage enhancement discussed above cannot be dismissed on this basis alone (Pulles et al. 2023).

Positioned within the broader Mediterranean urban context, in which several historic cities are structured around comparable systems of city walls the Roman case shares with these cities a set of recurring challenges: strong seasonal tourism pressure that can crowd out everyday resident use of heritage space; exposure to a hot-summer climate that shapes patterns of use and requires shade and vegetation as design priorities; and, in several cases, overlapping religious, state and municipal authorities with joint or contested responsibility over heritage assets, a condition Rome shares, in relation to the Leonine Walls, with the Vatican City State (see § 4.4). Read in this light, the Roman experience may offer transferable lessons not only to European walled cities in general, but more specifically to Mediterranean cities confronting similar combinations of climatic, touristic and jurisdictional pressures, a dimension that future comparative research could usefully develop.

4.3. Methodological contribution and limits of the research

The research's points of strength reside primarily in the exceptional nature of the case study: the Roman wall system offers an almost complete range of contextual situations – from full integration to the most advanced state of decay – and a historical and stratigraphic depth unrivalled in Europe, making it a privileged laboratory for reflection on linear urban heritage. The typological classification into four contexts (barrier, isolation, integration, appropriation) allows the wall system to be interpreted not as a uniform and undifferentiated whole, but as an articulated sequence of specific situations requiring differentiated design and management approaches. Its methodological contribution should, however, be qualified: the typology has so far been developed and applied only within the Roman case, and its

validity, discriminant power and transferability to other linear heritage systems have not yet been tested empirically. Establishing whether the four categories identified here can be applied consistently to other city-wall systems, or whether they require adaptation to different historical, morphological and institutional conditions, remains an open question for future comparative research rather than a result already demonstrated by this study. The limitations of the study must, however, be explicitly acknowledged.

Firstly, the research is based on qualitative methods of analysis: whilst these allow for an in-depth understanding of the phenomena and patterns of use, they do not permit their statistical measurement in terms of economic, social and cultural impacts (Borin, 2025). The difficulty of precisely quantifying the intensity, frequency and variety of the uses observed – in the absence of systematic surveys using counters, questionnaires or structured observation techniques – represents a significant limitation for the purposes of a comparative assessment of the effectiveness of interventions.

Secondly, the specific nature of the Roman context (due to its stratigraphic complexity, the scale of the system and the exceptional quality of the heritage) makes direct comparison with other, smaller-scale European wall systems difficult, limiting the generalisability of the comparative effectiveness of the various enhancement strategies.

Thirdly, the temporal scope of the analysis, which focuses on the present, does not allow for an assessment of the long-term evolution of the effects of the interventions carried out, nor does it enable the measurement of changes in usage patterns induced by the interventions themselves.

Finally, the research does not include a systematic investigation of residents' perceptions, preferences and evaluations, which would have required a specific sociological component (through in-depth interviews, focus groups or structured questionnaires) capable of capturing the viewpoint of the heritage's primary users and integrating external observation with the users' perspective.

4.4. Operational implications and research perspectives

The future implications for further research lie on two distinct yet complementary levels, concerning respectively the operational dimension of managing Rome's walled heritage and the theoretical dimension of research into regeneration guided by linear heritage.

On the operational level, the recurring association observed across the three strategies analysed in § 4.1 – between the availability of stable resources, coordinated institutional responsibility, and the durability of public use – points to the need for a unified strategy for the Roman wall system, supported by appropriate governance and stable, long-term resources; this connection is proposed here as an interpretation grounded in the empirical patterns discussed above, rather than as a self-standing policy prescription. The fragmentation of institutional responsibilities – distributed among the Ministry of Culture through the Superintendencies, the Municipality of Rome, the relevant individual Municipalities and, for the sections of the Leonine Walls, the Vatican City State – and the resulting lack of consistency in the interventions carried out constitute the main structural obstacles to an effective and coherent enhancement of the entire system. The establishment of a programme agreement between the various competent institutional bodies, accompanied by an urban-scale strategic plan, shared quality standards for interventions, and stable, multi-year funding mechanisms, represents the necessary precondition for any systematic enhancement strategy. In this regard, experiences of integrated governance already tested in other Italian and European contexts for the management of complex, multi-jurisdictional heritage can offer useful models and reference tools. These operational indications should nonetheless be read as directions suggested by the empirical patterns identified in this study, to be substantiated through dedicated governance-focused research, rather than as conclusions directly demonstrated by the case-study analysis presented here.

On a theoretical level, the research offers opportunities for further exploration in at least three directions. The first concerns the significance of linear heritage in sustainable urban regeneration processes and the identification of indicators capable of evaluating social, cultural and economic impacts of enhancement initiatives, thereby filling a significant methodological gap in the literature (Torrieri, Oppio, Rossitti, 2021). The second concerns the development of integrated governance frameworks for the management of complex heritage assets spanning multiple administrative jurisdictions, an issue that the Roman case highlights with particular urgency but which is of general relevance to many European walled city systems. The third direction, perhaps the most promising, concerns the participatory dimension: future research should analyse the ways in which local communities can be involved not only as end-users but as active co-producers of heritage enhancement, in line with Harvey's (2008) insights on the "right to the city", viewed as the collective right to shape urban space, and Sennett's (2018) considerations on the ethics of urban development, understood as an open, negotiated and inclusive process. Concretely, such research could examine instruments already tested in other heritage and public space contexts, such as community stewardship or 'adoption' agreements for the maintenance of specific sections, participatory budgeting processes applied to green-space and public-art programming, co-design workshops preceding intervention in the most contested contexts (those classified in this study as 'barrier' or 'isolation'), and structured neighbourhood committees with a formal advisory role in the ordinary management of the Estate Romana-type cultural programme described in § 4.1. It should be emphasized, however, that there is a practical difficulty in reconciling participatory ambitions with the conservation constraints inherent to protected heritage sites, as well as with the asymmetries in terms of time, expertise, and organizational capacity between institutions and community groups, which may limit participation to a consultative process rather than a genuinely co-produced one. Whether and how the Roman walls system can foster forms of participation that avoid this risk is a question that this study can raise but not answer, given its predominantly observational approach (see § 4.3).

5. Conclusions

The results of the research confirm that cultural heritage can take on new meanings and new functions for the contemporary city whilst retaining its historical identity. Rome's walls do not need to be radically transformed to become high-quality public spaces: their evocative power, imposing physicality and ability to connect different eras of urban history are extraordinary resources waiting to be freed from the conditions of marginalisation and neglect in which they are all too often found. The analysis has highlighted a situation of great potential but one in which development remains patchy and uneven. The Roman wall system possesses exceptional characteristics (physical continuity, architectural quality, the variety of urban contexts it traverses, and the depth of its historical stratification) which make it one of Europe's most significant linear heritage sites. However, the fragmentation of governance, the inconsistency of the interventions carried out and the lack of a unified systemic vision have produced a situation in which instances of excellence alternate with stretches of decay or neglect, compromising the legibility and usability of the system as a whole.

A methodological framework based on five operational principles constitutes the main theoretical proposal derived from the analysis (Figure 4). The first principle is that of an integrated reading of the wall system as a continuous linear infrastructure: before intervening on individual sections or nodes, it is necessary to understand the system in its entirety, its spatial distribution within the urban fabric, its relationships with the road network and green spaces, and its discontinuities and potential for connection.

The second principle is that of diversifying approaches according to context: there is no single optimal solution, but rather a range of design and management responses to be tailored to the physical and social characteristics of each section. The proposed typological classification (barrier, isolation, integration, appropriation) constitutes a useful operational tool for guiding design and management

choices in relation to the specific characteristics of each section, avoiding the mechanical application of standardised solutions to situations that require differentiated responses.

The third principle is that of prioritising everyday use over exceptional tourist use: a heritage site enhanced for residents automatically becomes more attractive to visitors as well.

The fourth principle is that of management sustainability as a design constraint: any intervention must be conceived with a view to its long-term manageability, favouring simple, robust and low-maintenance solutions.

The fifth principle is that of integrated governance and community participation as enabling conditions: even the best physical design will not produce the expected results unless it is supported by adequate governance and a participatory process involving local communities. Observation of spontaneous usage patterns has revealed the walls' capacity to generate collective appropriation even in the absence of formal interventions, indicating that the potential of the wall heritage as a generator of urban life is real and widespread, but needs to be supported by appropriate physical and management conditions.

Figure 4. The five operational principles: (1) integrated analysis, (2) contextual diversification, (3) prioritising everyday use, (4) management sustainability, and (5) governance and participation (compiled by the authors)

The methodological insights drawn from the Roman case are applicable, with the necessary adaptations, to other urban contexts featuring similar linear historical heritage. Future research should include: structured comparative analyses of historic wall systems in different European contexts, checking the transferability of the proposed framework; quantitative assessments of the social,

economic and cultural impacts of the enhancement interventions carried out, using established measurement methodologies (Habitat III, 2016); longitudinal studies on the evolution of usage practices and communities of appropriation in relation to enhancement interventions; experiments with models of participatory governance applied to the management of linear heritage, with the active participation of local communities in the redevelopment of these spaces. The challenge of enhancing historic walls is not merely technical or design-related, but cultural and political: it requires a long-term vision, a capacity for integrated governance among different institutional actors and, above all, the will to place heritage at the service of people's lives and the construction of a city that is fairer, more beautiful and more aware of its own history.

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Studies involving animal subjects: No animal studies are presented in this manuscript.

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Inclusion of identifiable human data: No potentially identifiable human images or data is presented in this study.

Conflict of Interests
The author declares no conflict of interest.

Contribution to the Field statement
This contribution is situated within the debate on heritage-led urban regeneration, offering advances on three levels. On a theoretical level, it proposes a systemic interpretation of linear cultural heritage that moves beyond the prevailing sectoral approach, shifting the perspective from a constraint to a strategic resource for the contemporary city. Methodologically, through the analysis of the Roman case study, five principles (systemic interpretation, context-sensitive diversification, priority of use, managerial sustainability, and participatory governance) translated into analytical terms, thereby establishing a heuristic framework for future comparative research. Empirically, the observed phenomena can be interpreted as indicators of the identity-forming potential of linear heritage for the regeneration of marginalized areas.

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Tactical Urbanism as an Approach for Reactivating Lost Urban Spaces in Developing Cities

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ABSTRACT

Lost urban spaces are sites of informal activities or areas which often become neglected, posing challenges to city management. However, they also hold significant potentials as assets for sustainable urban development by generating income and encouraging community participation, particularly in developing countries. Through tactical urbanism, lost spaces can be transformed into productive and community-serving environments. Tactical urbanism offers an effective approach for this transformation, relying on low-cost, flexible and service-oriented interventions. This paper explores the concept of lost urban spaces, their types and latent potentials, alongside with an overview of tactical urbanism, its definition, importance and mechanisms. An analytical study for different examples demonstrates how tactical urbanism can successfully reactivate lost spaces. Finally, the study proposes context-sensitive framework for integrating tactical urbanism into sustainable urban regeneration strategies that can be applied in developing cities and proposes recommendations at multiple levels.

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1. Introduction

Most cities contain lost urban spaces that directly benefits communities and can become sites of informal and undesirable activities, creating serious problems for urban management. Currently, the weakness of planning has led to the spread of urban voids and meaningless spaces on different scales over the city. Since these spaces are mostly noticed by the residents, they have become a safe place for crime and eventually the occurrence of social abnormalities. In addition, the lack of citizen's participation in the planning and designing process of spaces, causes stakeholders to not feel a sense of belonging to their surroundings and consequently, no sensitivity towards lost urban spaces and their

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revitalization. As a result, it is essential to inform citizens about lost urban areas and encourage them to reactivate them.

Despite these issues, such spaces represent untapped potential for fostering social interaction, economic activity and sustainable urban development, particularly in developing countries where strategic approaches to their activation remain limited or poorly integrated into planning frameworks.

Reactivating lost urban spaces is important because it helps to solve many problems. This can be achieved through various methods, one of which is clarifying the problem and spatial rearrangement commonly used in tactical urbanism. Tactical urbanism anticipates low costs with small interventions, produces site-specific and needs-oriented quick solutions, creates public awareness among users and it is considered as a participatory and a potential approach and a form of application particularly in contemporary urban environments in developing cities.

The study aims to bring attention to the potential and capabilities of lost urban spaces and encourage community residents, popular institutions and city authorities to reactivate them. Also, the study investigates tactical urbanism as an effective strategy for their reactivation. Additionally, examines the physical, social and functional characteristics of lost spaces while considering tactical urbanism principles, mechanisms and outcomes. The study proposes context-sensitive framework for integrating such interventions into sustainable urban regeneration.

Guided by four key research questions, what are the characteristics and types of lost urban spaces, what latent potentials do these spaces hold, how can tactical urbanism interventions effectively reactivate them, and what strategies can inform sustainable urban regeneration.

The study hypothesizes that lost urban spaces, if strategically activated, can generate social, economic and environmental benefits; that tactical urbanism, through low-cost, flexible and community-oriented interventions, can serve as a practical mechanism for such activation; and that context-sensitive application of these interventions can enhance urban sustainability and community engagement in developing cities.

To address these questions, the study employs a multi-method approach. It includes a comprehensive literature review that deals with the concept and typology analysis of lost urban spaces. It highlights the values and benefits of lost urban spaces on the community and its residents. Also, it presents the importance of tactical urbanism to reactivate the lost urban areas. Then, detailing the methodology, the study presents and analyses different international examples of tactical urbanism interventions and discussing the implication for sustainable urban regeneration. This is followed by various case studies from the Alexandrian context proposing framework for applying tactical urbanism in developing urban contexts. Finally, the study recommends and proposes actionable recommendations and practical guidelines for urban planners and policy makers (Figure 1).

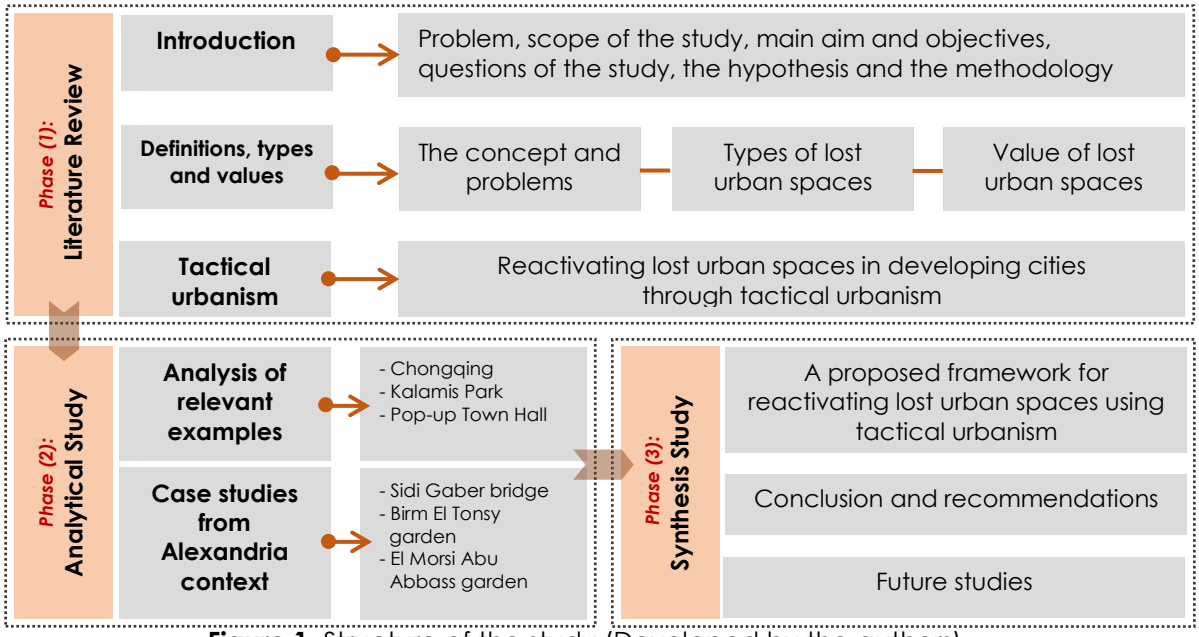

Figure 1. Structure of the study (Developed by the authors)

2. Lost Urban Spaces

2.1. Concepts and problems

Lost urban spaces refer to spaces that are neglected and have no clear function. "Lost urban spaces", the fundamental problem of the study, are defined by Trancik as "the undesirable urban areas that are in-need of redesign anti-spaces making no positive contribution to the surroundings or users". They are physically significant with low-flow rate of users (Trancik, 1986). Also, Yu Hui Sung states that "the absence of main users of spaces, the social purpose influence and the amorphous urban growth of the city may be the cause for the increase in the merging lost urban spaces" (Sung, 2009).

The term "lost spaces" is used to refer to settings and areas within the region of the city that are to forgotten, unused and abandoned. These spaces are typically located between residential and commercial areas. Sometimes these spaces are created unintentionally due to the construction of multiple projects. It is important to manage lost urban spaces and revive them by using them to improve the quality of life, especially in developing countries (Hashem, Wahba and Nasr, 2022). Additionally, the composition of lost spaces changes from city to city based on urban expansion which can be negatively affected through environmental, social and economic challenges.

Furthermore, lost urban spaces can negatively affect the urban fabric directly or indirectly. Community degradation can result from widespread criminal activity that threats the residents and visitors making the places undesirable (Demashkieh, 2022).

The majority of lost urban spaces are either occupied by planned structures or by spontaneous development. They always respond to shapes and dimensions according to their boundaries (walls, roads, natural barriers, etc.). The lack of maintenance in the lost spaces is more likely to affect specific interests such as sellers, temporary accommodation, parking and other factors which contribute to gradual deterioration of these locations (El Messeidy, 2019).

These spaces come with many problems that affect the lifestyle and health of the city where residents and visitors unconnected socially with their surroundings. Lost urban spaces can become areas to issues such as homeless, crime and environmental deterioration (Figure 2). The common problems associated with these spaces are:

a) Homeless
b) They offer shelter for homeless individuals due to their isolated nature. Lack of proper sanitation and security can exacerbate the challenges faced by this vulnerable population.
c) Safety concerns
d) These areas may draw criminal activities such as drug dealing, vandalism and graffiti. The lack of visibility and oversight makes it challenging for authorities to monitor and solve these concerns effectively.
e) Urban and Environmental degradation
f) Lost spaces can affect the overall aesthetic and appeal of the surrounding urban environment, leading to perceptions of urban blight and degradation. This can impact local property values and prevent local investment. In these areas, pollution, trash accumulation and lack of maintenance contribute to environmental deterioration. Dumping of wastes and dangerous materials can further harm the ecosystem and the surrounding water bodies.
g) Social isolation
h) The presence of lost spaces can create physical and social barriers within communities, isolating residents from essential services, recreational areas and economic opportunities.
i) Health risks
j) Inadequate sanitation and poor hygiene in these spaces may increase the risk of diseases and health issues for both residents and visitors.

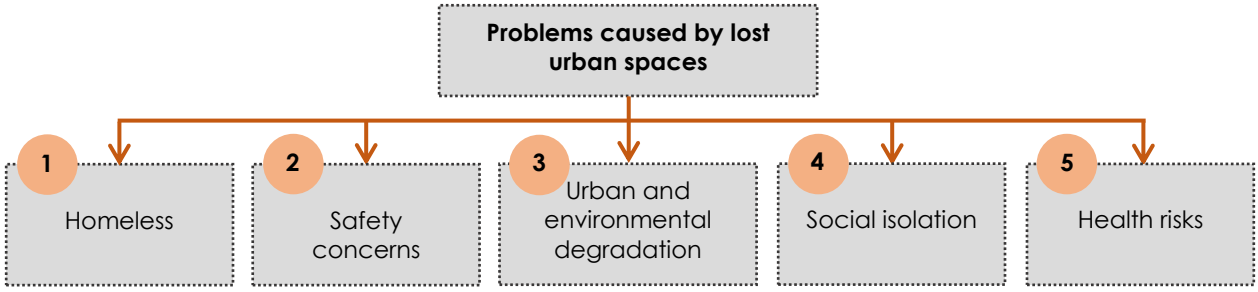

Figure 2. Problems caused by lost urban spaces in developing cities
(Developed by the authors)

In order to solve these problems, a comprehensive strategy involving collaboration government agencies, community organizations and residents is needed. Strategies may include regular maintenance and clean-up efforts, improved lighting and security measures, provision of supportive social services for individuals and initiatives to activate these spaces for recreational cultural activities (Figure 3). Additionally, tactical urban planning and design approaches can help transform neglected areas into vibrant and inclusive community spaces (Trancik, 1986 and Lak, Ramezani and Aghamolaei, 2019).

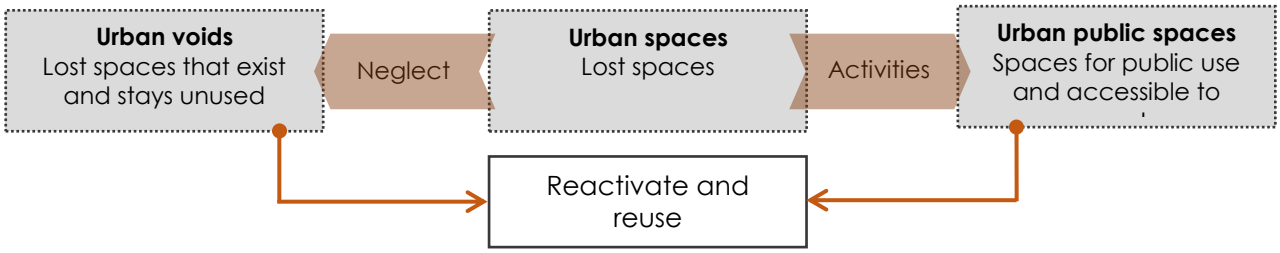

Figure 3. The transformation of urban spaces from urban voids to activated public spaces
(Developed by the authors)

2.2. Types and classification of lost urban spaces

There are various kinds of lost spaces such as isolated, disorganized, empty and purposeless areas. Abandoned lots such as parking lots, pedestrian walkways, spaces under bridges, parks, … etc. are referred to as lost urban spaces. Additionally, Jacob (1961) defines lost spaces as buildings, infrastructure and vacant spaces that create physical and social boundaries in cities. Morales gives examples of dangerous residential communities and abandoned industrial areas in his book Terra Incognia (Bowman and Pagano, 2004). He also notes that these areas are potential areas for urban revitalization projects. Different forms of lost spaces that emerged in the urban fabric are discussed among various planners and architects (Figure 4). Some of these may be summarized as follows:

a) Unused waterfronts: They are focused on the coastline and the shores of seas and rivers. They could be undeveloped lands or urbanized shores.

b) Spaces under bridges: They are typically ignored, neglected or abandoned which lead to lost chances for community involvement.

c) Socially inefficient green spaces: Land lots that are poorly designed mainly made as a green parks, but time and negligence led to their deterioration or areas where many plants grow uncontrollably.

d) Oversized streets: Large streets that are made for cars with no human connections, no trees and even nowhere to sit, play and socialize.

e) Parking lots: These are spaces where vehicles are parked temporarily creating unnecessary scattered voids between the buildings and the city or surface parking lots squeezed between two buildings.

f) Industrial sites: Abandoned factories bordered by fences and disorganized areas where waste from factories is thrown away and are filled with polluted spaces.

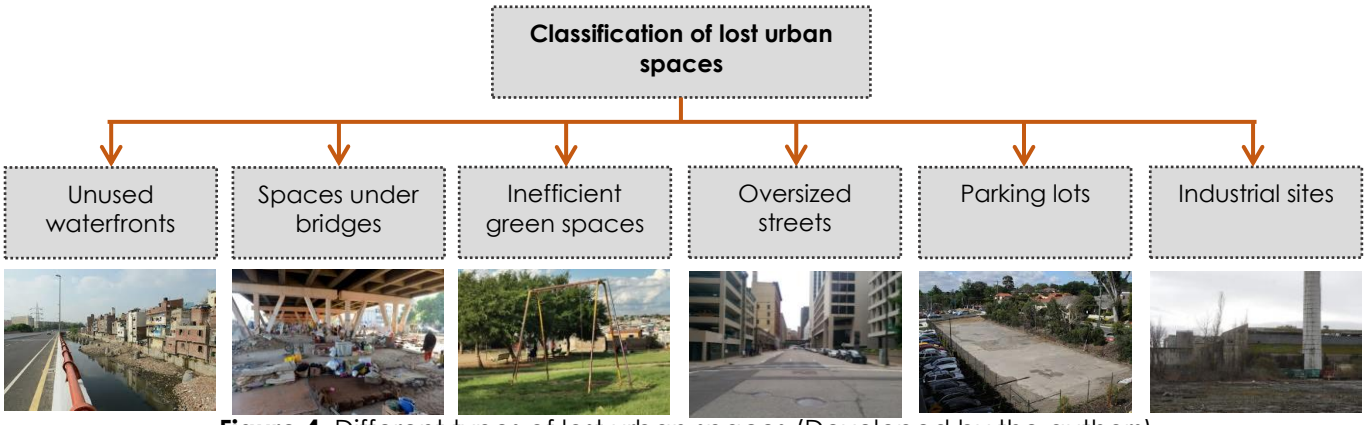

Figure 4. Different types of lost urban spaces (Developed by the authors)

Neglecting lost urban spaces can stay undeveloped due to ownership issues, physical conditions or lack of consideration during the planning process. As a result, they easily become trapped in a vicious cycle of decline that hinder the development of the area and cause it to be more neglected (Hwang and Lee, 2020).

It is possible to recycle, empower, densify, modify and incorporate green technologies in lost urban spaces, especially in residential neighbourhoods (Omar and Saeed, 2019). However, if these areas are neglected, the city may have economic, social and environmental problems. Thus, it is crucial to

address and repurpose these spaces to keep them from becoming a burden on the community (Kasarabada, 2020).

2.3. Values and potentials of lost urban spaces

Over the past few decades, many studies have focused mostly on urban public spaces such as piazzas, squares and public areas without going into detail into lost spaces and how to use them perfectly to benefit the city.

Regardless of the negative impacts of lost urban spaces on the city, they may be an important resource that greatly enhances the community's quality of life. These values are divided in environmental, social, economic, cultural, historic and visual values (Tobias, 2018). The study will review these values and their impact on improving the city's life to be liveable, healthy and sustainable.

2.3.1. Environmental value

Lost urban spaces may have environmental benefits such as improving the quality of life in communities.

By reducing environmental degradation through restoring natural habitats for a wide range of living organisms such as (plants, birds, insects, mammals, … etc.), promoting biodiversity and mitigating pollution and run-off through green infrastructure. Also, conserving resources by, minimizing energy use and implementing methods that reduce waste production and carbon dioxide emissions. Additionally, using design strategies and adaptive management techniques to increase resistance to climate change impact including heat waves, floods and se level rise.

These unused spaces can be utilized as a green infrastructure and ecological resources to support the ecosystem health (Kim, 2016). Lost urban spaces can also have a significant impact on the storm water management. Furthermore, adding vegetation and greening in lost urban spaces can enhance air quality and reduce pollution, both of which have positive effects on the public health. These can also establish a green network of large or small open spaces that encourage climate change adaptation and play an important role in air cooling by reducing the urban heat island impact and can sequent reducing the use of air conditions and energy consumption (Girolamo, 2013 and Rahman and Jonas, 2011).

Additionally, lost urban spaces can be used as spaces to produce renewable energy (wind energy, solar energy, … etc.) due to land can be rented to big power companies who will place their turbine or solar cells on these lands. Lost urban spaces can undoubtedly offer a variety of ecosystem services that promote sustainable urban regeneration.

2.3.2. Social value

Lost spaces represent a great chance to provide the society a variety of social opportunities and values that would enable them to compensate the lack of open spaces faced by many communities, particularly those in densely populated cities.

Open spaces play an essential role in achieving social advantages that enable people to behave and strengthen social relations and engaging communities. It facilitates various uses, purposes and events of social cultures such as public open spaces, pocket gardens, community gardens, parks, small gardens and public piazzas. These activities can increase the social interactions and sense of place.

Lost spaces can also give the ability to form a network of interconnected spaces capable of offering various levels of connections and different types of uses.

In addition, these spaces can be creatively used as social services such as entertainment activities, open-air restaurants, cafeterias, rickshaw, auto-stands, urban agriculture and education facilities

(Kushwah and Rathi, 2017). The regeneration of public spaces does not require high-cost or complex design, just comfortable, safe spaces where people can gather with one another enabling them to enjoy and interact (Kim, 2016). Furthermore, lost urban spaces can serve as venues for temporary uses such as seasonal celebrations, events, farmers' market. They can also offer housing for those in need or address shelter problems resulting from lack of housing.

By providing opportunities for recreation, cultural expression and civic participation, inclusive public spaces that are accessible to people of all ages, abilities and socio-economic backgrounds will promote social cohesion and community engagement.

2.3.3. Economic value

Lost spaces can provide a variety of strategic economic advantages to a community. It has a major effect on the economy to strengthening the city's economic infrastructure, contributing to further spending and creating more job opportunities. Also, they may include low-cost working spaces and areas for temporary usage which makes them urban catalysts for city development (Cirik, 2055).

Furthermore, such voids can create resources for small local economic sectors and support economic growth. These voids also create excellent chances for local communities to raise their income via small-scale businesses such as retail opportunities through kiosks, shops and markets. Moreover, job vacancies and skill improvement are also available (Rathi, 2017).

Simulating local economies by attracting investment, supporting small businesses and creating job opportunities through the development of lost spaces. Increasing property values and attracting tourism and visitors to the area through the provision of vibrant public spaces, cultural attractions and recreational amenities.

Regeneration and utilization of lost urban spaces through projects that aim to emphasize its qualities can give a power for these spaces and increase its value in the market.

2.3.4. Historical value

At the level of historical significance, these areas are crucial components of the city and represent its development overtime. Repurposing lost spaces while the city's history in mind, helps preserve the city's historical memory, identity and character. Sometimes lost spaces have a strong relationship with the city's history. It is important to improve the image of the city through reactivating these spaces which create a strong and connected urban fabric (Hashem, Wahba, and Nasr-Eldin, 2022).

2.3.5. Cultural value

From a cultural perspective, lost urban spaces offer a great opportunity to improve and promote cultural activities in the city. As a result, redesigning lost urban spaces as cultural spaces can foster a creative environment while also adding character and personality to a community. Besides, it can establish a temporary occupancy to permit arts uses and change existing structures to provide new cultural uses (Omar, 2019).

2.3.6. Visual and aesthetic values

Lost urban spaces are gap points in the urban tissue that disturb the urban context and are incomplete. These inefficient areas have a negative impact on the city's visual appearance and the connectivity of its urban structure. Furthermore, it lowers the economic value of the current assets (Wrobleski, 2015).

It is essential to enhance the identity and character of the city to create a cultural city center and to improve the education process and awareness through encouraging individuals and communities to

adopt more environmentally-friendly behaviors and practices in their everyday activities within the lost space (Lak, Ramezani and Aghamolaei, 2019).

The reuse and re-imagine of the urban lost spaces in creative attractive ways can solve the perception of these spaces and create better spaces and also contributes to the improvement of the visual connection with other parts of the city. Lost urban spaces have the ability to strengthen the urban fabric at the city level (Girolamo, 2013) (Figure 5).

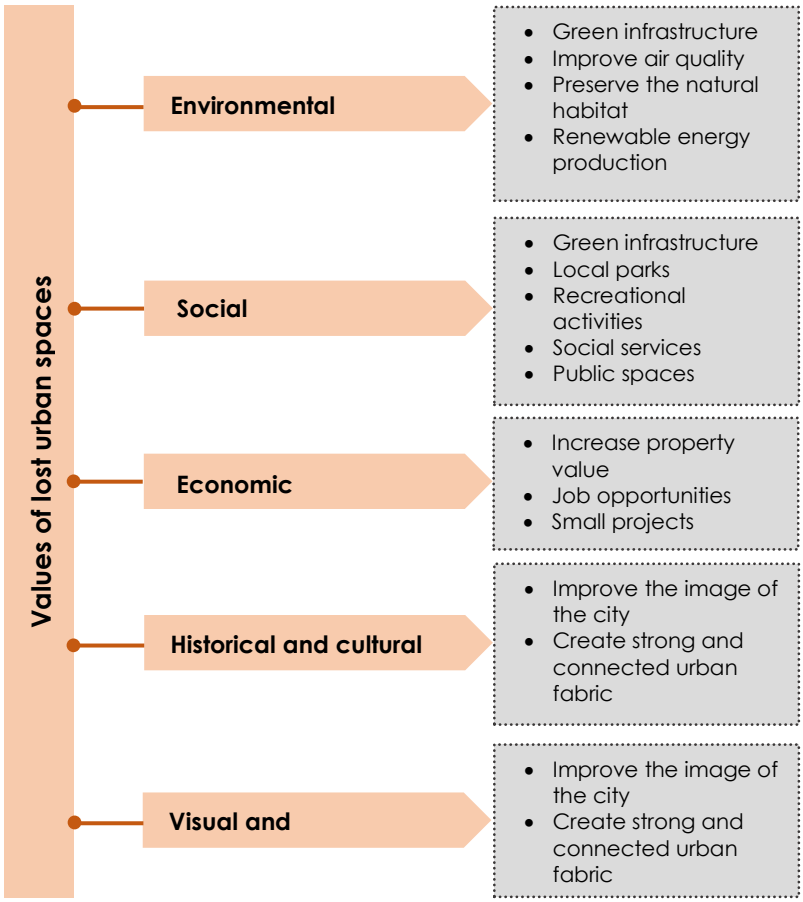

Figure 5. Values of lost urban spaces (Developed by the authors)

3. Tactical Urbanism as an Approach

In the past few decades and the beginning of the 21st century, many cities worldwide suffered from diverse challenges that include: population shifts, unpredictable economic conditions, rapid growth of technology and dissatisfaction of citizens. All these conflicts led to the rise of quick, low-cost, temporary, community-based, scalable and innovative projects to improve public spaces and the condition of cities, all of which developed the idea of tactical urbanism (Lydon and Garcia, 2015).

The tactical urbanism movement is credited to Mike Lydon, who led the Street Plan Collective. This movement gave rise to small-scale initiatives that made urban areas more liveable for local people. Tactical urbanism gradually made it possible for people to make changes to the urban environment without going through the conventional planning procedures. Tactical urbanism is a broad term that encompass a wide variety of inventions in urbanism that occur on different scales and are adaptable to different qualities (Marshall, Duvall and Main, 2016). It is a strategic approach to the field of urban

planning and design, characterized by the implementation of relatively small transient and frequent economical interventions within public spaces.

Tactical urbanism entails the installation of short, low-cost, small-scale projects in public areas. These interventions aim to include people in the design process, enhance the liveability and functioning of urban spaces fast and test prospective improvements prior to making long-term commitments (Nawzad and Ali, 2024).

These development initiatives have a variety of goals. Some seek the increase of economic recovery, while others seek to develop the general quality of life, enhance pedestrian safety, promote social contact and explore potential improvements before making any long-term commitments. They also seek to solve urban issues. Tactical urbanism projects frequently involve cooperation between local governments, organizations and local residents in order to improve environments in a creative way.

Tactical urbanism emphasizes on public participation, experimentation and the development of vibrant and safe spaces.

The design process of tactical urbanism involves a number of bottom-up interventions. In many cases, tactical urbanism design activities are carried out by local communities and social organizations to classify and solve the problems that local governments are unable to address. The design process of tactical urbanism is embodied in a cycle of "build-measure-learn" activities. From initially constructed a temporary, low-cost design concept and rapidly built out the design, launch it on the site for testing, learn and analyze the feedback data, then generating a further new design. These series of cycling processes are very important. Lost spaces can serve various purposes depending on the location and the community's needs. The following are examples to reactivate lost spaces through tactical urbanism (Table 1).

a) Environmental conservation: Lost urban spaces, next to water bodies, can be used for environmental conservation projects, such as coastline restoration, wetland preservation or wildlife habitat development. These initiatives support to biodiversity protection and ecosystem health (Carmona and Wunderlich, 2012).
b) A Network of Green spaces: These spaces can be transformed into vibrant green spaces such as small gardens, pocket parks or community gardens through the implementation of green infrastructure. This not only enhances the aesthetics of the surrounding area, but also contributes to environmental sustainability and biodiversity.
c) Community engagement and participation: In order to make sure that efforts satisfy the needs and preferences of local communities, it is important to involve them in the planning and activation process of lost spaces. Participatory design processes can empower residents to contribute ideas and collaborate with stakeholders to create inclusive and vibrant spaces (Mathew, 2010 and Hashem, Wahba and Nasr-Eldin, 2022).
d) Recreational areas: Lost areas can be used for recreational activities for activities such as skateboarding, biking or picnicking. These initiatives help realize unutilized urban areas and offer safe recreational spaces.
e) Retail and commercial spaces: In some cases, lost areas are suitable for small-scale or commercial ventures, such as markets, cafes or craft shops. These businesses can help activate the space, attract visitors and promote economic growth.
f) Art installation: Some cities have converted these spaces into outdoor art galleries or exhibitions that display local artists' work. This not only benefits the area but also encourages cultural engagement and revitalization.
g) Infrastructure upgrades: Depending on the condition of the lost spaces and the surrounding infrastructure, there may be opportunities for improvements and renovations to enhance safety, accessibility and aesthetics. This could involve upgrades such as lighting installations, pedestrian walkways or graffiti removal programs (Table 1).

Table 1. The effect of tactical urbanism on the value of lost urban spaces (By the authors)

Tactical urbanism approach	The value of lost urban spaces
Environmental conservation	Enhance environmental value
A network of green spaces	Enhance both environmental and aesthetic values
Community engagement and participation	Promote social value
Recreational areas	Promote social value
Retail and commercial spaces	Promote economic value
Art installation	Promote cultural value
Infrastructure upgrades	Promote aesthetic value

4. Urban Reactivation of Lost Urban Spaces in Developing Cities through Tactical Urbanism

Urban reactivation describes local strategies and policies that deal with urban deterioration, decline or change. It is a comprehensive approach to social, environmental, cultural and economic challenges, including local participation, preservation of damaged sites and urban life (Rossana, 2005). This idea has evolved overtime from specific urban policies to a comprehensive approach that takes into account the cultural background and structure in different communities and cities. As a result, tactical urbanism is beneficial since it breaks down the deadlocks of extensive planning processes. This policy can be considered for progress while maintaining long-term and large-scale goals. Tactical urbanism is based on a low-cost, temporary and urgent approach (Graziano, 2021).

Scientists and community activists have praised the method of tactical urbanism a successful means of promoting development in urban areas (Hou, 2010). This opens up possibilities for flexible, creative, adaptable and collaborative planning. They emphasize their local community's plan to find out what people want, which is compatible with each urban space (McGuire, 2017). Although the axis of this method is community participation, it varies in different countries. However, for developing countries, this approach should be supported by governments or private organizations (Lak and Zarezadeh, 2020).

Tactical urbanism can support a bottom-up relationship between various societal groups and government authorities by encouraging innovative urban experiences, resource allocation, environmental preservation and democratizing urban resource utilization through social involvement in civil society.

There are many challenges concerning the reactivation of lost spaces. For example, what guidelines should be followed to promote the benefits of activating lost urban spaces? Who will be in charge of making use and assessing these spaces? Also, what kind of technological installations should be used to achieve sustainability and meet the city's potential and capabilities? The reactivation of lost spaces is a challenging complex problem.

In some countries, this issue is addressed by government programs that encourage investment. Other countries, deal with this issue by establishing an appropriate, effective framework and administrative system that allows for private initiative while requiring individual responsibility and corrective action plan like Malmo city in Sweden, Zaragoza in Spain, Kwan Tong Bypass in Hong Kong and Cleveland in USA.

Therefore, a national plan is necessary to support the government in resolving different concerns related to the reactivation and revitalization process. There are frameworks that involve all parties and ensure that regional strategies complement and are compatible with national strategies.

According to Jackson, J.B. and after studying and gathering data about lost spaces and its features and how to deal with them, the following three key pillars are the most important elements for reusing and reactivating lost spaces besides involving all relevant stakeholders (Jackson, 2006).

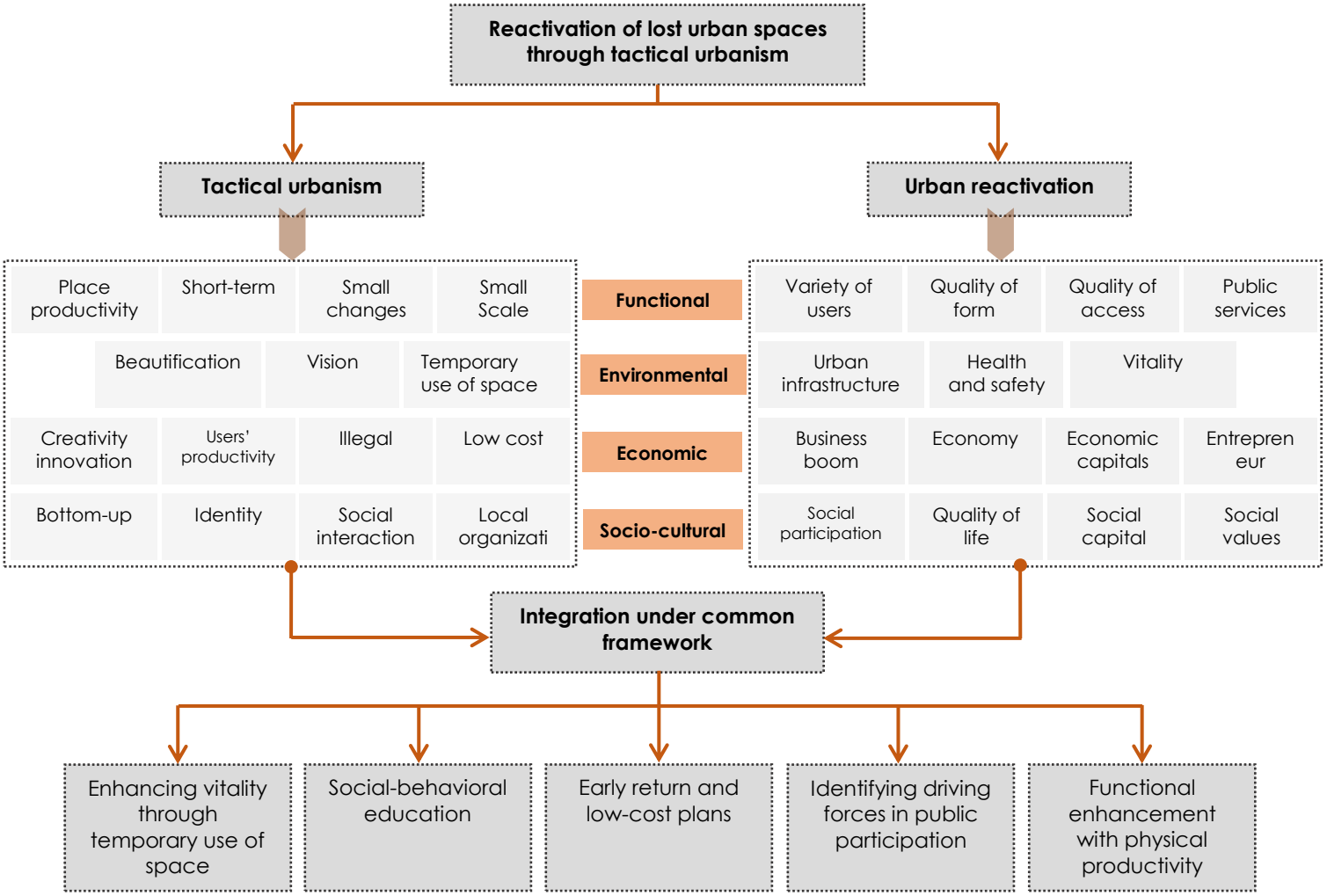

Figure 6. The conceptual framework and the relationship between the concepts of reviewing the literature on urban reactivation and tactical urbanism (Developed by the authors)

4.1. Functional strategy

The section highlights that successful reactivation of lost urban spaces depends on three key principles: form and vitality, accessibility, and design quality. Comfortable spatial form, diverse activities, and attractive design elements encourage continuous public use and social interaction. Safe, inclusive, and well-connected pedestrian access, supported by lighting and clear pathways, ensures usability for all users. Design should reinforce local identity while incorporating contemporary features, landscape elements, and interactive public art. Finally, climate-responsive planning, such as providing shade in summer and sunlight in winter, enhances user comfort and the overall quality of the revitalized space.

4.1.1. Form and vitality

Space form and scale play an essential role in making users feel comfortable and relax. Moreover, while reactivating lost urban spaces, a variety of activities should be provided and the hours of use extended to attract local residents and visitors. For example, a café, play areas or community apps can improve the revitalized space. Adding some components in designing the space can increase its efficiency, for instance a large shade tree, a sculpture or water feature, artwork, play or performance area or any other elements.

4.1.2 Accessibility

While dealing with urban lost spaces and implementing a reactivation process, it is important to enable easy and secure access for all users through the lost space. This could be achieved through connecting the reactivated space to the surrounding pedestrian network. Also, the entrances should be located with direct views to the users with continuous pedestrian walkways. Moreover, it is essential to place lighting elements to indicate paths and areas for night-time use facilities for services in a designated area away from the local pedestrian walkways and recreational facilities.

4.1.3 Design and visual preferences

Designers, architects and developers should encourage a strong feeling of place and local character even while reflecting the contemporary urbanization such as creating modern facades and adding new design features and achieving uniqueness.

Moreover, achieving richness of environment even in buildings or in landscape is an essential issue by selecting planting and landscape elements that support the area's existing character and preferred future character. In addition, some successful projects that integrated locally relevant urban art that people can interact with is widespread and can attract residents and visitors to the area. It is crucial to begin with the design of roads, seats and essential locations to capture the winter sun and be shaded in the summer in order to make sure of creating a comfortable and enjoyable space.

4.2 Environmental strategy

The reactivation of urban lost spaces should prioritize safety and security by providing essential public amenities that enhance users' sense of comfort and confidence. The integration of technological and sustainable solutions can improve environmental performance and user experience. Furthermore, the redevelopment of lost spaces contributes to economic growth. These interventions also enhance the marketability and functionality of urban areas through the promotion of mixed uses.

4.2.1 Safety and security

Feeling safe in the space is an essential concern. It is preferred to find public bathrooms, ATMs and recreational facilities that can be situated in lost spaces that users avoid because they feel unsafe.

4.2.2 Technological installations

The principles of reactivating urban lost spaces can be combined with technological advancements to create an interactive public space that encourages social interaction. This means that, creating enjoyable and sustainable places which can reduce energy consumption and minimize waste material and save time. Also, there is an opportunity to turn lost spaces into green areas. Lost urban spaces are typically paved with non-permeable materials, but it could be turned into breathable spaces to reduce solar heat gain and improve underground water resources. Also, the technological innovations could appear in lost spaces like interactive installations which are used in walkways, street furniture, lighting elements and public art installations.

4.3 Economic financial benefit

Urban lost spaces reactivation increase city investment, a broader tax revenue and job creation. Furthermore, by attracting as many prospective users as possible, the lost spaces offer to all users an additional opportunities of marketing the site and developing connections between diverse uses (FBRA, 2007).

Furthermore, because lost spaces are typically found more in developing cities, the reactivation of these sites can solve these issues. Some urban lost spaces offer better redevelopment chances, where usually the fair market is higher than the cost of redeveloping the space (Columbia, 2014). On the other hand, it is important to make sure that the urban lost spaces are appropriately used and maintained to keep it attractive for users and investors.

4.4. Socio-cultural

The successful reactivation of lost urban spaces should preserve place identity by respecting their historical and cultural significance while responding to users' needs. Community participation is essential to ensure that redevelopment enhances social interaction and provides recreational, educational, and public amenities. Furthermore, reactivated spaces should support diverse activities and events to promote an active, vibrant, and inclusive urban environment.

4.4.1 Homogeneity and place identity

The concept of reactivating lost spaces currently looks impossible, if not simply acceptable. Nonetheless, they should be viewed as spaces with history and memories and so working on developing them to give the city a new image. So, applying the required design components followed by achieving users' needs, reflected from the space identity, can generate useful spaces for users and the city.

4.4.2 Social interaction/Sense of community

Measurability, which is especially challenging to measure in social components like aesthetic values, security and community involvement, is the core problem in evaluating the reactivation process. This is why, while reactivating lost spaces, decision-makers should consider the demands and requirements of users, engaging community members to promote the final product advantages to the community. The redevelopment of lost spaces can create potential advantages for the area, such as health and recreation facilities, sports grounds, entertainment, recreation and social and educational facilities.

4.4.3 Active and vibrant lifestyle

Reactivated lost urban spaces should support various events (entertaining, sport, work, etc.) and promote uses at the boundaries of the space.

5. International examples: reactivating lost urban spaces in selected cities

This part of the study represents international examples that has experimented new ways of dealing with particular challenges or reuse of lost urban spaces as a potential source for the city development and the analysis of these experiments to take advantage of their positives and disadvantages in order to develop a framework to improve the way of development and reuse of lost urban spaces. This part focuses on three examples.

5.1 Chongqing (Southwest China)

The "Bridge Capital of China," Chongqing boasts over 10,000 bridges of all kinds. However, the areas beneath them are often neglected, either planted with bushes or used as parking lots. In many cases,

the space is simply unused. There was only a dilapidated wharf under the bridge where it was full of weeds and the road was too rugged to walk on.

Chongqing's innovative use of under-bridge spaces demonstrates how urban lost spaces can be repurposed to serve the community, improve urban aesthetics and provide functional public spaces in a densely built environment. Chongqing puts spaces under bridges to good use of China daily life. This approach can serve as a model for other cities facing similar challenges.

Chongqing has effectively utilized the spaces under its bridges, turning these areas into vibrant and functional parts of the landscape. Chongqing has creatively repurposed new designs under bridge spaces in several ways (Figure 5). Some spaces under bridges in Chongqing have been transformed into public parks and recreational areas. These green spaces provide residents with areas for relaxation and leisure helping to improve the urban environment and offering much-needed open space in a density populated city.

Chongqing has utilized some under-bridge spaces for cultural and community activities. These spaces host events, markets and performances, contributing to the cultural vibrancy of the city and fostering a sense of community.

The design of these spaces often incorporates elements of the bridges themselves, blending infrastructure with public amenities. This integration helps maximize the use of space while maintaining the functionality of the bridges. Green walls, vertical gardens and other environmental features have been added to improve air quality and beautify these under-bridge areas, contributing to the city's overall sustainability.

The transformation of under-bridge spaces has also created economic opportunities by attracting small businesses, vendors and tourism activities to the areas. The city has also developed facilities under its bridges, including basketball courts, badminton courts and skate parks. These facilities provide accessible recreational opportunities for residents. Under the bridge now sits the ne*wly-built Jiulongtan Square, where locals can experience intelligent work-out facilities powered by solar energy or take a leisurely stroll along the riverside walkways (Figure 7).

Figure 7. The reactivation of Chongqing in Southwest China (Source: http://chinedaily.com.cn)

5.2 Kalamis Park Collective Transformation Project (Kadikoy, Istanbul)

The project was initiated to increase the functionality of Kalamis Park, improve problematic uses and enable users to engage in various activities together and comfortably included the design of a skateboard track, basketball court, beach volleyball court, running track and the surrounding landscape. Additionally, to enhance the park's functionality, a bicycle rack, skateboard repair stand, lockers, recycling bins and picnic tables were also incorporated into the landscape.

Seating areas constructed parallel to the skate track provided both recreational opportunities and demarked the boundaries of sporting activity areas. User needs were analysed before selecting the features. The Kalamis Park Collective Transformation Project also uses recycled materials for the flooring and seating units on the basketball court and running track flooring and seating units.

The project meets numerous of the criteria of tactical urbanism. By emphasizing concepts like functionality and comfort, it transforms the project into a need-based practice. This initiative was implemented with residents and established a participatory framework. Also, the project raises the awareness of the concept of sustainability through the use of inexpensive materials with recycled products (Figure 8). It can be argued that the aim is to revitalize the area with diverse colours, thereby encouraging the use of this previously lost urban space (Altunok and Erkan, 2026).

Figure 8. The reactivation of Kalamis Park Collective Transformation Project (Source: https://www.onaranlarkulubu.com)

5.3 Pop-Up Town Hall

It is nestled between two existing buildings, the structure shelters a courtyard studio that is open to the street at both ends. The laboratory hosts free exhibitions and concerts and conducts urban studies and workshops. Through these activities, the area gained a public character. There is a wooden cabin that serves a café for visitors with picnic benches covered by a fabric canopy. Residents, experts and volunteer organizations participated in the tactical intervention implemented, creating a participatory discussion environment with range

of stakeholders. The space, with its functionally flexible and adaptable design approach, is notable for its ease of building and dismantling as well as risk-free implementation. The laboratory was built in a lost area that was destroyed in the first half of the 20th century and the land was left unoccupied for many years (Figure 9).

A lost urban space has been reopened for use in an original way. These efforts have led to the implementation of a tactical urban planning g program that has a strong potential for increasing public understanding of urban concerns (Altunok and Erkan, 2026).

Figure 9. The reactivation of Pop-Up Town Hall (Source: https://www.archdaily.com)

Table 2. Comparative analysis of international examples (By the authors)

	Functional			Environmental		Economic	Socio-Cultural		
Examples and the design approaches	Safety and security	Accessibility	Design and visual preferences	Safety and security	Technological installations	Economic Benefit	Homogeneity and place identity	Social interaction	Active and vibrant lifestyle
Chongqing		✓		✓	✓	✓	✓	✓	✓
Kalamis Park Collective				✓		✓	✓	✓	✓
Pop-Up Town Hall	✓	✓	✓					✓	✓

6. Case studies: observations in the Alexandrian context

6.1 Criteria of selecting lost urban spaces

The three case studies have been selected as hub sites in Alexandria city and due to their convergence of socio-spatial importance and intervention potentials. These lost urban areas act as critical areas between residential, commercial corridors and car traffic, maintaining daily interactions between residents. Furthermore, the three case studies are characterized by being part of the corniche overlooking the sea. Also, initial field observations revealed ongoing deterioration of these spaces. These problems provide opportunities for prototyping low-cost, high-impact solutions that address community design principles.

6.2 Problems

Unfortunately, Alexandria has one of the lowest green spaces per-capita statistics in the world and suffers from a lack of open spaces, since the city's urban open spaces have not kept up with the city's population increase. By walking in Alexandria city, one can overserve the scarcity of open spaces and the availability of underused lost spaces.

In Alexandria city, urban lost spaces emerged as a result of spontaneous actions like random growth in informal areas or sudden collapse of old buildings or emergence of deliberate actions such as public open spaces that are poorly designed and don't meet users' demands, or designing for highways and bridges which often produce lost spaces beneath them.

The following part is a reflection for the derived theoretical findings. Miscellaneous case studies are analysed and discussed. Then, qualities of these spaces are to be identified and the reactivating interventions upon these spaces based on the researcher's observations and physical inspection, which further elaborates the space's potentials.

6.2.1 Sidi Gaber Bridge

Sidi Gaber Bridge area in Alexandria is a crucial urban space with significant potentials for redevelopment and reactivation. It is a modern landmark on the sea that connects Sidi Gaber and Roushdy areas. It is distinguished by being part of the development of the upper corniche overlooking the sea. The area around the bridge includes several touristic and entertainment projects making it an important attraction point. However, the area under the bridge faces several problems such as the lack

of lighting elements which leads to unsafety and insecurity in the area. Also, the spread of homeless people which lead to health problems as well as the presence of commercial areas that do not work with the efficiency required (Figure 10).

Figure 10. Lost urban spaces under Sidi Gaber Bridge (Photos captured by the authors)

6.2.2 Birm El Tonsy Garden

It is one of the small city green spaces that once provides residents with a simple place for relaxation and social life. It is located in El Shatby area. However, it is suffering from noticeable deterioration overtime. This decline is often linked to poor maintenance, lack of cleanliness and insufficient facilities where neglect leads to broken seating, damaged pathways and reduced plant diversity. In addition to weak security, inadequate lighting and limited public awareness about preserving such spaces contributed to its gradual degradation, turning what was once a pleasant community area into an underused and sometimes unsafe environment (Figure 11).

Figure 11. Lost urban spaces in Birm El Tonsy Garden (Photos captured by the authors)

6.2.3 El Morsy Abu Al Abbass Garden

The garden is located in front of Al Mosry Abu Al Abbass Mosque which is a part of the wide mosque square (Midan El Masjed). While this area was originally designed as a spacious and attractive urban setting, the garden today shows signs of deterioration. Poor maintenance, worn-out greenery, damaged seating and lack of regular care have reduced its aesthetic and functional value. In addition, overcrowding, littering and insufficient supervision contribute to its decline making the space less inviting despite of its prime location in front of a major historical and religious site (Figure 12).

Figure 12. Lost urban spaces in El Morsy Abu Al Abbass area (Photos captured by the authors)

Thus, a SWOT analysis can explore the importance of these areas and how it will be integrated to evaluated its potentiality for sustainable development (Table 3).

Table 3. SWOT analysis for lost urban spaces in Alexandria city (By the authors)

Strengths	Weakness	Opportunities	Threats
Strategic location	Accessibility challenges	Community engagement	Funding constraints
High traffic flow	Noise and air pollution	Economic development	Maintenance and sustainability
Potential for innovation and creativity	Deterioration	Cultural and recreational uses	Stakeholders resistance
Proximity to key areas	Safety concerns	Enhanced connectivity	Environmental degradation
Environmental enhancement	Lack of maintenance	Environmental improvements	

7. A proposed framework to reactivate lost urban spaces

Through the theoretical study and analysing the previous international projects that experience the reuse of lost urban spaces and reviewing the advantages and disadvantages for these experiments, the research concludes a proposed framework for reusing and reactivating the lost urban spaces in the city in order to enhance its functions and to assist planners and designers to improve its functions and urban voids to optimize their utilization. The proposed framework contains many stages:

a) Project identification and goal setting

This stage determines the responsible parts and the stakeholders of the process, through recognizing the property of lost urban spaces, the users' needs and providing financial resources for the reactivation process by public or private sectors.

b) Inventory and data collection

It is the initial stage of the reactivation process through utilizing urban lost spaces. Significant progress towards the redevelopment and regeneration of lost urban spaces depends on the availability of accurate information and comprehensive database.

c) Analysing stage

The third step of the reactivation process involves analysing the inventory data and identifying how to use the information to determine the high priority for development through identifying the land suitability on which the process of planning specific criteria is based on the current conditions of the city and the goals of future development.

d) Reactivation and planning stage

In this stage, it is important to set up comprehensive strategies of urban development of lost spaces to achieve the best use of lost urban spaces. It is necessary to establish a strong vision for the reactivation of lost urban spaces which is identifying the opportunities and using full potential of space. In this stage some considerations should be taken into account such as:

- The design and planning of urban lost spaces should be integrated into the urban context since lost urban spaces are an essential component of the urban fabric.
- Planners and designers can maximize the environmental, social, economic, historical and aesthetic benefits of reusing these areas by understanding the typology of lost urban spaces.
- Redefining lost urban spaces with new functions by studying the economic, social, historical, culture and environment aspects, in addition to studying laws and legislations and finding design solutions to enhance the space components and conditions such as safety, accessibility, visibility, … etc. and fulfilling the users' needs.
- Large lots may be developed as neighbourhood parks, whereas small lots along the roadway may be developed as pocket parks, depending on the size of lost urban spaces and the reuse of services throughout the planning process.
- Considering the contextual and cultural dimension of the urban lost spaces and the conservation of historic value.
- Redeveloping of the lost urban spaces should support the city's sustainable growth.

e) Implementation stage (through tactical urbanism)

In this stage, it is necessary to establish policies to support flexible and sustainable management approach in the development of lost urban spaces process to deal with challenges in an integrated way. In addition, it is important to establish a horizontal collaboration of all stakeholders on all levels and vertical coordination between the regulatory agencies to ensure coherent development and an effective use of resources. This can be achieved through creating pop-up seating areas, lighting elements, a network of green spaces, … etc.

f) Post-occupancy stage

In this stage, it is crucial to provide tools that are used in the assessment of lost urban spaces reactivation projects and provide a pilot project to the regeneration of lost spaces. In order to evaluate the outcomes and avoid the mistakes in future projects. Also, represent evidences to citizens that positive changes can happen.

g) Maintenance stage

Establish maintenance program of different types of urban lost spaces by city government and multiple agencies. Also, providing financial resources for the maintenance through funding supplied from multiple resources (Figure 13).

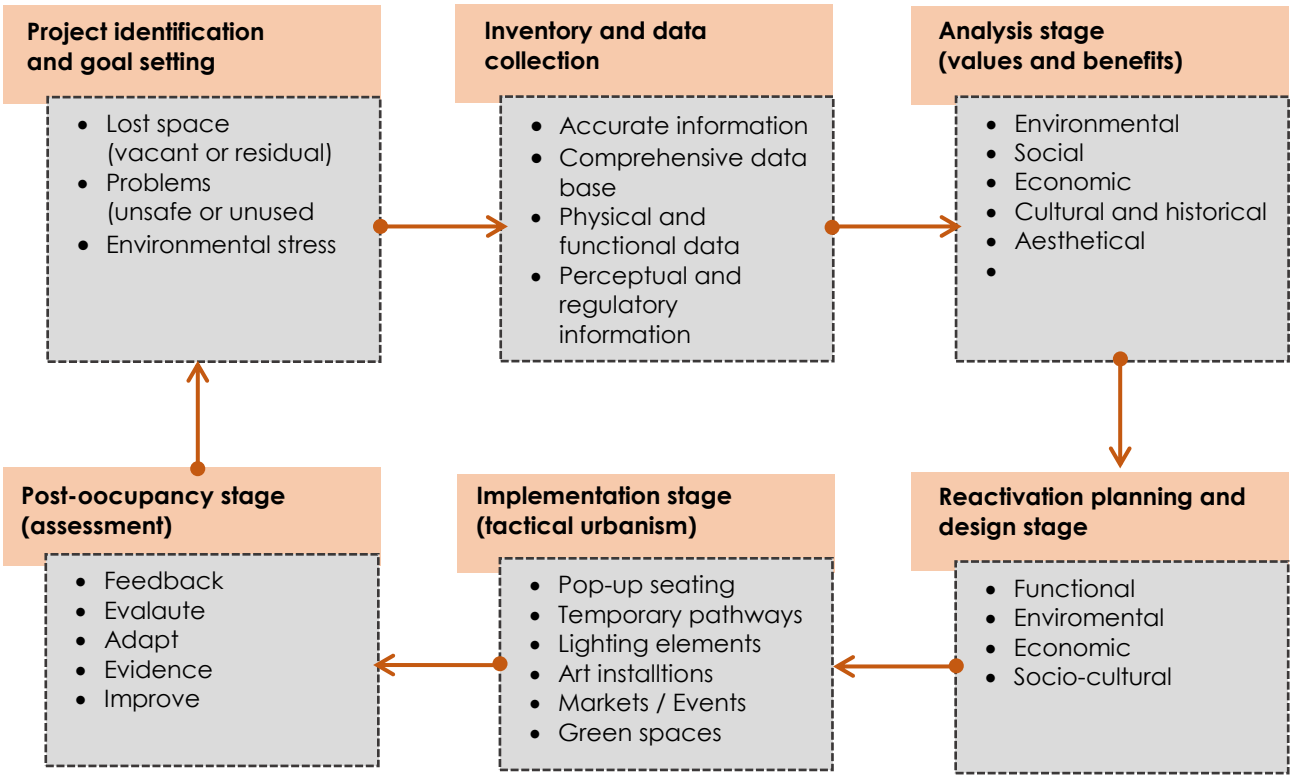

Figure 13. A proposed framework for the reactivation of lost urban spaces in developing cities (Developed by the authors)

8. Conclusion

Lost urban spaces are considered as great opportunity and potential to develop the city and enhance the quality of life of its residents particularly in developing cities. It is also regarded as a potential resource due to its value and benefits for urban development program. From reviewing of literature studies about urban lost spaces, the study offers understanding the meaning of urban lost spaces and the negative effect of the existing lost urban spaces on the city quality of life.

Through a theoretical study and an analysis of existing examples that have experimented the reuse of urban lost spaces, as well as an evaluation of the positives and negatives of such projects, the study explains the meaning of lost spaces and how they are formed, shed light on the importance of lost spaces as a resource and explore their environmental, social, economic, cultural and aesthetic values and benefits.

The study provides an understanding of urban lost spaces and the processes in which they evolve and develop and the negative impact on the city's quality of life. Based on studies of literature review studies about lost urban spaces. The study presents the value of lost urban spaces, concluding that the reactivation of lost spaces provides social and economic values by performing a variety of functions, including the use of technological installations in lost spaces as green infrastructure and improving air quality.

The reuse of lost spaces can provide environmental value by offering several ecosystem functions such as using lost urban spaces as green infrastructure, improving quality of air, preserving natural habitat and producing renewable energy. Lost urban spaces provide social values by reusing it as a community gardens, pocket gardens, entertainment activities, social services and public areas for community

gathering and interaction. These spaces also provide economic value by reusing it as small local businesses which promote economic revitalization for example temporary uses, raising the value of the nearby properties creating jobs opportunities through small-scale projects. Reusing of urban lost spaces takes into account the city's historic value and identity which support the city's identity and character, cultural events and educational process. In addition, re-imaging the urban lost spaces in creative attractive ways improve the visual appearance of the city and creates a strong urban fabric.

The research also represents international examples that has experience with new ways of dealing with particular challenges of reactivation of lost urban spaces as a potential resource for city development. The analysis of the examples takes advantages of their positives and disadvantages in order to create a framework to improve the way of development and reuse of lost urban spaces.

Through the theoretical study, analysis of international examples and the lessons learned of the Alexandrian case studies, the study proposes guiding reactivation framework to help designers and planners to develop a method of reusing lost spaces to maximize their values and benefits. The study concluded that the efficient use of lost spaces requires considering them as an integrated part of the city's urban fabric through coordinating cooperation between all parties who are involved in the development process to revitalize voids and increase city income.

The research concludes that the effective reuse of urban lost spaces requires:

- Strong vision and comprehensive strategies of urban lost spaces as a part of integrated development strategies.
- A flexible planning method which have some areas to unexpected changes.
- Design of lost urban spaces can be seen as ongoing process that continues beyond implementation.
- Long-term benefits can be achieved by providing a comprehensive city plan that identifies the location of lost urban spaces and defines appropriate uses for each location.
- Enable temporary uses which play a crucial role in cities growth because they can adopt the needs and capacities to available resources.
- Public- private partnerships are important to the process of redeveloping lost spaces.

Based on the analysis conducted, here are some recommendations for creating sustainable areas in lost spaces through tactical urbanism:

- Community-centred approach

Prioritize community engagement and participation throughout the planning and implementation process. This can lead residents to shape the vision for lost spaces and actively involve them in decision-making and programming efforts.

- Inclusive design

This means that to ensure that urban lost spaces are accessible and welcoming to people of all ages, abilities and backgrounds. Also, incorporate universal design principles to accommodate diverse needs and promote social inclusion. Flexible planning system with some areas susceptible to unexpected events. The design of lost spaces is a continuous process that does not end with the implementation phase.

- Long-term management and maintenance

Developing sustainable management and maintenance plans to ensure the ongoing viability of lost spaces. Establish dedicated funding mechanisms, maintenance schedules and community stewardship programs to support ongoing upkeep and programming efforts. Also, maintenance is an essential issue to keep the project in a good condition

- Government and public authority

Urban lost spaces often offer a potential alternative to the scarcity of open spaces. This alternative should be seriously considered by governments instead of depending completely on vacant plots of land - which are usually a scarce resource. This could be used by governments in drawing guidelines for the future on how to reactivate lost spaces in a way that appeals to the community and meet their needs. The public sector appeals to the community and meets their needs. The public sector should connect all groups and develop new policies to balance all parties involved in the process. A clear vision and appropriate strategies for developing urban voids as part of integrated urban development.

- Environmental stewardship

Integrate sustainable design features and green infrastructure elements to enhance biodiversity, manage rainwater and mitigate negative environmental impacts.

- Creative placemaking

Embrace creativity and innovation in the design and activation of lost spaces. Use public art, cultural programming and interactive installations to create memorable and engaging experiences that reflect the unique character and identity of the community.

- Multi-stakeholder collaboration

Foster partnerships and collaboration among diverse stakeholders, including local governments, community organizations, businesses and environmental groups.

Further research could reveal the roles and conflicts in the relationship between the different parties involved in the process, government, designers and users. There is a need for further investigation of patterns relating intervention preferences to space qualities. This might greatly influence the government's strategic visions for reactivating urban lost spaces. Moreover, this is expected to have its positive impact on the process of urban regeneration in general. Also, implement monitoring and evaluation mechanisms to track the performance and impact of sustainable areas in lost spaces over time. Collect data on key indicators such as usage patterns, economic benefits, environmental outcomes and social cohesion to inform decision-making and adaptation.

By embracing the mentioned recommendations above, communities can realize the full potential of urban lost spaces as catalysts for positive change, resilience and sustainability in urban environments. Through collaborative action and shared commitment, environmental responsible and inclusive spaces can be created that can enrich the lives of the present and future generations.

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The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

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Studies involving animal subjects: No animal studies are presented in this manuscript.
Studies involving human subjects: No human studies are presented in this manuscript.

Inclusion of identifiable human data: No potentially identifiable human images or data is presented in this study.

Conflict of Interests

The author declares no conflict of interest.

Contribution to the field statement

This study enhances urban regeneration research by establishing a context-sensitive framework that integrates tactical urbanism into the reactivation of lost urban spaces in developing cities. Unlike studies that primarily document tactical urbanism initiatives, this research synthesizes the characteristics, potentials and mechanisms of lost spaces with evidence from international case studies to formulate an adaptable approach for sustainable urban regeneration in Alexandria city, Egypt. The proposed framework provides both a conceptual foundation and practical guidance for planners, designers and policymakers to implement low-cost, participatory and incremental interventions that enhance social, economic and environmental sustainability while strengthening community engagement and urban resilience.

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Thermal Comfort Performance of Existing Perforated Solar Screens Across Different Façade Orientations: A Field-Based Study

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ABSTRACT

This study investigates the thermal comfort performance of perforated solar screens in educational and office buildings on university campuses, focusing on façade orientation. Although the performance of shading devices has been widely investigated through simulation-based studies, field-based evidence evaluating their thermal comfort performance under real operating conditions remains limited. To address this gap, classrooms and offices oriented along north–south and east–west axes were examined under real operating conditions. Field-based on-site measurements were conducted at representative points, defined according to the seating layout in classrooms and as window-adjacent and interior zones in offices. Thermal comfort was assessed using the Predicted Mean Vote (PMV), derived from on-site measurements, and compared with comfort ranges defined by ISO 7730 and ASHRAE 55. The results indicate orientation-related variations in PMV, particularly in south-oriented offices, where PMV values reached up to +1.16 at window-adjacent zones and frequently exceeded the comfort limits despite the presence of shading devices. In contrast, PMV values in north-oriented spaces generally remained within the recommended comfort range. In south-oriented classrooms, PMV values remained within acceptable limits but were biased toward warm conditions, with the observed conditions also reflecting active cooling and curtain use. Spatial PMV differences within classrooms ranged between 0.05 and 0.15, indicating differences in the spatial distribution of predicted thermal comfort conditions. These findings suggest that identical perforated solar screen configurations may not provide equivalent thermal comfort performance across different façade orientations. The originality of this study lies in its field-based evaluation of perforated solar screens under actual operating conditions. The findings emphasize the need for orientation-sensitive, climate-responsive shading design and provide empirical evidence that can support façade design decisions in educational buildings.

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1. Introduction

Educational and office buildings located on university campuses stand out as spaces with high thermal comfort requirements due to their long occupancy periods, high user density, and functions that require sustained cognitive performance. Indoor environmental quality has been shown to have a significant impact on occupant comfort, health, and work performance, particularly in educational and office buildings where cognitive performance is essential (Wargocki & Wyon, 2017; Frontczak & Wargocki, 2011).

In such buildings, façade orientation, solar radiation, window-to-wall ratio (WWR), and the design of shading devices are among the key design parameters that directly and indirectly influence indoor environmental conditions. The building envelope functions as a physical and environmental separator between the indoor space and the outdoor environment and is defined as the primary building component that regulates heat, air, and moisture transfer between these two environments (Straube, 2017).

Façade orientation determines the amount, timing, and angle of solar radiation received by the building envelope. Therefore, identical or similar shading configurations may not result in equivalent thermal conditions on different façades. East and west façades are exposed to low-altitude solar radiation, which is difficult to control with fixed shading devices and may increase the risk of overheating. This is mainly due to the low solar altitude angles in the morning and afternoon, which allow direct solar radiation to penetrate deep into indoor spaces. In contrast, north façades receive predominantly diffuse sky radiation, while solar radiation on south façades occurs at higher angles and can be more effectively controlled using horizontal shading devices due to higher solar altitude angles at solar noon (Szokolay, 2014; Lechner, 2014). This orientation-dependent solar exposure creates differences not only in solar heat gains but also in indoor radiant conditions, particularly in perimeter zones close to glazed façades.

Since thermal comfort is strongly influenced by environmental parameters such as air temperature, mean radiant temperature, air velocity, and humidity, mean radiant temperature plays a critical role in thermal comfort evaluation (Olesen & Parsons, 2002). Solar gains transmitted through or absorbed by façade components may increase surface temperatures and consequently affect mean radiant temperature. Since PMV is sensitive to changes in mean radiant temperature, façade orientation and shading configuration may influence the spatial distribution of PMV values within a room. Accordingly, this study is based on a conceptual framework in which façade orientation affects solar exposure, solar exposure influences indoor radiant conditions, radiant conditions affect PMV distribution, and perforated solar screens may moderate this relationship depending on their geometry and façade-specific suitability.

Shading devices, which are considered within the scope of passive design strategies, play an important role in limiting excessive solar gains and balancing radiant heat loads in indoor environments. In addition to controlling solar radiation, shading devices influence indoor air temperature, mean radiant temperature, and overall thermal comfort by reducing solar heat gains and lowering surface temperatures exposed to direct solar radiation (Olgyay, 2015; Givoni, 1998). Since mean radiant temperature is a key parameter in the radiant heat exchange between the human body and surrounding surfaces and plays a central role in thermal comfort evaluation (Fanger, 1970; Olesen & Parsons, 2002; Guo et al., 2020; Tamrakar et al., 2023), shading devices can significantly improve indoor thermal conditions by reducing radiant heat gains. However, the effectiveness of shading devices depends not only on their presence but also on façade orientation, solar angles, and building geometry. In the literature, horizontal shading devices are generally considered more effective on south façades, whereas vertical shading devices are more suitable for east and west façades due to differences in solar path and façade incidence angles (Szokolay, 2014; Lechner, 2014). Although these orientation-based design principles are well established, less is known about how existing perforated

solar screens perform in occupied buildings under actual operating conditions, where HVAC operation, curtain use, occupancy, and user behaviour may alter expected performance.

Previous studies on shading devices have primarily focused on energy and daylight performance, and many of these studies have been conducted using simulation tools. Studies addressing thermal comfort and real building conditions are comparatively limited (Kirimtat et al., 2016). Although simulation-based studies provide valuable insights during the design phase, field measurements are essential for validating simulation results and understanding actual occupant comfort conditions under real operating environments. Furthermore, field studies on thermal comfort have demonstrated that occupants adapt to their thermal environment, highlighting the importance of real building measurements in addition to simulation-based studies (de Dear & Brager, 1998; Nicol & Humphreys, 2002). As a result, discrepancies may occur between predicted shading performance and the thermal comfort conditions observed in real buildings.

This need is particularly relevant for perforated solar screens. Unlike conventional horizontal or vertical shading devices, perforated solar screens simultaneously influence solar transmission, daylight availability, outward visibility, façade permeability, and potentially ventilation. Their thermal performance is therefore not determined only by their presence but also by perforation characteristics, installation geometry, façade orientation, and operational context.

Existing studies on perforated solar screens have mainly addressed daylight availability, glare control, energy efficiency, and parametric optimization through simulation-based approaches. For example, Appelfeld et al. (2012) compared perforated shading screens with conventional shading systems through hourly building simulations, while Chi et al. (2017) optimized perforated solar screen configurations by integrating daylighting and thermal performance analyses. Similarly, Lavin and Fiorito (2017) employed genetic algorithms coupled with daylight and energy simulations to optimize perforation size and distribution for office buildings.

However, empirical studies examining PMV-based thermal comfort conditions in occupied buildings equipped with existing perforated solar screens remain comparatively limited. The unresolved issue addressed in this study is therefore not whether shading devices are generally beneficial, since this has already been widely established in the literature, but how thermal comfort conditions vary across façade o rientations and spatial locations in occupied buildings where perforated solar screens are already installed. This issue is particularly relevant under real operating conditions, where HVAC operation, curtain use, occupancy, and other user-related factors may modify the thermal conditions associated with façade and shading characteristics.

Therefore, there is a need for measurement-based studies that examine thermal comfort conditions associated with existing shading systems in real buildings. Within this context, the present study investigates PMV-based thermal comfort conditions in classrooms and offices located in university buildings oriented along the north–south and east–west axes and equipped with existing perforated solar screens. PMV values obtained from on-site measurements were comparatively analysed at different spatial depths and positions relative to the window, and the results were evaluated in relation to building orientation and façade orientation. By adopting a field-based approach, the study provides a context-specific evaluation that complements the predominantly simulation-based literature on shading performance.

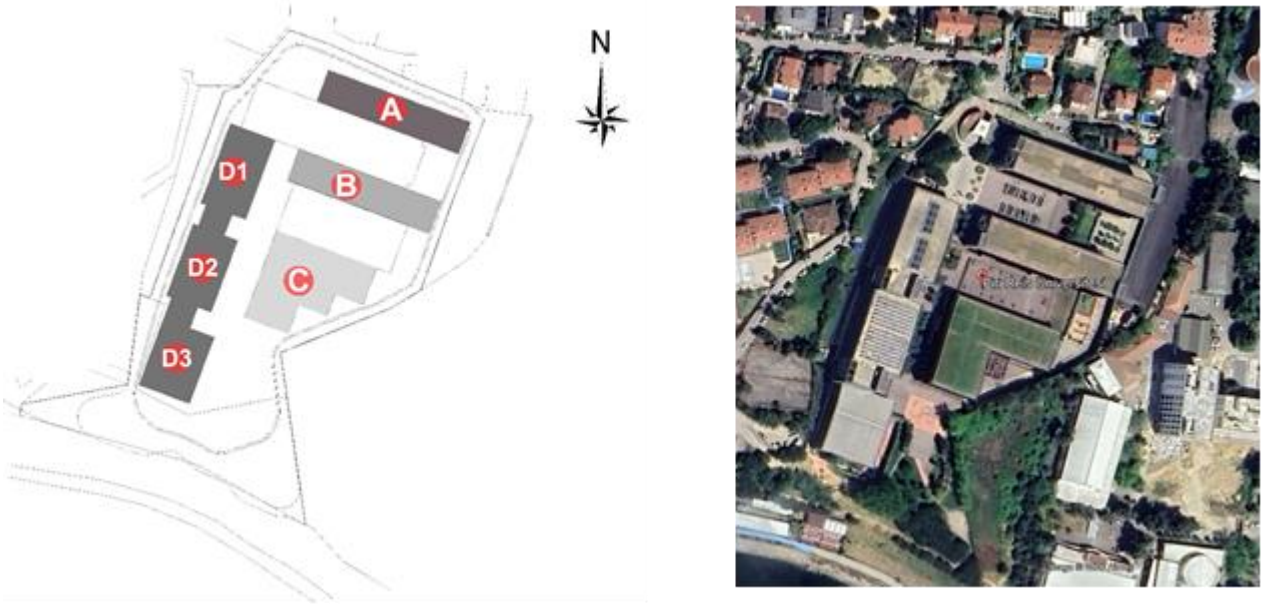
The study specifically examines whether orientation-related variations can be observed in the investigated spaces, how PMV conditions vary with spatial position, particularly between window-adjacent and interior zones, and whether similar perforated solar screen configurations are associated with comparable thermal comfort patterns across different orientations. These aspects provide the analytical framework for the comparative evaluation.

The study does not attempt to isolate the independent causal effect of perforated solar screens under controlled experimental conditions. Rather, it examines thermal comfort patterns observed in occupied spaces and interprets them in relation to façade orientation, existing shading configuration, spatial location, and operational variability. Accordingly, the findings are intended to provide context-specific empirical evidence rather than statistically generalizable conclusions regarding the performance of perforated solar screens.

The contribution of the study lies in complementing the predominantly simulation-based literature with field-based observations obtained from educational and office spaces under actual operating conditions. More specifically, the study provides a spatially differentiated evaluation of PMV conditions by considering façade orientation and distance from the window together. Rather than proposing a new shading geometry or establishing universal orientation-based design principles, the study provides empirical observations that may support the evaluation of existing perforated shading systems and inform further research on orientation-sensitive shading performance.

2. Methodology

This study employed a field-based measurement approach to evaluate the thermal comfort performance of existing perforated shading devices in educational and office buildings. PMV values obtained from on-site measurements were analysed in relation to façade orientation, building orientation, and spatial depth. Within this scope, the field study was conducted in classroom and office spaces located in buildings with different orientations and different shading device types at Piri Reis University Tuzla Campus (Figure 1). In this study, the shading devices were not newly designed or installed; instead, the thermal comfort performance of the existing shading devices used in the buildings was evaluated under real operating conditions.



(a) **(b)**

Figure 1. Site plan and aerial view of Piri Reis University Tuzla Campus: (a) Layout of the blocks where the field study was conducted; (b) Satellite image of the university campus. Sources: (a) Architectural drawings provided by the Technical Department of Piri Reis University; (b) Google Earth, 2026

Piri Reis University Tuzla Campus was selected as the case study area because it contains educational and office buildings with different façade orientations and existing perforated shading systems. The case study buildings were selected purposively to enable a comparative evaluation of thermal comfort performance under similar climatic conditions while representing different building orientations and shading configurations. The selected classrooms and offices represent the most frequently occupied educational and administrative spaces within the campus. All investigated spaces were located within reinforced concrete educational buildings of similar construction period, envelope characteristics, glazing systems, and functional use, thereby reducing variations unrelated to façade orientation and shading performance. The investigated spaces were selected based on comparable functional use, occupancy characteristics, construction systems, glazing properties, and accessibility during the measurement period, while representing different façade orientations and shading configurations. Measurements were performed using the same instruments, identical measurement procedures. All measurements were conducted on the same day to reduce, although not eliminate, variability associated with changing outdoor climatic conditions. The investigated buildings were oriented along the north–south and east–west axes and included different shading device configurations depending on façade orientation. In buildings oriented along the north–south axis, perforated vertical shading devices positioned at an angle to the façade were used, as shown in Figure 2(a). In contrast, in buildings oriented along the east–west axis, perforated shading devices installed parallel to the façade were used, as illustrated in Figure 2(b). These shading devices were part of the existing building façade systems. Table 1 presents the characteristics of the external shading systems used in the investigated buildings. The effects of these shading devices on thermal comfort were evaluated through field measurements conducted under real operating conditions (Figure 3).

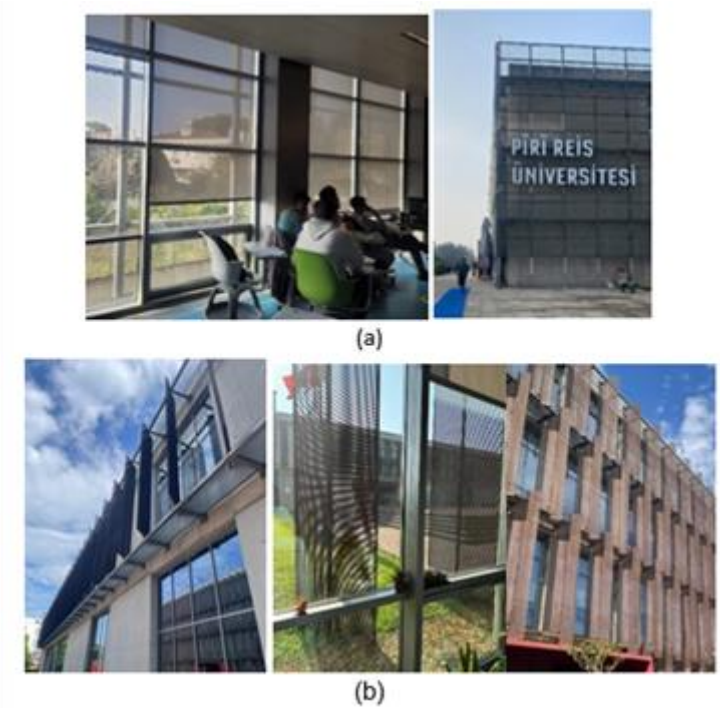


Figure 2. External perforated shading devices used in the buildings: (a) Vertical shading devices oriented towards the North (or North-South axis); (b) Shading devices installed parallel to the South façade (East-West axis.) Source: Prepared by the authors

Table 1. Characteristics of the external shading systems used in the investigated buildings. Source: Prepared by the authors

Building	Façade	Shading type	Panel dimensions	Installation angle	Distance from façade
Block A and B	North/South	Vertical perforated	Approx. 900 × 4660 mm (W × H).	approximately **20°–30°** relative to the façade normal	Approximately **200–300 mm**
Block D	East/West	Parallel perforated	Not available	0 (Parallel to façade)	Approximately **200–300 mm**

(a) (b)

Figure 3. Measurement equipment and sensor layout used during the field study: (a) Measurement points in the classroom; (b) Measurement points in the office space. Source: Prepared by the authors

The measurements were conducted on November 3, 2025, during two measurement periods: late morning (10:00–12:00) and afternoon (13:30–16:00). According to the meteorological records for Istanbul, the daily mean outdoor air temperature on the measurement day was approximately 16 °C, with a daily maximum of approximately 19 °C and a minimum of approximately 13 °C, indicating moderate outdoor thermal conditions during the field measurements.

Thermal comfort evaluation was carried out through in-situ spot measurements. Measurements were conducted at a minimum of two measurement points in each space; in classrooms, the points were determined according to the seating layout, while in offices, measurement points were selected near the window and in the interior zone of the space (Figure 4). This approach allowed the spatial distribution of thermal conditions and the façade effect on different zones within the space to be analysed comparatively.

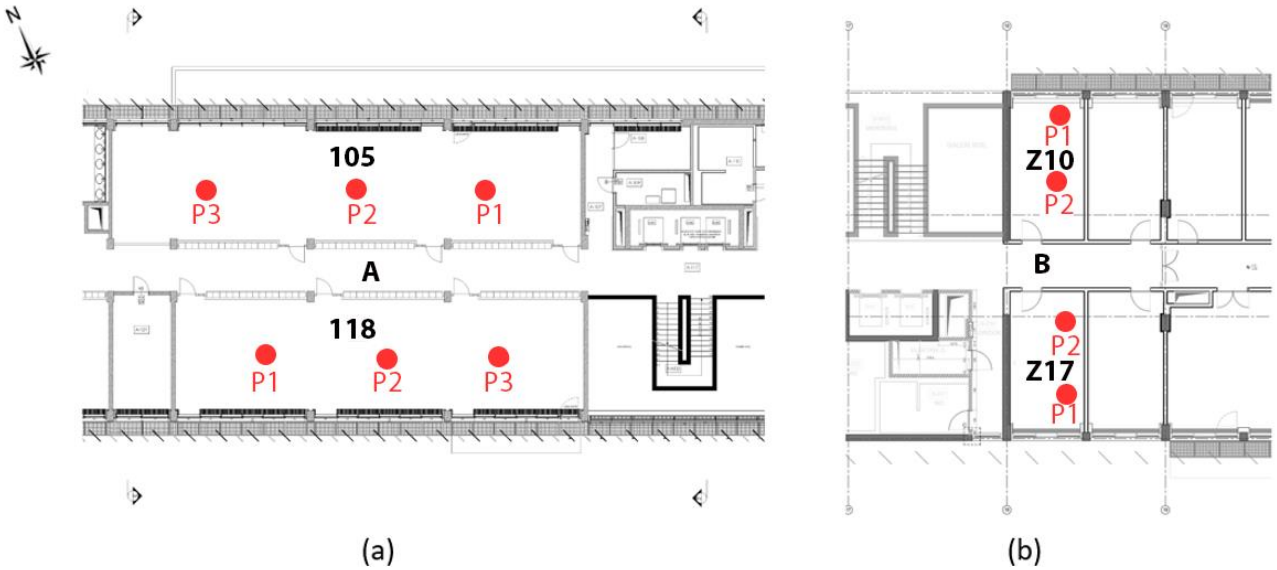


Figure 4. Example floor plans and measurement point locations: (a) Classrooms A105 and A118 in Block A; (b) Office spaces in Block B. Red dots indicate the positioning of sensors at different spatial depths relative to the window. Source: Architectural drawings provided by the Technical Department of Piri Reis University

There was no central building automation system in the investigated spaces, and indoor environmental conditions were controlled through passive strategies (e.g., external shading devices) and manually controlled heating/cooling systems. Since the aim of the study was to evaluate thermal comfort under existing usage conditions, the operation of the heating/cooling systems was left to the users during the measurements. All measurements were conducted under actual operating conditions, and windows remained closed during the measurement periods. Accordingly, HVAC operation and curtain use were intentionally not standardized, as the study sought to capture the influence of shading devices under actual occupancy and operational conditions rather than under controlled laboratory settings. These operational differences were considered part of the real building environment and are discussed as a limitation of the study.

During the field study, the heating/cooling system was active in south-oriented classrooms in the afternoon and in north-oriented classrooms in the morning, and the indoor temperature was set to 16°C by the users in these spaces. In other classrooms and offices, the heating/cooling system was set between 18–22°C or was turned off. In addition, it was observed that curtains were kept closed in some south-oriented classrooms and offices during the measurements.

During the measurement process, air temperature, mean radiant temperature, relative humidity, and air velocity were recorded simultaneously. Measurements were carried out in accordance with the procedures defined in ISO 7730 and ASHRAE 55 standards. All measurements were conducted at a height of 1.10 m from the floor level in accordance with ISO 7726 measurement standards. Thermal comfort evaluation was conducted using the PMV (Predicted Mean Vote) index in accordance with ISO 7730 (2005) and ASHRAE 55 standards. In PMV calculations, the metabolic rate was assumed as 1.2 met, representing sedentary educational and office activities such as reading, writing, and computer-based work. The clothing insulation level was assumed as 0.8 clo, which is considered representative of typical indoor clothing worn during the autumn season. These values were selected in accordance with ISO 7730 recommendations and previous field studies conducted in similar educational environments (Zoroğlu & Zorer Gedik, 2022).

The ideal thermal comfort range was defined as −0.5 < PMV < +0.5, as recommended in ISO 7730 and ASHRAE 55 standards. PMV values obtained from the measurement points were evaluated within this range, and the spatial distribution of thermal comfort within the spaces was analysed.

The measured data were analysed comparatively in relation to façade orientation, building orientation, and spatial depth parameters. In particular, PMV differences between points near the window and interior points were examined to evaluate spatial variations in predicted thermal comfort conditions and the potential for local thermal discomfort.

As this study was designed as a comparative case study rather than a statistically representative survey, the findings should be interpreted within the context of the investigated buildings. Due to the limited sample size, non-parametric statistical methods were adopted. The Mann–Whitney U test was used to compare PMV values between independent groups, including north- and south-oriented classrooms, east- and west-oriented classrooms, and north- and south-oriented office spaces. Differences between window-adjacent (P1) and interior (P2) measurement points in office spaces were evaluated using the Wilcoxon signed-rank test. Statistical significance was assessed at a significance level of $p < 0.05$. The statistical analyses were performed to support the descriptive evaluation of the measured data and to strengthen the interpretation of the observed orientation-related trends within the exploratory scope of the study. In addition, descriptive statistical parameters, including mean values, standard deviations, and minimum–maximum values, were calculated to summarize the variability of the measured PMV values and to support the interpretation of the comparative analyses.

3. Results

3.1. Effect of Façade Orientation on Thermal Comfort

The PMV values obtained from the in-situ measurements revealed orientation- and location-related variations in indoor thermal comfort conditions. In south-oriented office spaces, PMV values measured near the window were generally higher than those measured at interior points and approached or occasionally exceeded the thermal comfort limits. As shown in Figure 5a, higher PMV values were observed particularly at measurement points located close to the window on the south façade. In some measurement points in south-oriented spaces, PMV values reached up to +1.16, indicating warmer predicted thermal conditions at the most exposed measurement location. This trend is further supported by the high radiant-globe temperature values recorded in the same locations (Figure 5b).

In contrast, in north-oriented spaces, PMV values remained within the comfort range of −0.5 to +0.5 at most measurement points, and a more balanced and spatially homogeneous thermal environment was observed compared with the investigated south-oriented offices (Figure 5).

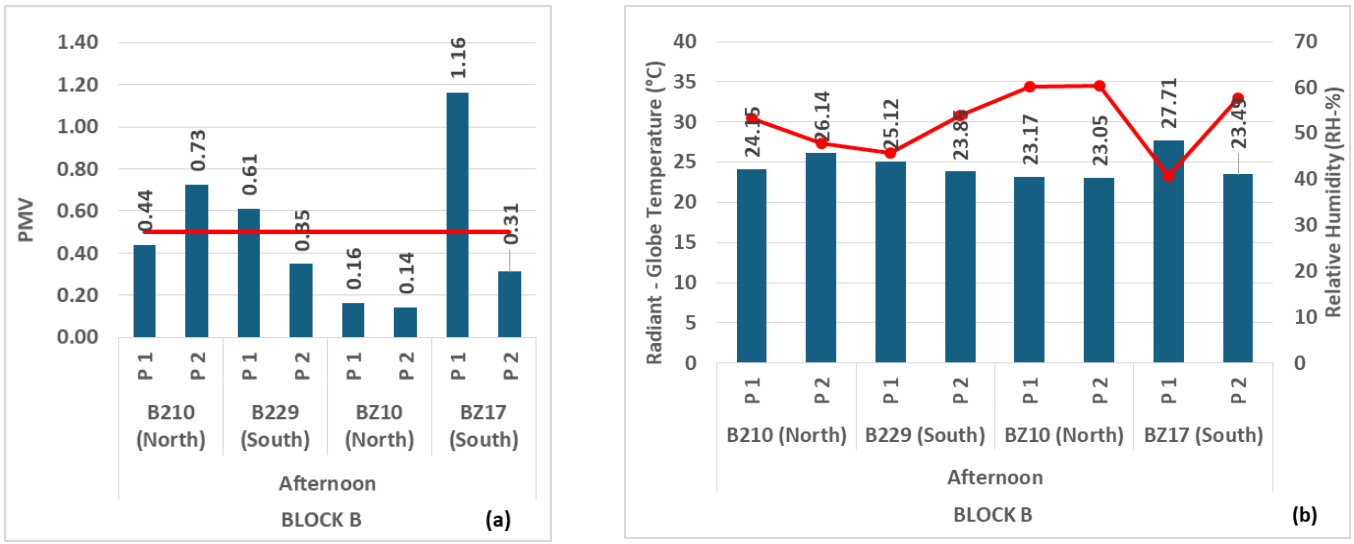


Figure 5. Thermal comfort measurement results for Block B offices in the afternoon: (a) PMV values; (b) Measured Radiant-Globe Temperature and Relative Humidity levels. P1 represents the window-adjacent point and P2 the interior point. Source: Prepared by the authors

PMV measurements conducted in the morning and afternoon in classrooms show that the temporal variation of PMV should be evaluated together with its spatial distribution. In classroom A105, an increasing trend in PMV values was observed at all measurement points in the afternoon, whereas in classroom A118, PMV values generally decreased. In both classrooms, small spatial differences among measurement points were observed during the measurement periods, with ΔPMV values ranging from 0.07 to 0.15 (Figure 6 and Table 2).

The contrasting temporal patterns observed in A105 and A118 should be interpreted in conjunction with differences in façade orientation and HVAC operation, which varied between the investigated classrooms. During the afternoon measurement period, the west-oriented classroom D109 exhibited a higher mean PMV (0.38) than the east-oriented classroom D115 (0.17). Within both classrooms, spatial PMV differences among the measurement points were small (ΔPMV = 0.05 in D109 and 0.08 in D115), indicating relatively limited within-room variation during the measurement period.

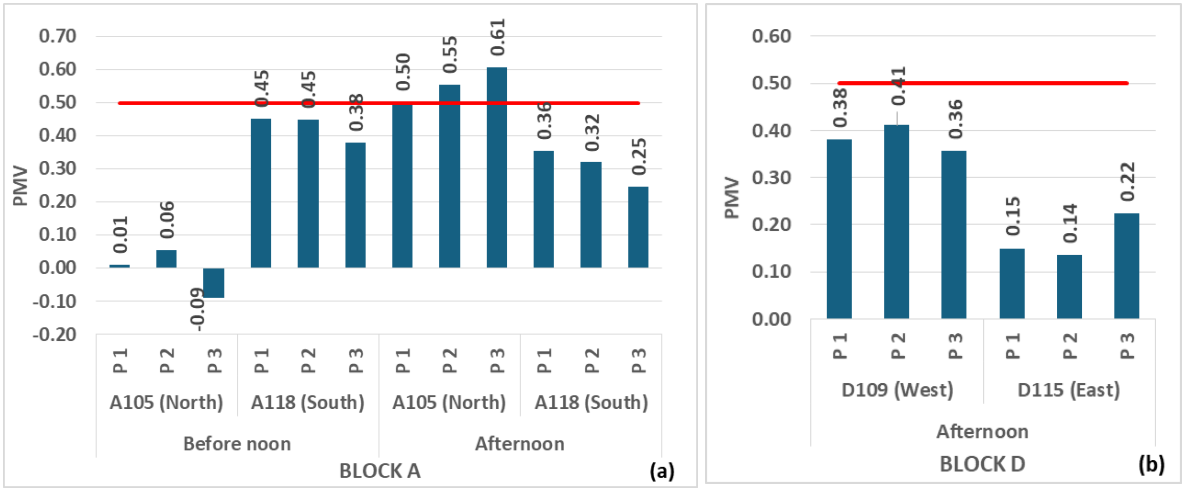


Figure 6. PMV measurement results in classrooms: (a) Block A during morning and afternoon periods; (b) Block D during the afternoon period. Source: Prepared by the authors

To complement the graphical presentation of the measurement results, descriptive statistical indicators (mean, standard deviation, minimum, and maximum PMV values) were calculated for each investigated space. Given the exploratory nature of the study and the limited sample size, the analysis primarily focused on descriptive statistics. Non-parametric statistical tests were additionally performed as a secondary analysis to examine whether the observed PMV differences between façade orientations and measurement locations were statistically significant. Table 2 summarizes the descriptive statistical results obtained for the investigated classrooms and office spaces. Overall, these descriptive statistics are consistent with the orientation-related trends observed in the field measurements. Among the classrooms, the highest mean PMV was recorded in the north-oriented classroom A105 during the afternoon (0.55 ± 0.06), whereas the lowest mean PMV occurred in the east-oriented classroom D115 (0.17 ± 0.04). Among the office groups, south-oriented offices exhibited a higher mean PMV (0.61 ± 0.39) than north-oriented offices (0.37 ± 0.28). In addition, among the individual office spaces, BZ17 exhibited the largest spatial difference between window-adjacent and interior measurement points (ΔPMV = 0.85), indicating greater thermal heterogeneity than the other investigated offices. The larger standard deviation observed in south-oriented offices further indicates greater spatial variability in thermal comfort conditions compared with north-oriented offices.

Table 2. Descriptive statistics of PMV values obtained in the investigated classrooms and office spaces. Source: Prepared by the authors

Space	Orientation	Measurement period	n	Mean PMV	SD	Min	Max	ΔPMV
A105 Classroom	North	Morning	3	-0.01	0.08	-0.09	0.06	0.15
A105 Classroom	North	Afternoon	3	0.55	0.06	0.50	0.61	0.11
A118 Classroom	South	Morning	3	0.43	0.04	0.38	0.45	0.07
A118 Classroom	South	Afternoon	3	0.31	0.06	0.25	0.36	0.11
D109 Classroom	West	Afternoon	3	0.38	0.03	0.36	0.41	0.05
D115 Classroom	East	Afternoon	3	0.17	0.04	0.14	0.22	0.08
North-oriented offices (B210 and BZ10)	North	Afternoon	4	0.37	0.28	0.14	0.73	0.59
South-oriented offices (B229 and BZ17)	South	Afternoon	4	0.61	0.39	0.31	1.16	0.85

Note: ΔPMV = Maximum PMV − Minimum PMV measured within the same classroom. For office groups, ΔPMV is not reported because each orientation group consists of different office spaces. Spatial PMV differences are discussed separately for individual offices

To further examine these descriptive findings, PMV values obtained from north- and south-oriented classrooms (A105 and A118) and east- and west-oriented classrooms (D115 and D109) were compared using the Mann–Whitney U test. The comparisons did not indicate statistically significant differences between the north- and south-oriented classrooms or between the east- and west-oriented classrooms (North–South: $p = 0.937$; East–West: $p = 0.100$). The east–west comparison nevertheless showed a descriptive difference during the afternoon measurement period, with higher PMV values in D109 than in D115. Considering the exploratory nature of the case study and the limited sample size, these results

should be interpreted as descriptive observation rather than statistically generalizable differences between façade orientations.

3.2. Thermal Comfort Performance of Existing Shading Devices Depending on Façade Orientation

The shading devices examined in this study consist of two different geometric configurations depending on building orientation (Figure 1). In buildings oriented along the north–south axis (Blocks A and B), perforated vertical shading devices positioned at an angle to the façade were used. In the investigated south-oriented offices, higher PMV values were observed near the window, with values approaching or exceeding the upper comfort limit at some measurement points (Figure 5a). Similarly, in west-oriented classroom exhibited higher PMV values than the east-oriented classroom during the afternoon measurement period, even in cases where curtains were closed and the mechanical cooling system was active (Figure 6b).

In buildings oriented along the east–west axis, perforated shading devices installed parallel to the façade were associated with relatively small spatial PMV differences within the investigated east- and west-oriented classrooms. However, since the same shading device geometry was used on both east and west façades and the devices were installed parallel to the façade, the west-oriented classroom exhibited higher PMV values than the east-oriented classroom during the same afternoon measurement period, even in cases where curtains were closed and the mechanical cooling system was active.

The results indicate that the thermal comfort performance of the existing shading devices was not uniform across the investigated façade orientations. While the examined shading devices were present in all investigated spaces, different PMV patterns were observed according to façade orientation and spatial location. However, these patterns should be interpreted together with differences in HVAC operation and curtain use under actual operating conditions.

Similarly, PMV values measured in north-oriented (B210 and BZ10) and south-oriented (B229 and BZ17) office spaces were compared using the Mann–Whitney U test. Although the difference was not statistically significant ($p = 0.486$), descriptive statistics showed higher mean PMV values and greater thermal variability in south-oriented offices. These findings suggest that the most pronounced spatial variation within the investigated office sample occurred in the south-oriented offices, particularly in areas located close to the façade.

3.3. Spatial Distribution of Thermal Comfort Within the Space

The results show that spatial PMV differences were observed among different measurement locations within the investigated spaces. Particularly in south-oriented offices, indoor thermal comfort was not homogeneously distributed, with greater differences observed between window-adjacent and interior measurement points (BZ17 ($\Delta PMV = 0.85$)).

PMV values obtained from three measurement points (P1–P2–P3) in classrooms indicate that the point-based PMV distribution varies depending on the classroom. The maximum difference between P1 and P3 (ΔPMV) ranged between 0.05 and 0.15, and the standard deviation values within classrooms ranged between 0.021 and 0.076. These findings indicate that thermal comfort was more evenly distributed in some classrooms, while spatial variation was more pronounced in others. These observations suggest that measurements at multiple spatial locations may provide additional information on within-room thermal variability compared with a single measurement point.

Measurements conducted in classrooms show that occupants are exposed to different thermal conditions depending on the seating layout. In offices, higher PMV values measured near the window indicate that warmer predicted thermal conditions occurred at some window-adjacent locations. As a result, PMV differences between zones near the window and interior zones were found to reach levels

that may affect occupant comfort and work performance. These results show that thermal comfort conditions are not uniformly distributed within the space and are strongly influenced by solar radiation and mean radiant temperature, particularly in perimeter zones close to the façade.

The findings of this study clearly demonstrate the importance of façade orientation-sensitive shading device design. Similarly, Olgyay (1963) emphasizes that solar control strategies in building envelope design should vary depending on façade orientation. These findings indicate that existing shading devices do not provide the same level of thermal comfort performance on all façades, and that indoor thermal comfort, particularly in façades exposed to direct solar radiation, cannot be adequately controlled in terms of spatial distribution. The results suggest that shading device design should be evaluated not only in terms of energy performance but also in terms of achieving a homogeneous distribution of indoor thermal comfort.

Considering the investigated space types separately, different orientation-related patterns were observed. South-oriented offices exhibited the highest individual PMV value and the greatest spatial variability, while north-oriented offices showed comparatively more stable conditions. Among the east- and west-oriented classrooms, the west-oriented classroom exhibited higher PMV values than the east-oriented classroom during the afternoon measurement period. However, the north-oriented classroom A105 also showed relatively high PMV values in the afternoon. Therefore, the findings should not be interpreted as indicating a single performance ranking among façade orientations.

Differences between window-adjacent (P1) and interior (P2) measurement points in office spaces were evaluated using the Wilcoxon signed-rank test. Although the differences were not statistically significant ($p = 0.625$), descriptive analysis indicated considerably larger spatial PMV differences in south-oriented offices than in north-oriented offices. This trend is likely associated with the limited number of paired observations and the exploratory nature of the present case study.

4. Discussion

The present findings address this methodological gap by providing empirical evidence obtained under real operational conditions, allowing the influence of occupant behaviour, HVAC operation, and façade orientation to be evaluated simultaneously. Rather than proposing a new shading geometry, the originality of this study lies in validating the thermal comfort performance of existing perforated solar screens through field measurements and demonstrating orientation-dependent performance differences under actual building operation. Although façade orientation and shading configuration constituted the primary comparative variables in this study, the observed PMV patterns should also be interpreted in conjunction with operational factors such as HVAC settings, curtain use, occupant behaviour, and internal heat gains. Since these variables were intentionally not standardized in order to reflect actual building operation, the measured differences represent the combined influence of façade orientation and operational conditions rather than the isolated effect of the perforated solar screens. While numerous studies have evaluated shading systems through simulation-based approaches, fewer studies have examined the thermal comfort implications of perforated solar screens through field measurements conducted in occupied buildings. Accordingly, this study contributes to the existing literature by providing field-based evidence on the interaction between façade orientation, perforated shading devices, mean radiant temperature, and PMV distribution under actual operating conditions. Unlike simulation-based studies, the present findings demonstrate that orientation-related thermal comfort differences remain observable under real building operation, where occupant behaviour and operational settings introduce additional variability that is difficult to capture through simulation alone.

Olgyay (1963) emphasized that solar control strategies and shading design should be developed according to the sun path and façade orientation. The present findings support this theoretical framework by demonstrating that the thermal performance of perforated solar screens is influenced by

orientation-dependent solar exposure under real operating conditions. However, unlike many simulation-based studies, the present research provides field-based evidence obtained under actual operating conditions, where occupant-controlled HVAC operation and shading use also influenced indoor thermal conditions.

These findings suggest that the thermal performance of perforated solar screens should be interpreted as the combined outcome of façade orientation, solar exposure characteristics, and occupant adaptation rather than as the result of shading geometry alone. Variations in PMV are therefore likely to reflect the interaction between solar altitude, exposure duration, operational conditions, and the adaptive actions of occupants.

This interpretation is consistent with Adaptive Comfort Theory, which proposes that occupants continuously modify their behavioural and environmental responses according to changing thermal conditions (de Dear & Brager, 1998; Nicol & Humphreys, 2002). In the present study, occupant-controlled HVAC operation and curtain use represent examples of such adaptive responses. Although occupant behaviour was not quantified through surveys, the observed operational differences indicate that adaptive actions likely contributed to the measured PMV patterns alongside façade orientation and shading configuration.

These findings are consistent with previous studies demonstrating that the thermal comfort performance of shading devices varies according to façade orientation, solar geometry, and climatic conditions (Tzempelikos & Athienitis, 2007; Ochoa & Capeluto, 2008). Tzempelikos and Athienitis (2007) showed that shading devices significantly influence indoor thermal comfort, with their effectiveness varying according to façade orientation and climatic conditions, whereas Ochoa and Capeluto (2008) reported that orientation-specific shading strategies achieve superior thermal and energy performance compared with conventional uniform shading approaches. Consistent with these studies, the present results indicate that orientation-dependent solar exposure remains an important determinant of thermal comfort even under occupied building conditions. Furthermore, because occupant perception surveys were not conducted, the measured spatial PMV differences should be interpreted as differences in predicted thermal comfort conditions rather than direct evidence of occupants' experienced local thermal discomfort.

The comparatively stable thermal conditions observed on north-oriented façades are likely associated with reduced direct solar exposure, which limits the contribution of short-wave solar radiation to mean radiant temperature. Under these conditions, other envelope-related factors such as heat transfer and surface temperatures may become relatively more influential. This finding is consistent with previous studies indicating that north-facing façades receive lower solar gains and therefore provide more stable indoor thermal conditions (Baker & Steemers, 2000). However, heat losses and low surface temperatures should also be considered, particularly during the heating season. ASHRAE (2017) emphasizes the importance of mean radiant temperature in the evaluation of indoor thermal comfort and states that low surface temperatures can significantly affect occupant comfort. This indicates that both solar heat gains and radiant cooling effects should be evaluated together under different seasonal conditions.

Rather than indicating that one façade orientation is inherently associated with poorer thermal comfort, the present findings suggest that thermal performance emerges from the interaction between façade orientation, solar geometry, shading configuration, operational conditions, and occupant adaptation. Consequently, façade orientation should be considered as one component of a broader building-environment system rather than an isolated determinant of indoor thermal comfort.

The orientation-dependent PMV patterns observed in this study can be explained by differences in solar altitude, exposure duration, and radiant heat exchange rather than by façade orientation alone. South-oriented façades are exposed to solar radiation for longer periods throughout the day, resulting in

cumulative heat gains and increased surface temperatures. In contrast, east- and west-oriented façades are subjected to lower solar altitude angles during morning and afternoon hours. Under these conditions, solar radiation penetrates deeper into the indoor space and may bypass shading devices that are primarily designed to block high-angle solar exposure.

As a result, façade orientation influences not only the amount of solar radiation received but also the effectiveness of shading devices in controlling solar heat gains. These observations suggest that perforated shading devices installed parallel to the façade may provide less effective solar control during periods of low solar altitude. This situation may lead to spatial variations in radiant and predicted thermal comfort conditions within the space. The relationship between solar altitude angles and mean radiant temperature appears to be particularly important in explaining the observed PMV differences. When low-angle solar radiation enters the space, interior surfaces such as floors, walls, furniture, and glazing can absorb and store solar energy, leading to higher surface temperatures. These warmer surfaces subsequently increase mean radiant temperature, which directly affects occupants' thermal sensation even when air temperature remains relatively stable. Therefore, thermal discomfort near the façade may be more strongly associated with radiant heat exchange than with air temperature alone. Fanger (1970) and ASHRAE 55 state that radiant temperature asymmetry is one of the main environmental factors causing local thermal discomfort in indoor environments. These findings suggest that shading strategies for east and west façades should be evaluated not only in terms of solar radiation control but also by considering changing solar angles and radiation characteristics throughout the day.

Another important finding of the study is that similar shading devices were used on both north- and south-oriented façades in the examined buildings. However, these orientations are exposed to significantly different solar radiation durations and solar altitude angles throughout the year. Therefore, identical shading configurations may not provide the same level of thermal comfort performance on different façade orientations. This finding highlights the importance of climate-responsive, orientation-sensitive, and performance-based façade design approaches, in which shading strategies are adapted to façade-specific solar conditions. Furthermore, the present findings suggest that thermal comfort should be evaluated as a spatially distributed environmental condition rather than solely through room-average indices, particularly in perimeter zones exposed to solar radiationIn this context, the observed spatial variability is likely associated with differences in solar radiation exposure and mean radiant temperature, indicating that shading performance should be assessed not only in terms of reducing air temperature but also in its ability to control radiant heat exchange. Although occupant perception surveys were not conducted, the observed variations in PMV indicate differences in predicted thermal comfort conditions depending on façade orientation and spatial location within the building rather than direct evidence of occupants' experienced local thermal discomfort.

It was also determined that the examined buildings did not have a central building automation system, and that the spaces were mainly operated using passive climate control strategies, while cooling systems were active in south-oriented spaces during the measurement period. Although indoor air temperatures were set to approximately 16°C, PMV values exceeded the comfort range on south façades. These observations suggest that mechanical cooling alone may not always fully compensate for solar heat gains under the investigated operational conditions.

The elevated thermal conditions in perimeter zones further emphasize the dominant role of mean radiant temperature in determining local thermal comfort near glazed façades. Similarly, Tzempelikos et al. (2010) reported that mean radiant temperature increases near glazing façades due to solar radiation and that shading devices can significantly affect thermal comfort in these areas. Their study demonstrated that shading devices can improve indoor thermal comfort by reducing radiant temperature asymmetry. Simulation-based studies in the literature show that climate-responsive shading solutions can improve both energy and thermal comfort performance. Therefore, it is recommended

that simulation-based performance analyses and optimization processes should be used together in the design of shading devices.

This study is based on measurements conducted in a limited number of spaces on a specific university campus. Since the measurements were carried out within a specific time period, the results may vary under different seasonal and operational conditions. Nicol and Roaf (2017) emphasized the importance of long-term field data in thermal comfort studies. Therefore, the findings of this study should be considered as context-specific results rather than universally generalizable outcomes, but they can be used as a comparative reference for buildings with similar climatic and architectural conditions.

The study suggests that evaluating the thermal comfort performance of shading devices together with façade orientation, building orientation, and spatial depth may provide a more comprehensive understanding of indoor thermal conditions under real operating environments. The study provides a complementary and context-based contribution to the literature through field-based data collected from university buildings. Unlike many previous simulation-based studies, this study provides field-based evidence on the thermal comfort performance of perforated shading devices under real operating conditions.

The findings of this study are particularly relevant to Mediterranean climatic conditions, which are characterized by high solar radiation levels, prolonged cooling periods, and significant solar exposure throughout much of the year. In Mediterranean regions, shading devices represent a fundamental passive design strategy for controlling solar heat gains, improving indoor thermal comfort, and reducing cooling energy demand. The results may therefore have broader relevance for university campuses and educational buildings in Mediterranean cities, where prolonged solar exposure and seasonal variations in solar altitude can create orientation-dependent thermal conditions. Although the present results are specific to the investigated campus and measurement period, similar challenges may occur in warm and temperate Mediterranean climates, particularly in buildings with highly exposed façades and uniform shading configurations. In this context, the study highlights the potential value of considering façade orientation, solar geometry, and operational conditions together when evaluating existing shading systems and developing climate-responsive design strategies for educational buildings in Mediterranean regions.

4.1. Limitations

Several limitations should be considered when interpreting the findings of this study. The study was conducted on a single university campus. Although the selected buildings provided different façade orientations and shading device configurations, the results may not be directly generalizable to other climatic regions, building types, or institutional settings.

The field measurements were carried out in a limited number of classrooms and office spaces. While the selected spaces were considered representative of the investigated buildings, a larger sample size could provide a more comprehensive understanding of the relationship between façade orientation, shading performance, and thermal comfort. In addition, the study did not include reference spaces without shading devices. Consequently, the findings should be interpreted as comparative observations among existing façade orientations rather than as direct evidence of the isolated effect of shading devices.

The measurements were conducted on a single day during the autumn season. Consequently, the observed thermal comfort conditions represent the climatic characteristics of the measurement period and may differ under summer or winter conditions. In particular, south-, east-, and west-oriented façades are expected to experience greater seasonal variations because solar altitude, solar radiation intensity, and exposure duration change considerably throughout the year. Therefore, long-term measurements covering different seasons would provide a more comprehensive assessment of the

annual thermal comfort performance of perforated shading systems and help distinguish orientation-related effects from seasonal climatic variability and improve the generalizability of the findings.

Another limitation is the variation in HVAC operation among the investigated spaces. Since the study aimed to evaluate thermal comfort under actual operating conditions, heating and cooling systems were operated according to user preferences. Consequently, differences in HVAC settings may have influenced the measured thermal comfort conditions. Similarly, curtain usage was not standardized across all spaces. In some south-oriented classrooms and offices, curtains were closed during the measurements, while in others they remained open. This may have affected solar radiation levels and indoor thermal conditions.

Occupant behaviour also represents a limitation of the study. User actions such as operating heating or cooling systems, adjusting curtains, and occupying different locations within the space may have influenced the thermal environment during the measurement periods. In addition, PMV calculations were based on assumed clothing insulation (0.8 clo) and metabolic rate (1.2 met) values derived from ISO 7730 recommendations and previous studies. These assumptions are consistent with ISO 7730 recommendations and are commonly adopted in field studies where individual occupant data cannot be collected. Although these assumptions are widely accepted for educational environments, actual occupant clothing levels and activity patterns may have varied during the measurement period.

Finally, the study focused exclusively on physical measurements and PMV-based thermal comfort assessment. User perception surveys were not conducted. Therefore, the findings reflect predicted thermal comfort conditions rather than occupants' actual thermal sensations, preferences, and satisfaction levels. Future studies integrating both field measurements and occupant surveys could provide a more comprehensive evaluation of thermal comfort performance.

5. Conclusion

This study evaluated the thermal comfort performance of existing shading devices used in educational and office buildings on a university campus through field-based measurements, in relation to façade orientation and building orientation. Field measurements conducted in spaces with different orientations and spatial depths suggest that indoor thermal comfort conditions are influenced by the combined effects of façade orientation, building orientation, and distance from the window under real operating conditions.

The findings suggest that PMV values frequently approached or exceeded the comfort limits in zones close to the window, particularly in south- and west-oriented spaces. In contrast, lower and more stable PMV values were obtained in north-oriented spaces, where indoor thermal conditions were found to be more homogeneous and stable. These findings suggest that existing shading devices may not provide the same thermal comfort performance on different façades and therefore may benefit from evaluation according to façade orientation.

The results show that the impact of shading devices on thermal comfort is not only related to their presence but also to their suitability for façade orientation and solar conditions. In particular, shading devices used on east and west façades may be insufficient to control solar radiation due to low solar altitude angles, which may lead to spatial variations in radiant and predicted thermal comfort conditions. This suggests that, in the investigated buildings, not only the presence of shading devices but also their orientation-sensitive design may play an important role in thermal comfort performance.

Therefore, performance-based shading strategies considering façade orientation, building orientation, and spatial characteristics may provide a more appropriate approach than uniform façade solutions.

This case study contributes to the existing body of knowledge by providing empirical evidence on the relationship between shading devices, façade orientation, and indoor thermal comfort under real

operating conditions. While many previous studies have focused primarily on simulation-based assessments, the present study offers field-based measurements that capture actual thermal comfort conditions in occupied university buildings. The study therefore contributes not only by complementing simulation-oriented knowledge through empirical observations, but also by demonstrating that the thermal effectiveness of perforated solar screens varies considerably according to façade orientation under real operational conditions. In this respect, the study adds context-specific data that may support future research on orientation-sensitive shading performance and thermal comfort evaluation. Rather than proposing new shading geometries, the principal contribution of this study lies in providing field-based evidence on the thermal comfort performance of existing perforated solar screens under occupied building conditions, thereby complementing previous simulation-based studies with empirical observations obtained from real building operation.

The findings also have practical implications for architectural design. The results suggest that the application of identical shading solutions on different façades may not always lead to similar thermal comfort outcomes. Therefore, the study provides practical insights that may assist architects and designers in developing more climate-responsive and performance-oriented shading strategies for both new construction and retrofit projects.

Based on the findings of this study, the following recommendations can be made for shading device design:

- Shading devices should not be considered as single-type solutions for all façades; instead, shading strategies should be adapted to façade-specific solar conditions, considering differences in solar altitude, exposure duration, and radiant heat exchange.
- The design of shading devices should be supported by performance data and simulation-based analyses during the early design stage.
- Shading strategies should be evaluated not only in terms of solar radiation control but also in terms of their impact on the spatial distribution of indoor thermal comfort.
- For façades exposed to different solar geometries, shading strategies should be evaluated separately; in particular, low-angle solar exposure on east- and west-oriented façades and prolonged solar exposure on south-oriented façades should be considered in façade-specific design decisions.
- Field measurements should be integrated into the evaluation and improvement processes of shading device design.

In conclusion, the findings of this case study suggest that the thermal comfort performance of shading devices may vary depending on façade orientation, building orientation, and spatial depth. By providing field-based evidence, this case study complements the predominantly simulation-based literature on shading performance. The study offers a measurement-based reference framework for the development of orientation-sensitive shading strategies and may support architectural design and retrofit processes. Furthermore, the findings indicate that the performance of shading devices may benefit from being evaluated not only at the building scale but also at the spatial scale, considering façade orientation and spatial depth. Within the scope of the investigated buildings, the results suggest that shading devices can be considered not only as architectural elements but also as performance-related components that may influence occupant comfort and indoor environmental quality.

Given the exploratory nature of this case study, the limited sample size, and the restricted measurement period, the findings should be interpreted as context-specific rather than statistically generalizable. Nevertheless, the field-based methodology presented in this study may provide a useful framework for future investigations evaluating the thermal comfort performance of shading systems under real operating conditions.

Future research should expand the scope of field-based investigations through long-term monitoring campaigns across different seasons and climatic conditions. Since the present study was based on measurements obtained during a single period, multi-season assessments would provide a more comprehensive understanding of the relationship between façade orientation, shading performance, and thermal comfort. In addition, studies involving a larger number of buildings and different building typologies would improve the generalizability of the findings.

Future studies may also benefit from integrating field measurements with simulation-based analyses to compare predicted thermal comfort performance with conditions measured under actual building operation. Furthermore, the performance of adaptive and dynamic shading systems could be investigated and compared with that of fixed perforated solar screens. Finally, a more holistic assessment could be achieved by integrating thermal comfort evaluation with assessments of daylighting performance, visual comfort, and building energy consumption.

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Conflicts of Interest
The authors report no conflicts of interest.

Data Availability Statement
The data that support the findings of this study are available from the corresponding author upon reasonable request.

CRediT Author Statement
All authors contributed equally to the conception, methodology, analysis, writing, and revision of the study. All authors have read and approved the final version of the manuscript.

Contribution to the Field statement
This study contributes to the literature by providing field-based evidence on the thermal comfort performance of existing perforated solar screens in occupied educational and office buildings under actual operating conditions. While previous research has predominantly relied on simulation, this study evaluates PMV based thermal comfort using in-situ measurements across different façade orientations. By examining façade orientation together with building orientation and spatial depth, it demonstrates that identical perforated solar screen configurations may not provide equivalent thermal comfort conditions under real operating conditions. The findings complement existing simulation based research with context specific empirical observations on orientation dependent thermal comfort performance.

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The Post-Landslide Collapse in Small Italian Villages: New Utilisation Paradigms

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A B S T R A C T

This work focuses on small towns and the need for post-disaster planning. While it is widely acknowledged that a shift from 'emergency planning' to 'aware spatial planning' is advisable, this simple concept often remains inapplicable, as we too often find ourselves having to intervene in an area only after a disaster has occurred. Small villages in Italy are a treasure of cultural heritage. The topic has been the subject of research by the "Borghi Group" of the Italian Ministry of Culture, in which the first author participated. It moves from emergency planning to project design, from knowledge of historical and artistic heritage to territorial security, including the important issue of landscape conservation. This paper aims to develop a methodology for interpreting territory that considers its various components, presenting a case study in southern Italy, specifically in the Municipality of Monacilioni, which in the 1960s was subject to repeated landslides that destroyed much of the historic centre. The project described here aims to improve the landscape quality of the urban centre, guided by a methodology that can be replicated in other similar contexts.

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1. Introduction

In recent decades, urban planning has been addressing the 'fragility' of cities and regions. Transcending national borders, vulnerability affects the state of heritage – both natural and built – which suffers the consequences of natural disasters linked to seismic and hydrogeological risks, with watercourses increasingly at the mercy of extreme weather events. Furthermore, in the context of historic cities – which, particularly in Europe, date back many centuries – the age of the built heritage and its often poor state of maintenance exacerbate the aforementioned natural phenomena. Italian urban planning may not yet have found effective solutions, but it is addressing the issues of deterioration and structural defects, viewing them as a strategic opportunity for the regeneration of the contemporary city, going far beyond the mere physical reconstruction of the urban fabric.

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This research is based on a combination of two sets of studies and research: on the one hand, those concerning the definition of a place's identity (which encompass key aspects of historical culture and environmental and landscape characteristics) with a view to achieving a sense of social well-being; on the other hand, those concerning the challenges faced by local areas (which encompass key aspects of the geomorphological nature of places) with a view to achieving a sense of physical well-being characterised by 'safety'.

1.1. The Main Aim

The primary aim of the research endeavour was to formulate a methodological framework that would serve as a guide for the conscious design process, incorporating the historical and cultural nuances of the locale into the design. The application of the principles of spatial and landscape planning has the potential to provide a framework for such research. For a considerable period, the working group of the L.a.co.s.t.a. Laboratory (Laboratory for Activities Related to Territorial and Environmental Development) founded at the University of Molise in 2005 has been addressing these issues. The focus of the research is on territorial analysis, landscape planning and environmental regeneration, adopting an integrated approach combining environmental, natural, agricultural-productive and historical-cultural issues.

Work is currently under way on the "Drafting of the new Molise Regional Landscape Plan" to focus on the landscape features that characterise the region – an area of focus that has not yet been developed to the same extent as in other regions. Both in the preparatory studies for the Plan (commissioned in 2011) and in the analyses carried out for the drafting of the Plan itself (commissioned in 2019), attention has consistently been paid to areas at risk from natural disasters, and the methodology adopted here was tested during the drafting of the aforementioned plan.

Furthermore, as part of the 'Allocation of the Territorial Planning Fund' (as per the Decree of the President of the Council of Ministers of 17 December 2021), the Laboratory was entrusted with the Feasibility Study for the 'Regeneration Plan for the southern historic centre: "Case spallate e non solo…" (Ruined Houses and more...) and, subsequently, the Executive Regeneration Plan "Borghi in frana" (Landslide Villages), funded under Measure "M1C3 2.1 Attractiveness of Villages" of the National Recovery and Resilience Plan. Consequently, in drawing up the Monacilioni Regeneration Plan – the results of which are presented in this article – the previously tested criteria are used; these will be briefly described in the section on methodology.

As regards the structure of the paper, the Introduction is followed by Section 2, regarding the international debate, then by Section 3, Materials and Methods (which outlines the research methodology employed and describes the Study Area). The subsequent Section 4 presents the results and discussion and reflects on the potential scope of the research, followed by Section 5, Conclusions, which summarises the key points of this article.

2. The International Debate

The global and local debate regarding cities and towns is currently very active. The establishment of the 2030 Agenda with its 17 Sustainable Development Goals has confirmed the existence of a specific urban dimension within the discussion on the future of the planet: within this, Goal 11 calls for "inclusive, safe, resilient and sustainable cities and human settlements" (United Nations, 2015, 2019; Cialdea et al., 2022).

The relationship with nature also plays an important role, and this must be increasingly fostered within urban centres. In particular, Italy is the country most exposed to the effects of climate change, with significant economic losses resulting from these effects: there is clear evidence of the substantial funds increasingly required to restore areas affected by extreme weather events (European Commission, 2018). The restoration of nature and attention to degraded ecosystems are emphasised in all European Union documents stemming from the Biodiversity Strategy for 2030 (European Commission, 2020).

The proximity of areas of natural value to major urban centres, or their closer coexistence within small villages, is, in fact, a central theme for sustainability policies. The literature on the subject highlights the need for greater precision in urban policies in order for natural areas to be able to act as a driving force for improving quality of life, even within urban settlements (Nadin & Stead, 2008; Vizzari & Sigura, 2015; Zasada et al., 2017; Cialdea, 2020; Cialdea & Privitera, 2021). Spatial planning alone is not sufficient to ensure this synergy; it must be complemented by landscape planning and the aspirations of local communities interested in their own economic development (Council of Europe, 2009; Sandströma & Hedforsb, 2018).

In particular, the international debate on small villages focuses on their regeneration as a response to the crisis in urban centres, transforming them into hubs of sustainability and slow tourism, with a strong emphasis on the enhancement of the wider heritage and the fight against depopulation. There is discussion of the role of villages as 'heritage communities' capable of generating new vitality, going beyond mere conservation. It should also be noted that the post-lockdown context has accelerated interest in more balanced lifestyles, making small villages attractive not only to tourists but also for potential repopulation through remote working.

In Italy, 'villages' are understood as small urban settlements, characterised by ancient architecture, often dating from the medieval period. They are often seen as synonymous with authenticity, capable of attracting, above all, the curiosity of tourists. The fundamental problem is that for far too many years now, they have been subject to depopulation. The debate, particularly in Italy, invariably centres on a wide range of issues, some positive (such as a strong sense of identity and a rich landscape and cultural heritage), others negative (such as neglect and marginalisation).

Small villages are rich in cultural heritage in historical and architectural terms, but they are also centres of traditional production, particularly in the food sector: 90% of Italian food products classified as Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI) being produced in such sites. It seems appropriate to define, in line with other authors, how small villages, predominantly situated in the country's inland areas, serve as a 'local repository' of knowledge, referred to as a 'cultural ecosystem', which is, however, difficult to access precisely due to physical barriers and topographical challenges (De Rossi, 2019; Barbera et al., 2022; Colaprice, 2023). In order to allocate funding, The Italian Ministry of Culture (MIC) has formulated a precise definition of 'village', identifying as such those municipalities with a population not exceeding 5,000 inhabitants and which possess a significant artistic and architectural heritage. In fact, there are a great many of them: they cover more than half of the country's total land area and account for around 70% of all Italian municipalities. They are mainly located in mountainous areas (along the Apennine range and the Alps) and are suffering from depopulation, as they are home to less than one-sixth of the entire national population. For these small municipalities, the MIC has recently issued a call for proposals with total funding of one billion euros, comprising two strands of support: Line A (known as Pilot Projects) to support 21 projects (one per region and for the autonomous provinces of Trento and Bolzano) to promote the 'cultural, social and economic regeneration of villages at risk of abandonment or already abandoned'; Line B (known as Local Projects) provided for the selection of 229 projects aimed at the cultural regeneration of historic villages (MIC, 2022). The National Plan for Small Towns fits well within a path towards sustainability, drawing on Goals 8 and 11 of the 2030 Agenda for Sustainable Development and going beyond the mere promotion of tourism to also aim for residential appeal. Having compared similar situations in European countries, therefore, the case study focuses on Italy, characterised by a predominantly mountainous and hilly terrain within a context that also boasts significant landscape values. Certainly, this work has the underlying aim of applying territorial knowledge to enhance its usability, safeguarding landscape values and enabling citizen participation in its enhancement (in this sense, it is essential that local authorities promote the safety of places and increasingly guarantee the opportunity to enjoy open spaces, especially in the post-pandemic era).

3. Materials and Methods

The methodology seeks to combine the two systems of information and their relevant spatial data. The review of the international scientific literature is based on the principle that a place's history is the main driving force behind the research: every country has its own distinctive features (and therefore the relevant scientific literature will also have different characteristics), and Italy (which is most comparable to European contexts) is certainly characterised by a rich historical stratification spanning many centuries, albeit with significant regional differences.

The model will not merely consist of producing 'territorial knowledge' and 'social knowledge', but must itself serve to build a shared body of practices and know-how. This, therefore, is the most important phase: that of deepening the analytical understanding, which underpins the design process and from which all future proposals for transformation can be derived. The Recovery Plan aims to foster close relationships with the area's natural and landscape features. The project was therefore conceived in close connection with the local context, which informs the area's action plans and development. Although the area itself is currently abandoned and considered a negative feature, the project's vision aims to regenerate it as a key hub for the town, becoming a hub for information on enhancing the area's landscape and cultural network.

3.1. General Asset

The Recovery Plan's main aim is to improve the landscape quality of the urban centre. The new area will serve as a memorial to the history of the city centre before the landslide that completely altered its character. The project intends to unite the community through nature and memory, respecting nature as an integral element in limiting landslide risk. The new arrangements highlight important landmarks of the urban centre and simultaneously offer new opportunities that connect the urban centre to the rest of the municipal territory and also to the historical and landscape surroundings of the municipality itself (Getimis, 2012; Rudolf et al., 2017; Melzer et al., 2019).

The methodology employed in this study to emphasise significant elements is predicated on the selection of indicators derived from the extant literature, as specified below for each category of landscape elements. Despite the extensive body of literature addressing indicators related to natural resources, the innovative element of this methodology lies in the introduction and comparison of parameters related to planning tool forecasts. The present paper employs the methodology that has been previously tested, developed, and utilised by the L.a.co.s.t.a. Laboratory during the research period on the projects cited in the introduction (Cialdea, 2007; 2017; 2018; 2021).

The collected data relating to resource system indicators were entered into a database. This followed a previous experimental application in territorial research in other regions, including Molise (Regione Molise, 2011;2019). The aim of this was to refine landscape value assessments, implement heritage protection, and enhance sustainable development compatible with the territory's characteristics (Repubblica Italiana, 2019). A substantial corpus of literature exists on the subject of assessing landscape character, which is defined as the arrangement of landscape elements that imbue a landscape with a distinct identity and differentiate it from adjacent landscapes (Jellema et al., 2009; Butler & Berglund, 2014; Bartletta et al., 2017; Tudor, 2014; Vogiatzakis, 2011; Griffiths, 2018). The development of this information commenced with elementary data, which was then subjected to classification according to the evaluation of the identified resource systems. The System of Environmental Values includes:

- The Water System: This includes watercourses, springs, wells, water sources and fountains.
- Wooded Areas and SAC/SPA Zones: These are areas of woodland which are subject to special protection under European law.
- Wind Potential: This includes windmills and wind parks.

The System of Restrictions is comprised of the following:

- Landscape restrictions
- Hydrogeological restrictions
- Architectural and Archaeological sites of special interest

The Planning System finally involves:

- Provincial Territorial Plan
- Regional Landscape Plan
- Extract from the Basin Plan for Hydrogeological Structure
- Seismic Microzonation Study of the Settlements in the Municipality of Monacilioni
- Urban Masterplan

These systems were categorised as follows (Figure 1):

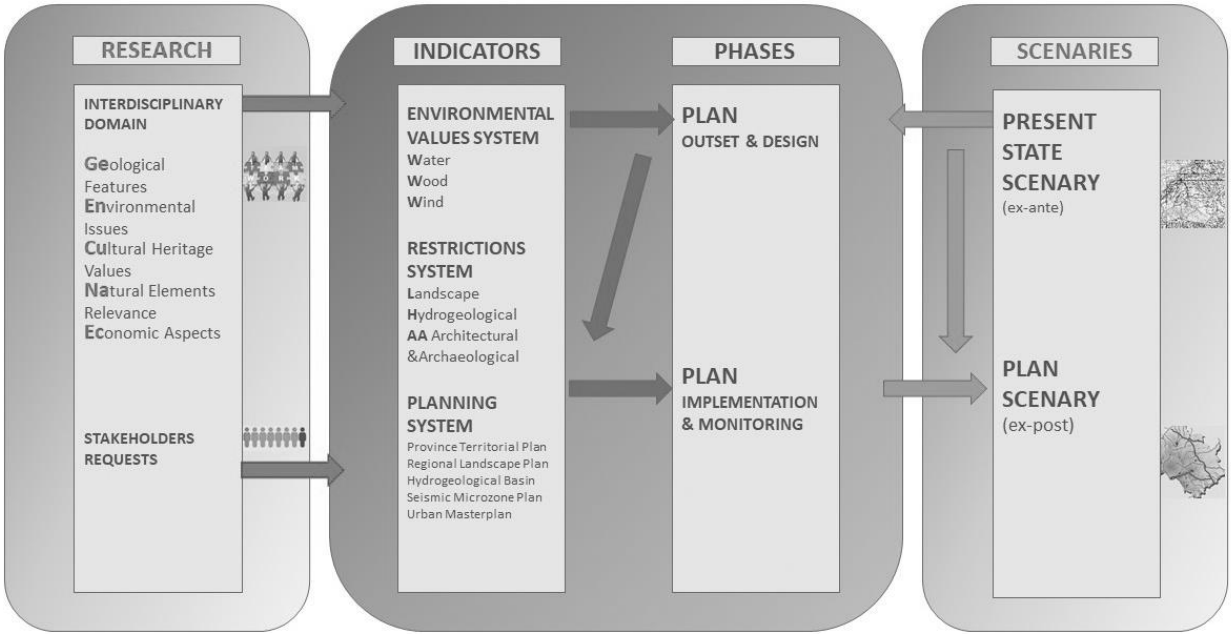

Figure 1. The Methodology's Flow-chart (Source: L.a.co.s.t.a. Laboratory, 2025)

3.2. The case-study

The Feasibility Plan for the 'South Historic Centre Recovery Plan: "Case spallate e non solo…" (Ruined Houses and more...), has been drawn up in line with the objectives set out in Article 3 of Regulation (EU) 2021/241 (European Parliament and the Council of the European Union, 2021), which establishes the Recovery and Resilience Facility. It is intended to be an innovative instrument designed to provide effective and significant financial support to accelerate the implementation of sustainable reforms and related public investments in Member States, and to help address the consequences and negative effects of the COVID-19 crisis within the Union.

'Resilience' – defined as the ability to cope with economic, social and environmental shocks and/or persistent structural changes in a fair, sustainable and inclusive manner – aims to foster the development of robust economies underpinned by sound financial and welfare systems, in order to help Member States respond to shocks in a fair and inclusive manner and achieve a swifter recovery, not least in the interests of the Union's cohesion: "a lack of resilience can also lead to negative spillover effects resulting from shocks between Member States or within the Union as a whole, thereby posing challenges for convergence and cohesion within the Union".

The Feasibility Plan, whilst taking all objectives into account, specifically addresses the guidelines relating to the theme of "Urban Regeneration" – which aims to provide for "infrastructure works and the regeneration of buildings and public spaces for civilian use, designed to house services and activities of collective interest"; the theme of "Environment and natural resources", with the aim of "mitigating territorial risks" and "enhancing natural resources, including for development purposes"; and the theme of "Culture", aimed at implementing "measures to protect and enhance cultural heritage and the landscape, and to promote cultural activities". Such planning must aim to "give priority to the character of the local area, identify solutions compatible with general urban planning regulations, and must in any case be easily and swiftly implementable, even with minor adjustments, whilst incorporating solutions with low environmental impact focusing on the restoration and enhancement of the existing heritage".

As mentioned earlier, work then proceeded on the drafting of the Executive Urban Regeneration Plan, following a subsequent commission from the local council (Comune di Monacilioni, 2022a). Monacilioni features a historic centre situated on a rocky outcrop; between 1961 and 1963, it suffered a series of landslides leading to the disappearance of a substantial part of the settlement. Indeed, it was already the subject of Royal Decree No. 1547 of 3 November 1921 (Repubblica Italiana, 1921) which provided for the inclusion of the settlement of Monacilioni, in the province of Campobasso, amongst those to be consolidated at the expense of the State, pursuant to Law No. 445 of 9 July 1908 (Repubblica Italiana, 1908), was again the subject of Presidential Decree No. 1348 of 22 October 1970 (Repubblica Italiana, 1970) with the partial inclusion of the village of Monacilioni amongst those to be relocated at the State's expense, since, due to the landslide-prone nature of the terrain, instability has occurred affecting in particular the north-eastern part of the village, hence the need to proceed with the partial relocation of the village itself" (Figure 2).

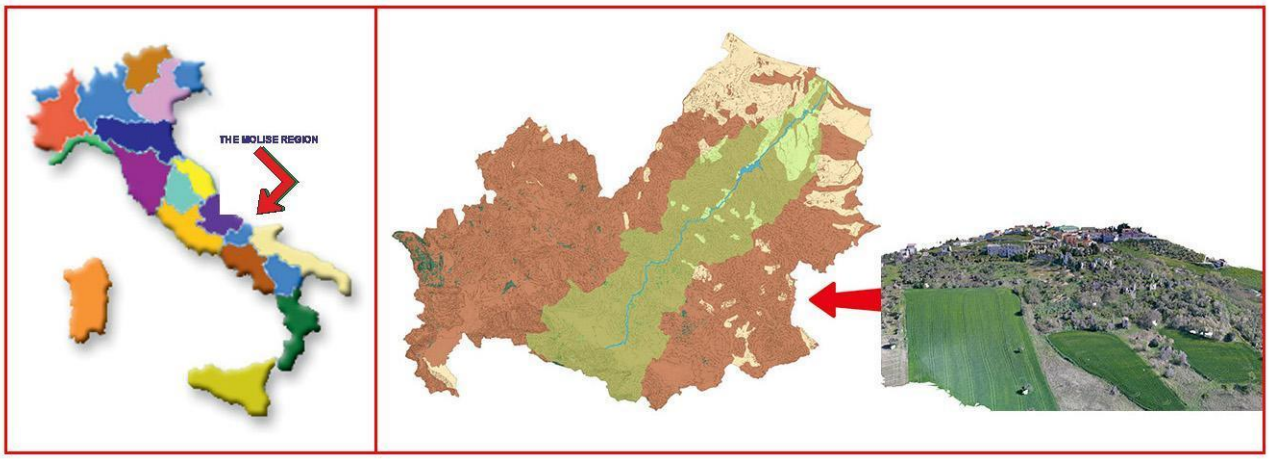

Figure 2. The localisation of the Monacilioni Municipality (Source: L.a.co.s.t.a. Laboratory, 2025)

The Plan aims to restore a sense of identity to this part of the village, which is defined in the current town planning regulations as "Zone A2: landslide-prone area due for demolition" (Comune di Monacilioni, 1979). The area identified by the Municipality for the Feasibility Study is commonly known as "le case spallate". Adjacent to the historic town centre, more than sixty years after the catastrophic event, stand the remains of the houses that were the focus of the most disastrous phenomena to have occurred in the Municipality of Monacilioni – phenomena that recurred constantly but which, in the early 1960s, brought about a change in the fate of its population. In fact, a substantial part of the housing stock and the public spaces where village life took place disappeared. The comparison of aerial photographs of the town centre presented here demonstrates what happened in those years and how the state of neglect has

persisted over time to the present day (Figure 3): it also allows one to recognise the changes in the blocks and central areas of the village.

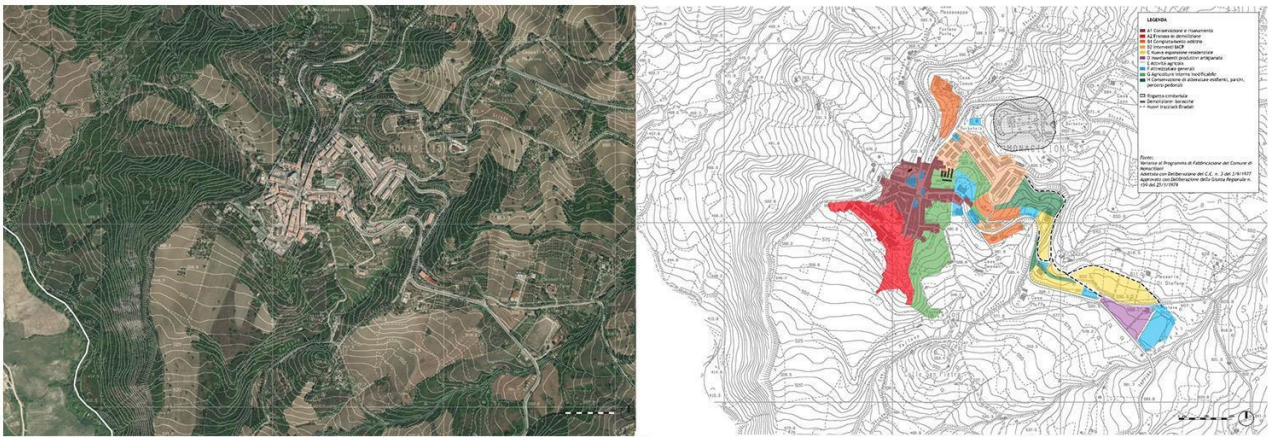

Figure 3. Monacilioni Municipality: Orthoimage and the local Planning Tool (Source: L.a.co.s.t.a. Laboratory, 2025)

Consequently, the urban and landscape regeneration plan drawn up for this area is driven by a desire to restore the urban identity, whilst preserving the memory of the disaster. Undoubtedly, the most striking aspect was the loss of a large part of the built heritage (in some cases of considerable architectural merit). Even more significant was the loss of communal spaces, public spaces and roads. But the most serious consequence was the loss of a sense of community (with the departure of a large part of the population who chose to move elsewhere). Since the 1960s, these disastrous events have persisted over time, fuelled in part by extreme weather conditions. Consequently, the persistence of landslides has been a constant feature of life in Monacilioni and has brought with it two significant negative consequences. The first concerns the loss of the built heritage, the settlements and the church – a cultural and religious focal point for the population – with the negative consequences associated with the forced relocation to council housing (where residents are no longer homeowners but are forced to pay rent). The second consequence has been a severe demographic decline.

4. Results and Discussion: from territorial analyses to concept design

The project insists on an area characterized from a surface territory of about 8 ha and provides for the creation and arrangement of open spaces dedicated to usability. These elements defined the areas of intervention that will be the main drivers of the project: they were defined as Identity Elements, or those elements that guided the design of the area. The interventions, in fact, will fundamentally involve the desire to re-propose the memory of the fabric of the area of the disappeared town. The executive phase consisted of defining the areas more specifically involved in the project, going into detail on the different types of intervention that the project envisages. During the already described phase in which the Feasibility Plan was developed some preliminary studies have been conducted. They were:

- Data Collation: Cartographic surveys and territorial data
- Local Surveys: Site inspections and comparisons with old photographs
- Ground and Drone Surveys: Surveys conducted on the ground and utilising unmanned aerial vehicles (UAVs); The photogrammetric survey is conducted utilising a drone platform; New Ortho-image; The creation of an orthophotograph of the current situation

The following Executive Plan encompasses the creation and development of open spaces for the benefit and enjoyment of residents. As illustrated in Figure 4, the Masterplan exemplifies the project's conception

in close alignment with the local context. Despite the present state of abandonment and perceived deficiencies in the area, the project's vision entails its regeneration as the town's primary hub. This ambition is underpinned by the objective of transforming the area into a captivating locale where information regarding the region's landscape and cultural network can be both collated and disseminated. The new developments highlight and emphasise significant landmarks in the urban centre, while concurrently presenting novel opportunities that facilitate connectivity between the urban centre and the broader municipal territory, as well as the surrounding historical and landscape areas. As will be demonstrated in the project description, this area is closely connected to the rest of the urban centre, and one of the primary objectives was precisely its connection to the pre-existing fabric.

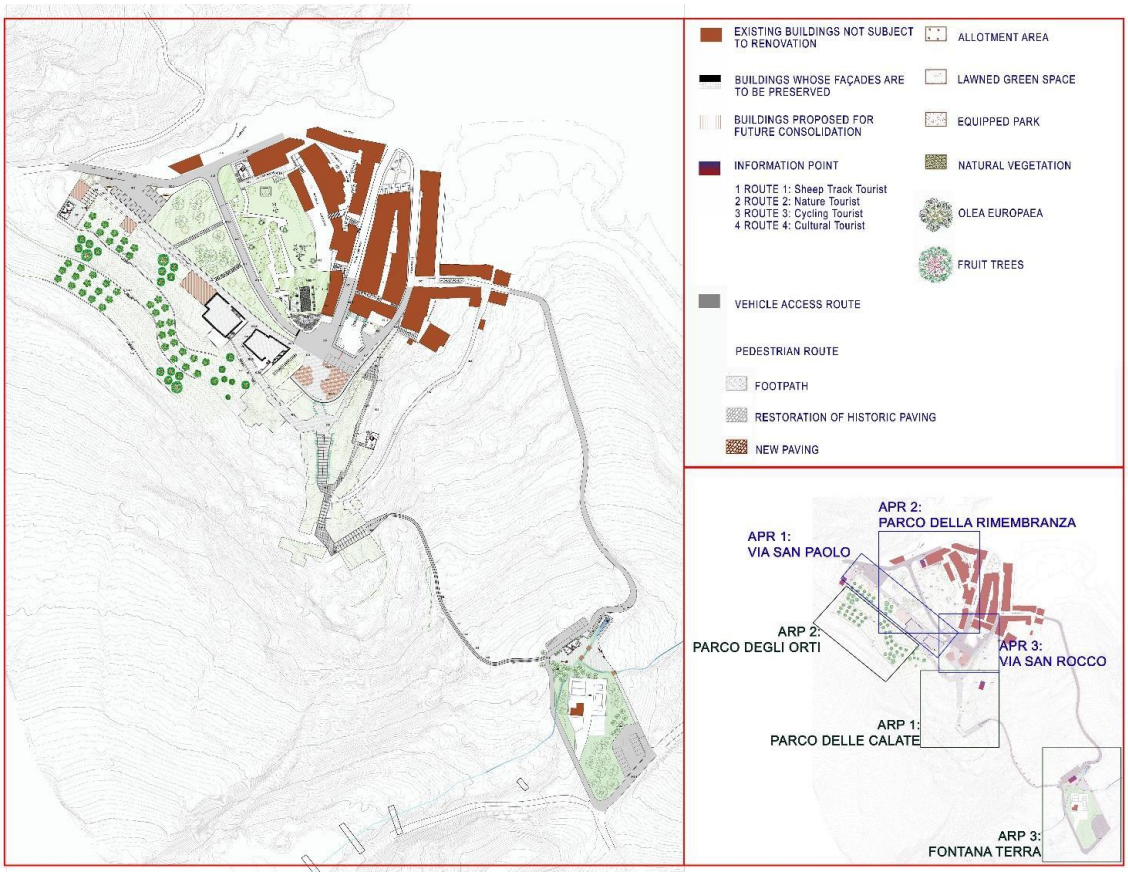

Figure 4. The Monacilioni Masterplan (Source: L.a.co.s.t.a. Laboratory, 2025)

The following two categories of intervention have been identified:

- APR zones (Aree di Parziale Recupero)

The term 'APR' is an acronym for 'Partial Recovery Areas'. These include:

- Maintaining the visibility of Via San Paolo;
- Demolition of the dilapidated and abandoned buildings in the A2 zone, from the current concrete square to the Fontana della Terra;
- Renovation of the current Parco della Rimembranza, which houses the remains of the destroyed Church and also includes small areas for a playground;

  - Connection of the already funded projects for both the urban start of Calata Fontana and the renovation of the road to the Fontana della Terra, which falls within the project area.
- ARP zones (Aree di Ricomposizione Paesaggistica)
  - The term 'ARP' is an acronym for 'Landscape Reconstruction Areas'. These include:
  - Redevelopment of the terraced area located behind Via San Paolo;
  - Demolition of all dilapidated buildings in Zone A2 that compromise the safety of the site;
  - Reconstruction of the axes as memorial paths and reconstruction of the "scalette" (stairways).

In the ensuing paragraphs, two emblematic cases will be illustrated: the design of an APR and the design of an ARP.

4.1. 'Partial Recovery Areas': the main square and the disappeared church

The redevelopment of the square in front of the main church (of which only the entrance balustrade remains) consists of the "ideal" completion of the terminal block on Via San Rocco, which is also no longer existent. The edifice will also serve the purpose of a memorial to the former Town Hall.

The area has previously been examined by the Municipality, which has specifically drawn up a Disposal Plan, with the aim of acquiring the previously privately owned areas. The 2022/2024 Real Estate Disposal and Enhancement Plan (Comune di Monacilioni, 2022b) was approved, as was the 2022/2024 Real Estate Disposal and Enhancement Plan - Integration (Comune di Monacilioni, 2022c).

Moreover, the project encompasses the development and promotion of a series of routes, which symbolise the aspiration to establish a connection between the urban centre and the broader municipal territory, in addition to existing tourist routes within the surrounding municipalities. The Via San Rocco block is interrupted at its extremity by the collapsed edifices, the remembrance of which has been eradicated by the square that has been constructed to consolidate that portion of the terrain. The abrupt interruption at the conclusion of the block is evident in Figure 5a. The project's objectives also include the transformation of the square, which, at present, disrupts the urban fabric and its relationship with the landslide-prone area being treated, which were once connected. In light of this, a strategy has been devised to restore its historical configuration. This strategy involves two primary components: the regeneration of the concrete square, which will be adorned with new paving that reflects the historical blocks that are no longer extant, and the renovation of the block's extremity, where a memorial to the erstwhile Town Hall will be erected. The demolition will involve the asphalt sections in the areas where the reconstruction of the disappeared blocks is planned, and the ground-level slab on the Corso Umberto side. Excavation for the construction of the new parking lot is also planned. In the area where the old Town Hall once stood, a lightweight structure with steel pillars and a roof is planned, along with a steel access ramp for the new staircase, providing access from the lower level of Via San Rocco. The remains of the edifices that formerly occupied the southern side of the extant concrete square are to be constructed in sandstone. The erection of a panel will finally see the light of day, and this panel will reproduce the old image of the Town Hall, which has now disappeared Figure 5b.

Via San Rocco
There is a brutal interruption at the end of the block. The urban fabric is no longer legible. The current concrete square, which was rebuilt 20 years ago for consolidation purposes, completely disregards the consolidated urban fabric of Via San Rocco. Above all, the layout of the final section remains unresolved, and the solution visible in the photo is absolutely unsatisfactory in terms of the differences in level and the urban and architectural quality of the area.
Foto: Authors

Figure 5a. Via San Rocco: present condition (Source: L.a.co.s.t.a. Laboratory, 2025)

Figure 5b. Via San Rocco's comparison: a. ante-post aerial view; b. ante-post Old Town Hall memory (Source: L.a.co.s.t.a. Laboratory, 2025)

4.2. Landscape Reconstruction Areas ': the "Calate" Pathway - where the houses were
This area is of pivotal significance to the project. The objective of the project is to revive the memory of the ancient urban centre (Figure 6a) through several primary interventions, including the demolition of ruined buildings that compromise the safety of the site, the reconstruction of the memory of the "stairways," and the recovery of the memory of the lost buildings through permanent exhibitions supported by photographic and video documentation, and plexiglass display panels reconstructing the ancient views.

The most significant interventions involve the complete demolition of the remains of the civil buildings, both underground and above ground, with the subsequent clearance of debris and vegetation infestations. The pavement will then be reconstructed using recovered materials from previous demolitions, thereby restoring the appearance of the old routes. Consequently, the restoration of salvaged local stone pavement will be executed through a meticulous process of removal, preparation, and cleaning of the subgrade, followed by the replacement of the stone, including the completion of any missing sections. Along the Calata Colle path, side panels will be installed to recreate the feel of the old blocks and lead to the small square connecting Via Vattuta and Via Vista l'Oste, where a panel will be installed depicting the image of the church as it was perceived while walking up the Calata. The panels will be composed of Corten steel.

A particularly interesting solution was to propose a reimagining of the image of the disappeared church through the creation of this panel, which reproduces the facade as it was. (As has been demonstrated, at present only the balustrade with the access stairs to the church has remained.) Concealed behind the facade, however, is a diminutive elevator. In order to surmount the disparity in height occasioned by the construction of the aesthetically displeasing concrete square, which, it was acknowledged, could not be eradicated, a freight elevator was installed to convey passengers to the level of the square (Figure 6b).

Calata Colle

The Calata Colle route is a path that ascends to the highest point of the village, leading towards the primary church.

The square's closure has resulted in the formation of a belvedere, surrounded by a grove of trees. However, the current arrangement of these trees creates an image that is disconnected from its surrounding context. Continuity that once existed between the upper and lower parts of the village, which is currently undergoing restoration to preserve its historical significance, is no longer perceptible.

Foto: Archive Pannitto

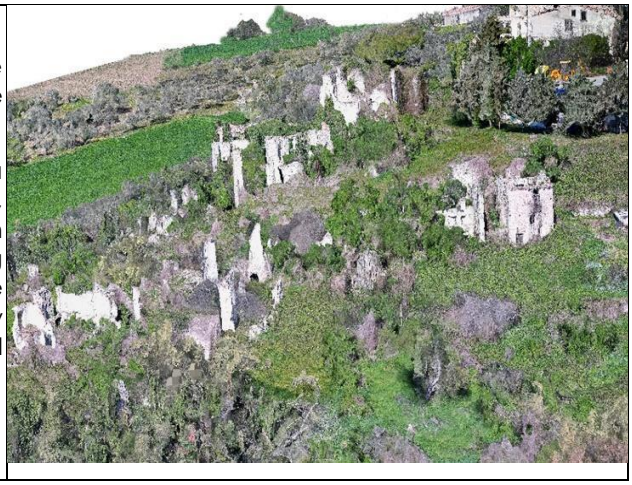

Figure 6a. Calata Colle: present condition (Source: L.a.co.s.t.a. Laboratory, 2025)

Figure 6b. Calata Colle's comparison: a. ante-post view; b. panel of the Old Church memory (Source: L.a.co.s.t.a. Laboratory, 2025)

These two examples, selected from among the various projects to be carried out, can be regarded as emblematic of the aims of our Executive Plan, the purpose of which is to translate strategic decisions into concrete interventions, whilst protecting and enhancing the local area in accordance with landscape regulations.

5. Conclusions and Remarks

In conclusion, the research underpinning the project focused on the evolving data from territorial analysis, the guidelines of the emerging landscape planning framework, and the principles of environmental regeneration, adopting an integrated approach that combines environmental, natural, agricultural and historical-cultural aspects. These themes were explored through a comparative analysis of the territory, in particular through a diachronic comparison drawing on recent research based on geographic information systems (GIS) concerning changes in territorial and landscape characteristics.

The ongoing refinement of the methodology through its application in various locations is certainly not yet complete, but it is based on the experience gained from these case studies, which we are currently testing in the Molise region. This is a deliberate design process, aimed at integrating the historical and cultural nuances of the area into the project. This also highlights the contribution of these experiences to the drafting of the Regional Landscape Plan, which is currently lacking in the region and on which we are working. It has become clear that urban planning must take into account the effective control of land-

use development and the historical local memory. In Italy, "there is a major problem of discrepancy between older-generation urban plans – which are still so widespread – and actual changes. A similar observation can be made regarding emergency planning in the context of natural disasters: whilst implementation mechanisms are accelerated, there is subsequently a failure to integrate these changes into the structure responsible for governing the wider territory beyond the urban area. In short, the mechanism for monitoring transformations is difficult and unclear; whilst it is effective in many other countries, in Italy it is carried out inconsistently and with significant differences from one region to another' (Cialdea, 2023). Despite the extensive literature on indicators relating to natural and landscape resources, this methodology is innovative in that it introduces and compares parameters that can be incorporated into planning tools. This is a particularly significant aspect in the region under consideration, given that the municipalities' urban planning tools are outdated, as was clearly demonstrated in the case study.

In any case, the aim of this project was to improve the following aspects during both the preliminary and implementation phases:

- Quality of public space

Improving the usability of the entire integrated system of communal public spaces is a fundamental requirement of the project. The overall aim of the project is to encourage a sense of shared ownership of these spaces and to increase their use, as a prerequisite for the development of social activities.

- Quality of the landscape

The reconnections achieved by the design scheme (both in terms of the restoration of existing buildings and landscape interventions) help to enhance the appeal of the urban landscape.

- Environmental quality

A key environmental requirement is undoubtedly to make the area affected by the landslide – which is currently off-limits – safe, by demolishing the collapsed houses and creating a footpath.

- Social quality

The active involvement of citizens began with the public consultation at the launch of the Regeneration Programme and continued with a survey on citizens' preferences regarding issues of public interest, conducted via a multiple-choice questionnaire.

This experimental Recovery Plan is, however, based on the methodology used to draw up the landscape plan for the Molise Region, an area characterised by a large number of small towns with significant territorial vulnerabilities. It is hoped that the design phase – which was successfully presented to local residents, who also took part by completing a questionnaire we provided to understand their wishes – will be followed as soon as possible by the implementation of the planned measures.

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Conflict of Interests
The author declares no conflict of interest.

Contribution to the Field statement
The issue of small towns that have always been prone to landslides is a subject that has been addressed by many researchers. This study aims to combine historical factors with physical factors (and thus the susceptibility to instability as a permanent feature). For this reason, the study is based on an extensive analysis of territorial factors, collected and analysed within a Geographical Information System specifically designed for the case under examination. The innovation lies in proposing a new layout for the destroyed substantial part of the village, taking into account the 'potential' of the territory, where physical resources can be channelled towards new uses.

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