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About the Journal

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.

The growing needs to foster a deeper understanding of standards and emerging aspects in the region lead to the need for a scientific platform in which academics, professionals and stakeholders work together to deal with and act to address the rising forces in our cities. Therefore, governmental, and non-governmental organizations from different countries come together to lay the foundations and set pillars for achieving the goals and needs of today and tomorrow.

Accordingly, 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.

Coverages

The journal explores a range of academic and policy concerns including:

- Water and Land
- Dwelling and Communities
- Heritage & Vernacular Studies
- Environment and Sustainability
- Education

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All research articles in this journal have undergone rigorous peer review, based on initial editor screening and anonymized refereeing by two referees.

The manuscript submission and peer-review process are broken down into the following steps:

The author submits a manuscript;
The Editor assigns Reviewers to the manuscript;
The Reviewers review the manuscript;
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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.

Educational Technology

Journal of Mediterranean Cities has an international editorial board of eminent experts in their field from Algeria, Bangladesh, Botswana, Bulgaria, Egypt, Erbil, Finland, Iceland, Italy, Jordan, Latvia, Lebanon, Netherlands, Nigeria, Morocco, Palestine, Portugal, Prague, Saudi Arabia, South Africa, Spain, Turkey, United Arab Emirates, United Kingdom, and United States of America. We are confident that JMC will attract a great number of editors, eminent scientists in the field. The selection will be based on the activities of the editors and their desire to contribute to the development of the journal. *Journal of Mediterranean Cities* provides a platform for academics and scientists professionals to refer and discuss recent progress in the fields of their interests. Authors are encouraged to contribute articles that are not published or not under review in any other journal. Each submitted manuscript is evaluated based on the originality of its contribution to the field of scholarly publishing, the soundness of its theory and methodology, the coherence of its analysis and its availability to readers (grammar and style). The normal turn-around time for the evaluation of manuscripts is one to two months from the date of receipt.

Submission of an original manuscript to the journal will be taken to mean that it represents original work not previously published, that is not being considered elsewhere for publication; that the author is willing to assign the copyright to the journal as per a contract that will be sent to the author just before the publication and, if accepted, it will be published in print and online, and it will not be published elsewhere in the same form, for commercial purposes, in any language, without the consent of the publisher. The names and email addresses entered in this journal site will be used exclusively for the stated purposes of this journal and will not be made available for any other purpose or to any other party. The requirement for the submission of a paper implies that it has not been published before; that it is not under consideration for publication anywhere else.

When considering submitting an article, the Editors have provided the following criteria to assist authors with preparing their submissions:

Originality – The author should ensure that the manuscript has not been previously published nor is being considered by another journal.

Plagiarism - All articles are test ted with Turnitin software. Content should be properly referenced. Be sure to check the paper for possible accidental plagiarism. Some plagiarism checker websites include: http://www.turnitin.com/, www.antiplagiat.ru, www.grammarly.com, www.plagtracker.com or www.duplichecker.com

Writing – Please write in good English (American or British usage is accepted, but not a mixture of these). For non-native English speakers, and perhaps even for some native English speakers, grammar, spelling, usage, and punctuation of the texts are very important for an effective presentation. Hence, manuscripts are expected to be written in a clear, cogent, and readily understandable by an international readership.

Manuscripts must be submitted online. Electronic submission reduces the editorial processing and reviewing time. As part of the submission process, authors are required to check off their submission compliance with all the following items, and submissions may be returned to authors who do not adhere to the following guidelines:

-The submission has not been previously published or presented to another journal for consideration (or an explanation has been provided in Comments to the Editor).
-The submission file is in OpenOffice, Microsoft Word, RTF, or WordPerfect document file format.
-Where available, URLs for the references have been provided.
-Where available, DOI numbers for the references have been provided.

The text is single-spaced; uses a 12-point font; employs italics, rather than underlining (except with URL addresses); and all illustrations, figures, and tables are placed within the text at the appropriate points, rather than at the end. The text adheres to the stylistic and bibliographic requirements outlined in the Author Guidelines. If submitting to a peer-reviewed section of the journal, the instructions in ***Ensuring a Blind Review*** have been followed.

A manuscript goes through the peer-review process. Authors submit manuscripts to **Editorial office** via the online system. The acknowledgement letter should be sent to the author to confirm the receipt of the manuscript. The Chief Editor first

reviews manuscripts. Chief Editor is assisted by Section Editors (could also be Co- or Associate Editors). The Editor assigns a Section Editor to see the manuscript through the complete review process and return it with a recommendation or decision. The manuscript is checked to see if it meets the scope of the Journal and its formal requirements. If it is incorrect or unsuitable, the author should be informed, and the manuscript filed (or returned if requested) – direct rejection. Manuscripts that are not suitable for publication in the Journal are rejected. A Rejection letter is sent to the author stating the reason for rejection. If the manuscript conforms to the aims and scope of the Journal and formally abides by the Instructions to Authors, it is sent out for review. Depending on the type of paper, it could be accepted immediately for publication (invited Editorial, Book review etc.) by the Chief Editor. Check that the manuscript has been written and styled in accordance with the Journal style; that it carries an abstract (if applicable), keywords, correct reference system etc. and check that the correct blinding system has been used. If anything is missing, Editor in Chief through the associate editor will ask the authors to complete it before the manuscript is sent out for review. The manuscript is sent out for review. The reviewer reads and evaluates the manuscript and eventually sends a review report to the Chief Editor. The time for review can be set to 2-6 weeks depending on the discipline (more time is usually given to papers in the humanities and social sciences). Make sure to provide the reviewer with clear instructions for the work, e.g., outlined in the form of a Review report or several questions to be considered. Based on the reviewers' comments the Chief Editor decides to:
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An acceptance letter is sent to the author and the final manuscript is forwarded to production. Sometimes, the authors are requested to revise in accordance with reviewers' comments and submit the updated version or their manuscript to the Chief Editor. The time for review can be set to 2-6 weeks depending on the discipline and type of additional data, information or argument required. The authors are requested to make substantial revisions to their manuscripts and resubmit for a new evaluation. A rejection letter is sent to the author and the manuscript is archived. Reviewers might be informed about the decision. After review, a manuscript goes to the Copy Editor who will correct the manuscript concerning the correct referencing system, confirmation with the journal style and layout. When Copy Editor finishes his/her work they send manuscripts to the Layout editor. Layout Editor is responsible for structuring the original manuscript, including figures and tables, into an article, activating necessary links and preparing the manuscript in the various formats, in our case PDF and HTML format. When Layout Editor finishes his/her job they send manuscripts to Proof Editor. Proof Editor confirms that the manuscript has gone through all the stages and can be published.
This issue contains 7 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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Evidence on the Improvement of the Thermal Comfort Index and Habitability in Bioclimatic Spaces of the Mediterranean Region

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ABSTRACT

Climate change is a critical environmental challenge of this century, with particularly severe impacts projected for the Mediterranean region. In Spain, maximum temperatures are expected to increase by more than 2°C by the end of the century, with more frequent and longer-lasting heatwaves. Urban adaptation strategies such as bioclimatic architecture and integrating vegetation into built structures are effective tools to moderate microclimates and create climate shelters. However, a gap in empirical research connecting these tools in hot semi-arid Mediterranean contexts remains. This study addresses this gap by examining the impact of bioclimatic design on thermal comfort through fieldwork conducted at two distinct locations in the province of Málaga: Coín (rural) and Teatinos (urban). The research hypothesizes that spaces where the five fundamental pillars of bioclimatic design (urban planning, architecture, vegetation, landscaping, and materials) are well integrated tend to exhibit better thermal comfort. To test this, a Thermal Comfort Index (THI) was employed, adapted to the specific climatic conditions of the study areas, allowing a more accurate environmental performance assessment in each setting. Bioclimatic urban strategies, architectural configurations, vegetative elements, and material choices were analyzed in situ, revealing that the most thermally comfortable areas are aligned with a strong synergistic presence of all five pillars. The results support the notion that a thoughtful convergence of these principles mitigates heat stress and enhances spatial habitability in Mediterranean climates. This research contributes to current discussions on climate-resilient design by offering empirical evidence from two real-life case studies under urban and rural contexts.

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1. Introduction

Climate change is one of the most pressing environmental challenges of the 21st century, with particularly severe impacts projected for the Mediterranean region. Climate models consistently indicate that southern Europe will experience more intense warming than other areas of this continent (AEMET, 2024). In Spain, for instance, maximum temperatures are expected to increase by an average of 2.3 °C by the end of the century. This trend is already observable, as average maximum summer temperatures have risen by 1.4 °C in recent decades, while the frequency and duration of heatwaves have intensified significantly (Junta de Andalucía, 2022; AEMET, 2024).

In this context, urban areas in southern Spain, particularly the Málaga Metropolitan Area and Costa del Sol (AMACOS), illustrated in Fig. 1, face specific risks linked to the Urban Heat Island (UHI) effect. This phenomenon, amplified by dense construction and limited green infrastructure, can raise local temperatures by up to 4 °C compared to surrounding rural zones, exacerbating heat-related health risks and deepening socio-spatial inequalities.

To cope with these ever-increasing concerns, urban adaptation strategies have arisen as potential solutions; however, these should consider passive, low-energy design principles to be successful (Ramírez-Cuastuza & Alarcón-Rodríguez, 2024). Hence, bioclimatic architecture, and more specifically, the integration of vegetation into built structures through pergolas, green roofs, and facades, have emerged as effective tools to moderate microclimates and create climate shelters (Cano Giraldo, 2024). However, a gap in empirical research that connects UHI theory with the actual thermal performance of such vegetated elements in hot semi-arid Mediterranean contexts remains. Accordingly, the aim of this study is to address this gap by evaluating how the traditional bioclimatic structures, e.g., pergolas and grapevine arbors, among others, perform under extreme heat conditions. The analysis focuses on two contrasting, yet climatically similar sites: 1) the urban Teatinos University Campus in Málaga, and 2) the rural Todobarro estate in Coín. Both sites fall within the thermo-Mediterranean bioclimatic zone and share a dry to semi-arid ombroclimate; nonetheless, they differ in urban density, materiality, and vegetation cover.

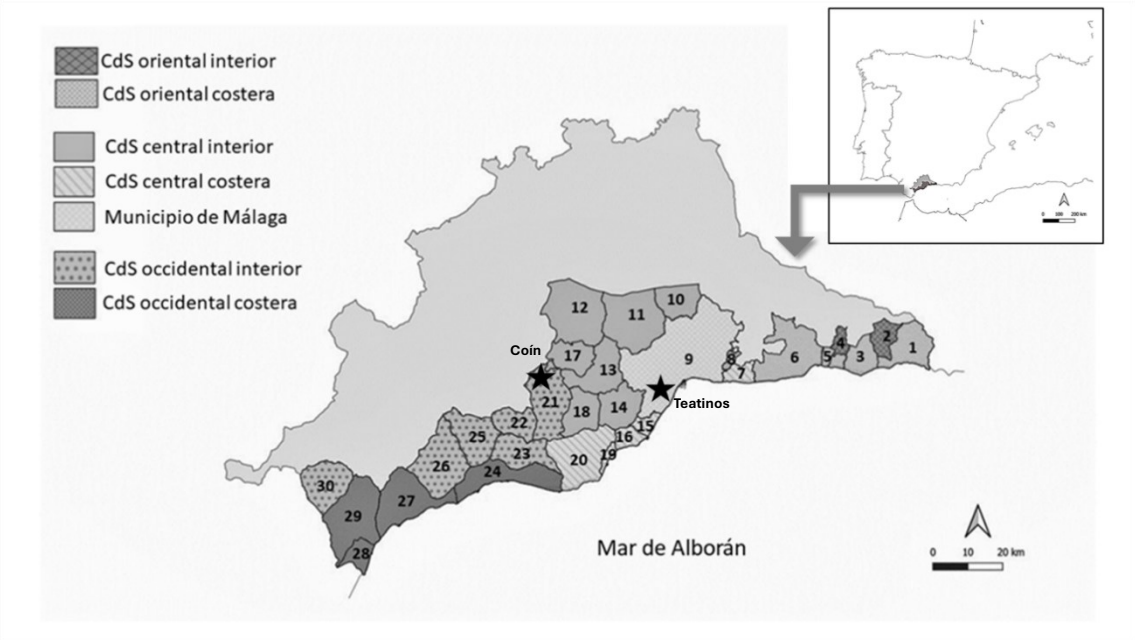

Figure 1. Map of the Metropolitan Area of Malaga and Costa del Sol (AMACOS). The stars indicate the study locations within this area (1. Nerja, 2. Frigiliana, 3. Torrox, 4. Sayalonga, 5. Algarrobo, 6. Vélez-Málaga, 7. Rincón de la Victoria, 8. Totalán, 9. Málaga ( ), 10. Casabermeja, 11. Almogía, 12. Álora, 13. Cártama, 14. Alhaurín de la Torre, 15. Torremolinos, 16. Benalmádena, 17. Pizarra, 18. Alhaurín el Grande, 19. Fuengirola, 20. Mijas, 21. Coín ( ), 22. Monda, 23. Ojén, 24. Marbella, 25. Istán, 26. Benahavis, 27. Estepona, 28. Manilva, 29. Casares, and 30. Gaucin). Source: elaborated by the authors

Unlike studies that rely solely on air temperature or broad comfort indices, this research employs an adapted Thermal Comfort Index (THI), tailored to Mediterranean climatic conditions. Since traditional THI models were developed in temperate or tropical regions, they may not reflect thermal perceptions in semi-arid climates accurately. By adjusting the THI accordingly, this study aims to better capture *in situ* the human experience of heat.

The central hypothesis is that an effective combination of the five foundational pillars of bioclimatic design, i.e., urban planning, architecture, vegetation, landscaping, and materials, can significantly improve thermal comfort, even under extreme heat conditions (Rodríguez Escandell, 2024). The findings aim to contribute not only to theoretical debates on urban adaptation but also to provide reliable input to elaborate practical guidelines for designing effective climate shelters in vulnerable regions.

In the Mediterranean region, with projected extreme climates and where both study areas are located, there is an urgent need to develop bioclimatic spaces that integrate architecture, urban planning, landscape design, vegetation, and thermoregulatory materials (Pesqueira et al. 2018). Within this framework, the concept of climate refuges has gained traction, promoted by multidisciplinary teams who define them as spaces that offer thermal comfort to people and biodiversity during extreme temperature events (Guerrero Serrano et al., 2024; Morelli et al., 2016). These refuges are grounded in passive design strategies that reduce reliance on artificial thermal control systems. Hence, this study contributes to this growing body of knowledge by calculating the Thermal Comfort Index, commonly referred to as the Temperature-Humidity Index (THI) (Equation 1), in various urban and rural environments using *in situ* measurements, to

evaluate the effectiveness of passive design solutions. The results highlight how the convergence of vegetation and architecture, particularly in pergolas with well-selected plant species, i.e., with vernacular solutions, can lead to significantly more comfortable and resilient spaces. These findings reinforce the potential of nature-based solutions to enhance climate adaptation at the local scale (Morelli et al., 2016).

In this context, vegetated architectural systems emerge not only as aesthetically or culturally valuable but also as vital tools for improving thermal comfort and environmental health in urban areas. Their importance is further emphasized by future climate scenarios developed by the Intergovernmental Panel on Climate Change (IPCC, 2014), that has projected increasingly frequent and intense heat events for the Mediterranean region in the coming years. Representative Concentration Pathways (RCPs) or trajectories describe future greenhouse gas concentrations (not emissions) and have been formally adopted by the IPCC (IPCC, 2023). This study adopts two of these pathways; RCP8.5 (high emissions) and RCP4.5 (intermediate mitigation), to assess how key variables affecting thermal comfort, such as maximum/minimum temperature, hot days and nights, heatwave duration, and precipitation, are expected to evolve in the years 2024, 2025, 2045, and 2095 (Amblar et al., 2017; Rodríguez-Camino, 2013). Data from the AdapteCCa Climate Change Scenario Viewer (AdapteCCa 2023) provide a robust base for projecting future climatic stress.

Accordingly, this study aims to evaluate the effectiveness of vegetated architectural systems, such as pergolas and vine arbors, as passive climate adaptation strategies in urban and rural settings within the Mediterranean region. By calculating the Thermal Comfort Index (THI) under real-life conditions, the research assesses how the integration of vegetation, architectural shading, and permeable materials can enhance thermal comfort during periods of extreme heat (Motalbán-Pozas, 2025). The study also incorporates future climate projections based on RCP8.5 and RCP4.5 scenarios to examine how critical variables, such as temperature, humidity, and heatwave duration, may evolve by the years 2024, 2025, 2045, and 2095. This research approach contributes to the growing field of nature-based solutions by demonstrating the potential of bioclimatic design to create resilient and low-energy climate refuges that promote environmental health and human well-being in the face of intensifying climate stress.

2. Materials and Methods

2.1. Study Area

Two locations were strategically selected to compare the effectiveness of bioclimatic solutions across contrasting environmental and architectural contexts: 1) the Teatinos observation area, and 2) the Coín observation area. The first is the urban Teatinos University Campus, situated in a densely urbanized environment in Málaga, affected by the Urban Heat Island (UHI) effect and characterized by having contemporary and innovative architectural approaches. The second is a private estate in Coín, the Todobarro farm, representing a rural setting with vernacular and ancestral architecture rooted in a passive climate adaptation strategy. The two locations have a straight-line distance from each other of 26 kilometers, allowing for climatic comparability while enabling the assessment of how bioclimatic design strategies perform under different degrees of urbanization and built typologies. This contrast provides insight into the relative effectiveness of modern versus traditional bioclimatic architecture in enhancing

thermal comfort and resilience to heat stress. Details on each location are found as follows.

2.1.1. Teatinos Observation Area (urban)

In this area, six sampling points strategically distributed were selected according to their solar exposure, vegetation cover, surface materials, and their potential to enhance environmental comfort (Table 1, Fig. 2). To measure air temperature and relative humidity, a Psychrometer with IR *5020-0896* (Wertheim am Main, Germany) was used, equipped with an infrared thermocouple input, humidity sensor, and laser sighting system. To validate the temperature data, a Testo 856s thermal imaging camera (Titisee-Neustadt, Germany), was employed.

This device allows for non-contact temperature measurement by converting energy signals into a thermogram, namely, a thermal image representing the infrared energy emitted, transmitted, or reflected by the surface of an object (Weller et al., 1996; Lee et al., 1998). Both devices were calibrated according to the procedures specified in the manufacturers' technical datasheets to ensure the accuracy and reliability of the measurements registered during the study, in compliance with the recommended standards for each instrument.

Table 1. Sample Points Selected in the Teatinos Observation Area (urban).

Sample Point	Altitude (m a.s.l.)	Vegetation Cover	Construction System	Maintenance	Description
Spaces that lack elements that mitigate direct solar radiation (without shade or water)					
PM.01 – Dirt Area	44	5%	No	Seasonal pruning	*Open space without vegetation cover or buildings.*
PM.02 – Asphalt Area	49	0%	No	Seasonal pruning	*Hard and dark surface, highly exposed to the sun.*
Spaces with vegetation					
PM.03 – Pergola with Wisteria (vine)	51	30% wisteria in winter / 100% in summer	Pergola	No	*A structure covered with climbing plants that provides filtered shade.*
PM.04 – Interior Courtyard	52	25%	Courtyard	No	*Enclosed or semi-open space with plant shade and moderate thermal characteristics.*
PM.05 - Pavilion E4	49	15%	Pavilion	No	*Architectural element that combines structural shade with a vegetated environment.*
Space that combines traditional materials and the presence of water with vegetation					
PM.06 – Botanical Garden	46	25%	Pergola	No	*Integrates elements of mud, a sheet of water, and vegetation, optimizing environmental comfort.*

Figure 2. Location of sampling points (SP) in the Teatinos Observation Area (urban). Source: elaborated by the authors

Sampling was conducted from April 21 to June 25, 2024 (Fig. 3). During this period, data were collected on three randomly selected days per week during three time slots. To ensure capturing the most thermally significant periods of the day, measurements were taken in the morning (9:30 to 10:30), at around noon (13:30 to 14:30), and in the evening (18:30 to 21:30).

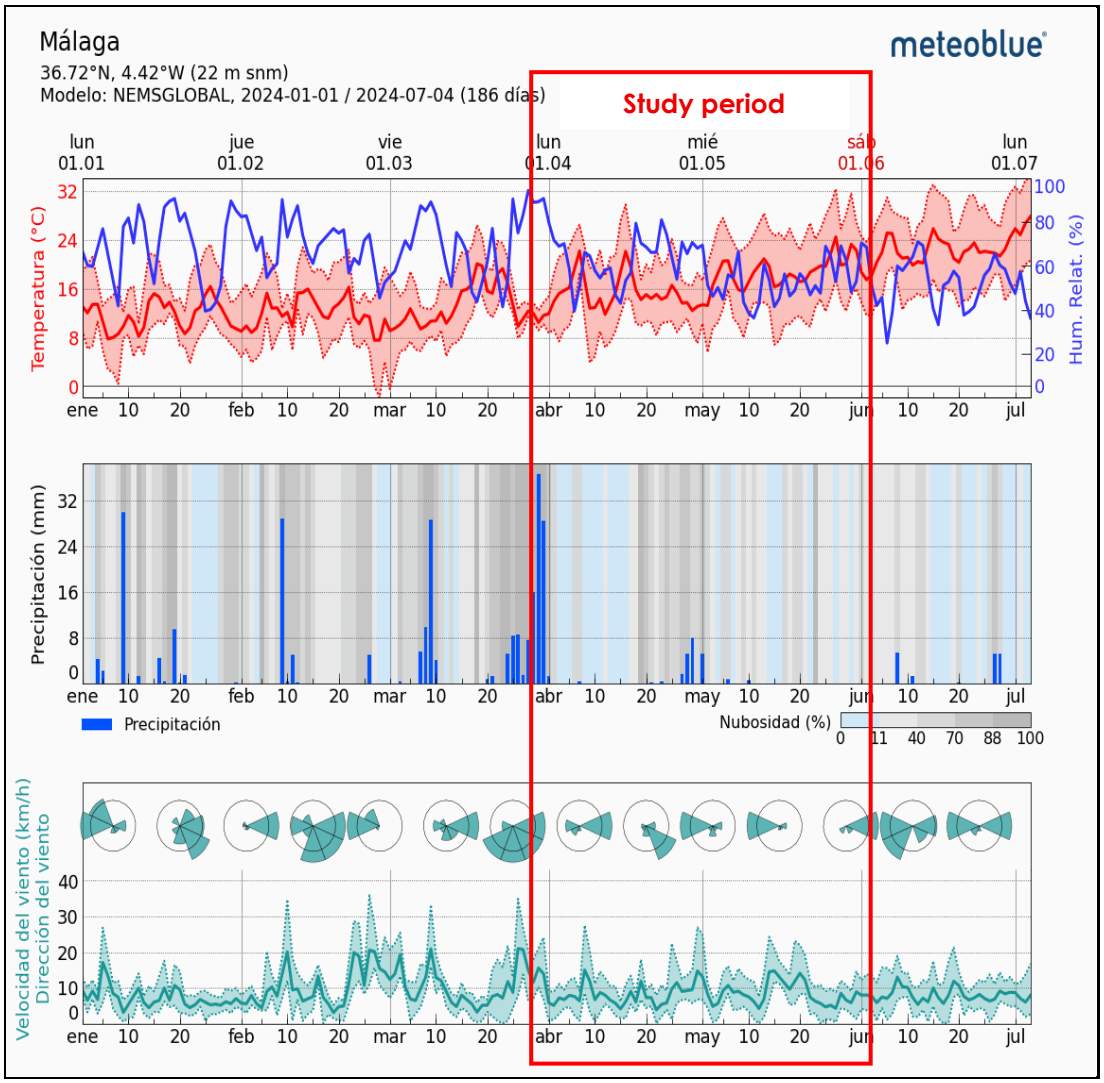

Figure 3. Climatic conditions during the study period in the Teatinos observation area (urban). Top graph: Temperature °(C) in the left x-axis, and relative humidity (%) in the right x-axis, center graph: precipitation (mm) and cloudiness (%), and bottom graph: Wind speed (km/h) and direction. Red rectangle indicates the study period. Source: elaborated by the authors based on data from AEMET (2024)

2.1.2. Coín Observation Area (rural)

The todobarro farm, located in the region of Valle del Guadalhorce, Coín (see Fig. 4), covers a 1-ha area and exhibits a high degree of environmental heterogeneity. Devoted initially to intensive olive monoculture, some of the areas are currently undergoing a renaturalization process, while others are used for diverse organically managed crops. The topography of the area features steep slopes converging into a narrow valley with a southwest–northeast orientation, through which a nearly permanent stream flows. The variation in slope exposure (sunlit vs. shaded), the vertical gradient in relative humidity from the streambed to the upper slopes, and a diverse plant mosaic contribute to a high topo-climatic diversity within this experimental landscape. Sampling points were selected based on the presence of vegetation, surface water, and architectural structures (Fig. 4, Table 2).

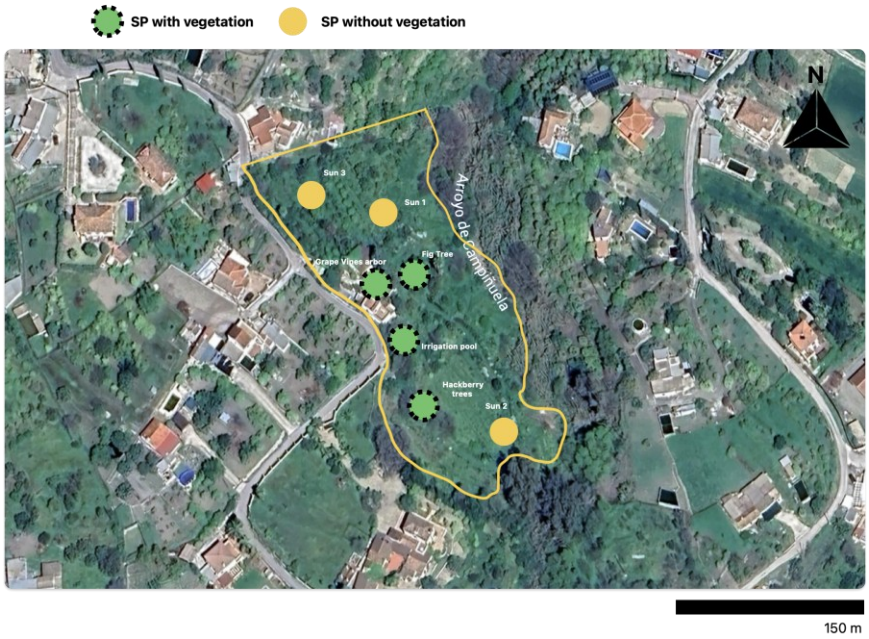

Figure 4. Location of the sampling points (SP) in the Coín Observation Area (rural). Source: elaborated by the authors.

Table 2. Selection of Sample Points in the Coín observation area. Source: elaborated by the authors.

Sample Point	Altitude (m a.s.l.)	Vegetation Cover	Construction System	Maintenance	Description
Spaces with plant shade					
CO.01 – Grapevine arbor	175.4	30% in winter / 100% in summer (vine)	Trellis	Seasonal pruning	Trellis: A structure covered with climbing plants that provides filtered shade.
CO.02 – Irrigation pool	176.1	Coverage: 25% in winter / 100% in summer (hackberry trees)	Pool	Seasonal pruning	Open-air irrigation pool surrounded by hackberry trees
Spaces with vegetation					
CO.03 – Fig tree	169.32	20% / 100%	No	No	Area with a fig tree
CO.04 – Hackberry trees	175.15	25% / 100%	No	No	Area with hackberry trees
Spaces that lack elements that mitigate direct solar radiation (without shade or water)					
CO.05 – Sun1	169.1	15%	No	No	Vacant area: Open space without vegetation cover or buildings.
CO.06 – Sun2	168.98	10%	No	No	Vacant area: Open space without vegetation cover or buildings.
CO.07 – Sun3	171.13	5%	No	No	Vacant area: Open space without vegetation cover or buildings.

Sampling was conducted during April 2023, specifically on days 13, 14, 18, 19, 21, 24, and 25. As illustrated in Fig. 5, the prevailing wind during these days was the Levant wind, which is an easterly wind that blows westwards with frequent gusts exceeding 25 km/h, resulting in mostly clear skies. A light, non-significant precipitation event occurred on April 23. Throughout the sampling period, temperature and relative humidity remained within the normal range for the location. Measurements were taken around noon, from 10:00 to 13:30, to register the maximum thermal stress period.

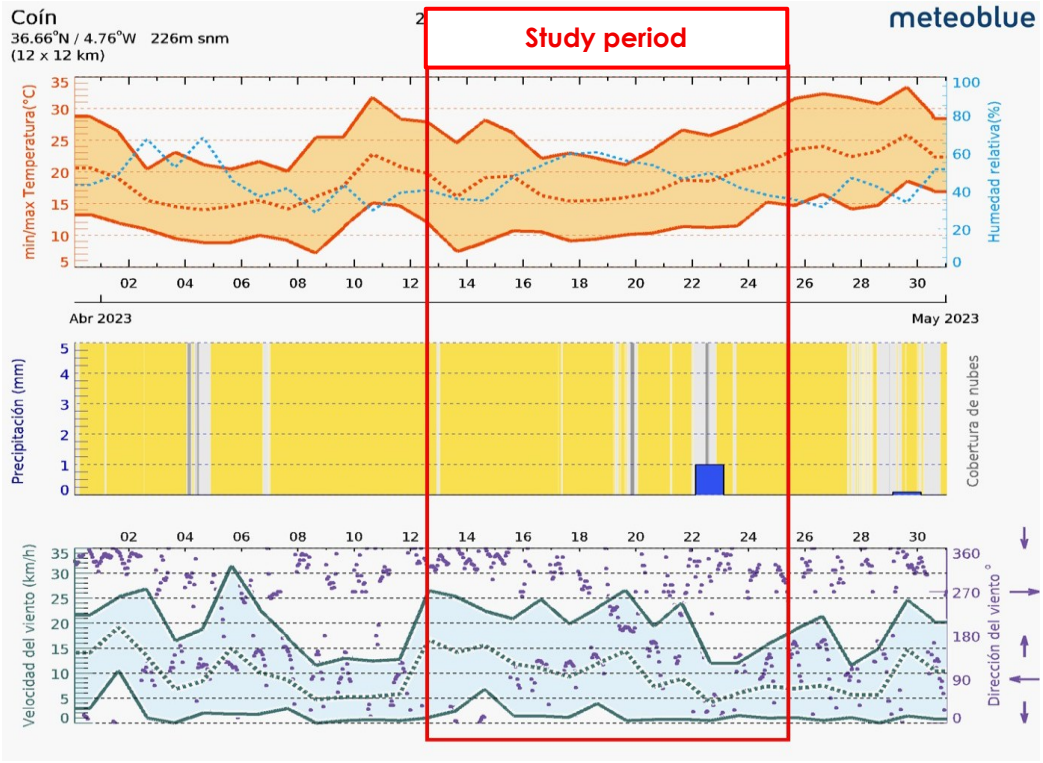

Figure 5. Climatic conditions during the study period in the Coín Observation Area. Top graph: minimum/maximum temperatures °(C) in the left x-axis, and relative humidity (%) in the right x-axis, center graph: precipitation (mm) and cloud cover (%), and bottom graph: Wind speed (km/h) in the left x-axis and direction in the right x-axis. Red rectangle indicates the study period. Source: elaborated by the authors based on data from AEMET (2024)

To measure air temperature and relative humidity, a Psychrometer with IR 5020-0896 (Wertheim am Main, Germany) was used. This device includes an infrared thermocouple input, a humidity sensor, and a laser aiming system. The sampling protocol involved visiting all preselected measurement points on each scheduled sampling day, following a fixed itinerary, and completing the route in the shortest time possible to ensure consistency across readings. The device was calibrated following the protocol specified in the manufacturer's technical datasheet to measure air temperature and relative humidity. Calibration ensures the precision and reliability of the measurements obtained during the study, following the recommended standards for the instrument.

2.2. Calculation of the Temperature-Humidity Index (THI) as a Measure of Climatic Comfort

According to Jendritzky (1991), climatic comfort is defined as the relationship between the local climate and the sensory perception the population has concerning that particular climate. This perception is subjective and can vary depending on individual factors such as gender, diet, age, or health status. Nevertheless, understanding how people perceive climate is essential for the design and planning of urban environments (Ferrelli & Piccolo, 2017).

To quantify climatic comfort, the index proposed by Thom (1959) was used. This index is commonly referred to as the Temperature-Humidity Index (THI) and must be adjusted to reflect both local climatic conditions and the optimal metabolic conditions of the species under study (Espín-Sánchez & Olcina, 2025; De Oliveira et al., 2006). For this purpose, the original formula was adapted to incorporate variables representing the ecological optimum for humans (García, 2003), resulting in the following expression (Eq. 1):

$$THI = T - (0.55 * (1 - 0.01 * RH) * (T - 14.5)) \quad (1)$$

Where *T* represents the mean air temperature in °C, and *RH* is the relative humidity. Index results interpretation follows the classification shown in Table 3, which is based on the optimal climatic ranges for humans.

Using the data obtained from both stations, a Basic Data Matrix (BDM) was created, and the THI (Equation 1) was calculated for all sampling points. For statistical processing, the PAST software (Hammer et al., 2001) was employed to perform a Principal Component Analysis (PCA) and a clustering analysis, to identify groupings among the sampling points and to evaluate how the variables contributed to these groupings. Furthermore, three isopleth maps were generated using spatial autocorrelation gridding (kriging method) to visualize THI values. Fig. 6 illustrates the local THI deviation, the average temperature difference (DIF T), and the average relative humidity difference (DIF RH) between the sampling points and the reference meteorological station.

Table 3. Thermal sensation according to the Temperature-Humidity Index (THI) value. Source: elaborated by the authors based on the optimal climatic ranges for humans.

Thermal Sensation	THI Range (°C)
Refreshing	9–15
Pleasant	15–21
Warm	21–27
Hot	27–30
Extreme Heat	>30

3. Results and Discussion

It is important to acknowledge that this study is seasonally and temporally limited, as the thermal comfort data were collected during specific months of the year and at different times of the day. These constraints inevitably introduce a degree of sampling bias, restricting the generalizability of the findings across all seasons and climatic variations.

However, despite these seasonal and temporal limitations, the conclusions drawn from both locations, i.e., Teatinos University Campus (urban) and Todobarro farm (rural), are remarkably consistent. This convergence suggests a robust correlation between the integration of vegetation and architectural design and improved thermal comfort, regardless of the specific urban or rural context. The consistency of these outcomes highlights the validity of the initial hypothesis. Nevertheless, expanding the study to include additional sampling locations, a broader range of microclimates, and year-round data collection would not only mitigate current limitations but would significantly strengthen the empirical foundation of the findings. Such an expanded approach would enhance the reliability and applicability of the results, providing a stronger basis to classify vegetated spaces as effective climate refuges across diverse environments.

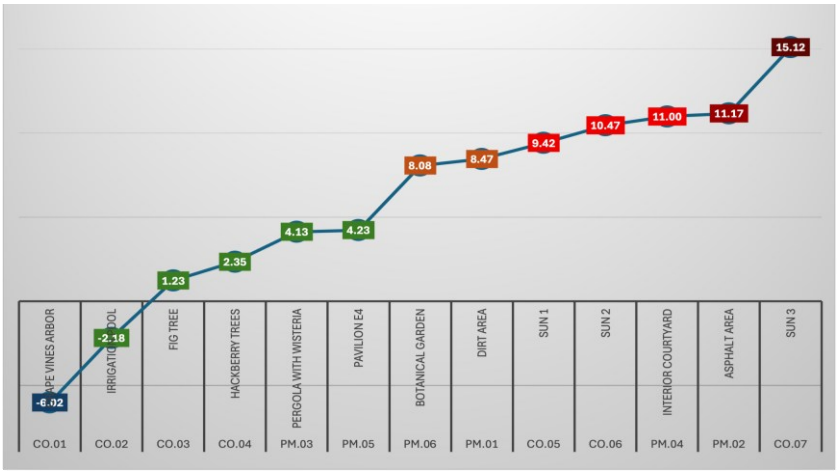

Figure 6. Deviation of the local Temperature-Humidity Index (THI) values of each sampling point concerning their respective reference location: Malaga (PM), and Coín (CO). Five categories are identified: Refreshing (9-15; blue); Pleasant (15-21; green); Warm (21-27, ochre); Hot (27-30; red); Extreme Heat (>30; maroon). Source: elaborated by the authors

a. Teatinos Observation Area (urban)

As illustrated in Figs 6 and 7, the Teatinos University Campus in 2024 reveals a pronounced spatial differentiation in thermal behavior driven by solar exposure and surface characteristics. At the maximum thermal stress period, solar radiation strikes the surface of the Earth at a nearly perpendicular angle, intensifying heat absorption, particularly in unshaded zones. This effect is especially evident in the "Dirt Area" and the "Asphalt Area," which exhibit the highest recorded surface temperatures due to their lack of vegetation or structural cover and high thermal inertia.

Figure 7. Temperature and humidity index (THI) calculated on April 21 at 12:30 (noon) at the Teatinos (PM, urban) and Coín (CO, rural) Observation Areas. PM.01: Dirt Area, PM.02: Asphalt Area, PM.03: Pergola with Wisteria (vine), PM.04: Interior Courtyard, PM.05: Pavilion E4, PM.06: Botanical Garden, CO.01: Grapevine arbor, CO.02: Irrigation pool, CO.03: Fig tree, CO.04: Hackberry trees, CO.05-07: Sun1-Sun3. Source: elaborated by the authors according to Eq. 1

In contrast, areas such as the "Botanical Garden", the "Pergola with wisteria", and the "Pavilion E4" consistently maintain lower temperatures, as can also be observed in the morning isopleths. These zones demonstrate the critical role of shading and airflow in mitigating heat. "Pavilion E4" exemplifies this effect. Its roofed structure, combined with louvered side panels, provides effective protection from direct solar radiation while facilitating cross-ventilation. Similarly, the pergola benefits from the combined shading of vegetation and open architectural design, reducing radiant heat load while allowing air movement.

The mapped thermal comfort values (THI) confirm that these shaded and vegetated environments provide the most thermally comfortable conditions on campus during peak heat hours. Notably, the midday period exhibits the widest thermal differentials across the site, highlighting the spatial impact of bioclimatic interventions. Areas with greater vegetative density and architectural shading exhibit significantly moderated microclimates, characterized by lower ambient temperatures and more stable relative humidity, which are conducive to human comfort and meet the criteria to be designated as climate refuges.

b. Coín Observation Area (rural)

As illustrated in Fig. 6, the THI in the sampling points "Grapevines Arbor", "Hackberry trees", and "Irrigation pool" registered the best THI values, indicating elevated levels of thermal comfort and a more pleasant thermal sensation for humans. In this same figure, these

locations appear below the positive line, confirming that they recorded lower temperatures relative to the Coín reference meteorological station. Conversely, sampling points "Sun 1", "Sun 2", and "Sun 3" are situated in topo-climates characterized by elevated temperatures and low relative humidity, which translate into marked thermal discomfort conditions.
The superior thermal performance of "Grapevines Arbor", "Hackberry trees", and "Irrigation pool" is closely linked to the presence of vegetation, which plays a critical role in microclimatic regulation. Vegetation can block up to 90% of incoming solar radiation, absorbing and transforming it into energy for photosynthesis and evapotranspiration, significantly reducing ambient temperature beneath the canopy (Aram et al., 2020). During evapotranspiration, leaf stomata act as thermoregulatory valves, opening under high temperatures (when water is available) and releasing moisture into the air, thereby increasing relative humidity and cooling the surrounding environment (Castelán Lorenzo, 2022; Poveda Santos et al., 2021).

Among all sampling points, the "Grapevines arbor," a vegetated architectural system, emerged as the most thermally comfortable and health-supportive microenvironment. It consistently recorded the lowest temperatures and maintained optimal humidity levels throughout the day. These favorable conditions can be attributed to the presence of climbing plants and its horizontal structural orientation, maximizing shading. A pergola, thus, represents a climate refuge prototype, offering a thermally stable and human-friendly environment even under extreme weather conditions.

4. Conclusions

This study highlights that among the architectural elements analyzed, structures integrated with well-selected vegetation provide the most effective improvement in thermal comfort. Compared to other sampled spaces, such as bare soil zones and asphalt parking lots, which exhibited high thermal stress due to direct solar exposure and lack of shading, vegetated architectural models consistently showed lower temperatures and more favorable Thermal Comfort Index (THI) values (Equation 1). Notably, the results reveal that the grapevine arbor in Coín (rural area), representing a vernacular, low-impact design, outperformed the modern wisteria-covered pergola in Teatinos (urban area). This demonstrates that ancestral architectural practices and the use of traditional, climate-adapted plant species can be more effective than contemporary bioclimatic adaptations. While other systems, such as green roofs were not examined in this study, the findings support the conclusion that the strategic convergence of the five bioclimatic pillars, i.e., urban planning, architecture, vegetation, landscaping, and materials, when applied to vegetated architectural models, creates optimal microclimates that enhance thermal comfort. As such, well-designed, vegetated pergolas stand out as a low-cost, high-impact solution for mitigating urban heat and improving habitability in Mediterranean climates.

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Data availability statement

The original contributions presented in the study are included in the article; further inquiries can be directed to the corresponding authors.

Ethics statements

Studies involving animal subjects: No animal studies were carried out in this study.
Studies involving human subjects: No human studies were carried out in this study. Inclusion of identifiable human data: No potentially identifiable human images or data are included in this study.

Conflict of Interests

The Authors declare that there are no conflicts of interest to disclose.

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Casablanca Between Land Speculation and Heritage Preservation: Issues of an Urbanization Under Tension

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ABSTRACT

This article investigates the interplay between land speculation and heritage preservation in Casablanca, Morocco's economic capital, where urbanisation has long been driven by speculative logics. From the colonial period to the present, rising land values, regulatory loopholes, and real estate-led redevelopment have profoundly reshaped the city's central districts, notably Sidi Belyout and Anfa. Drawing on a mixed-methods approach—ethnographic observation, semi-structured interviews, spatial and archival analysis, and land price data from 2015–2024—the study reveals how speculative practices exert increasing pressure on built heritage. Anchored in critical urban theory (Harvey, Lefebvre, Smith), the research highlights that patrimonial mechanisms (Davallon, 2023), while formally acknowledged, are often fragmented, selectively applied, and subordinated to short-term market interests. As a result, heritage is less a safeguard of architectural memory than a vehicle for capital accumulation and symbolic revalorisation. The findings underscore a structural tension between urban development and preservation, questioning the capacity of regulatory frameworks to mediate between economic imperatives and cultural values. The article calls for stronger institutional coordination and renewed reflection on the political economy of heritage in rapidly transforming cities of the Global South.
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1. Introduction

Casablanca, Morocco's largest city with around 4 million inhabitants, is the economic heart of the country. Situated within the Casa-Rabat duopoly, it dominates the national metropolitan landscape thanks to its port, airport, industrial and commercial infrastructures. A veritable engine of national growth, the Casablanca-Settat region contributes approximately 32% of Morocco's GDP[1][2] Its

[1] Source: According to 2024 General Census of Population and Housing. High Commission for Planning (Morocco)

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attractiveness is undeniable: it accounts for 48%[3] of investments in Morocco, attracting both domestic and foreign companies and capital. Its role in international trade is just as crucial: its port, one of the busiest in Africa, consolidates its position as a strategic platform for Morocco's imports and exports.

Figure 1. Casablanca, Morocco (Source: google earth Pro)

Casablanca's economic weight is the result of a long trajectory of growth. From a modest port in the mid-19th century, exporting wool and grain, it quickly became a hub of foreign trade. By the late 1800s, it handled over a quarter of Morocco's international commerce, attracting traders from across the country (Dernouny et Leonard, 1987).

The French Protectorate (1912–1956) marked a decisive turning point: the construction of the major port and modern infrastructures propelled Casablanca into its role as Morocco's economic engine. The city also became an urban laboratory, blending architectural innovation with rapid expansion.

This growth, however, was fueled by aggressive land speculation, already present before colonization and intensified by settler privileges. After independence, speculative dynamics persisted, driven by population pressure, industrial needs, and land scarcity. Today, real estate profitability continues to dominate, often at the expense of planning and heritage

As Casablanca continues to densify and expand, speculative dynamics, understood as the range of practices aimed at maximizing land rent through the anticipation of urban value increases, play a central role in the reconfiguration of its urban fabric. This pressure is particularly acute in the city's central districts, which are rich in architectural heritage inherited from the colonial period and Moroccan modernism. Yet, the patrimonial mechanisms for safeguarding and enhancing this heritage (legal tools, inventory systems, classifications, public interventions) are struggling to regulate these transformations.

This gives rise to a structural tension: how do land valorization logics reshape the priorities of urban action? To what extent can patrimonial mechanisms (Davallon, J., 2023) resist, or adapt to, economic dynamics that tend to instrumentalize space and marginalize memory? The case of Casablanca thus invites a broader reflection on the actual capacity of public regulation to mediate between economic interests, preservation imperatives, and the right to the city.

This article posits that land speculation has become a structuring force in Casablanca's urban development. It operates through spatial differentiation, unregulated densification, and increasing pressure on the built heritage. We hypothesize that this speculative dynamic overrides the mechanisms intended to regulate urban growth and protect architectural heritage, which remain fragmented, weakly enforced, and often subordinated to short-term economic priorities. In this context, patrimonial mechanisms struggle to assert their role. This imbalance fosters an urban transformation where land

[2] Source: High Commission for Planning (Morocco)

[3] Figures for 2024. Source: Casablanca Regional Investment Center. *www.casainvest.ma.*

value takes precedence over historical and cultural values, producing tensions that reshape the urban landscape and question the capacity of public action to mediate between economic and heritage logics.

2. Methodological approach

This research adopts a mixed-methods approach combining ethnographic observation, qualitative interviews, spatial and archival analysis, and a review of land price data. The aim is not to produce an exhaustive account of Casablanca's heritage dynamics, but to interrogate the structural mechanisms through which land speculation reshapes the governance of architectural heritage. Methodologically, the study is anchored in a long-term engagement with urban development issues in Casablanca, drawing on critical urban theory (Lefebvre, Harvey) to examine how space is produced, contested, and commodified.

The first author's doctoral research (Aljem, 2018) on urban megaprojects revealed early on how 20th-century colonial and modernist heritage was systematically marginalized in planning policies. This foundation was complemented by a decade of informal documentation, interviews, and media monitoring, providing a historical depth to the present investigation. In 2024, the second author conducted an independent field study focused on deteriorating heritage buildings, combining photographic surveys and site assessments. These findings significantly contributed to the research design and empirical foundation of the current study. These findings led to a more structured investigation, conducted jointly between 2024 and 2025.

The empirical component consisted of three main strands: (1) ethnographic observations in central districts to document material transformations and everyday appropriations of contested heritage; (2) around ten semi-structured interviews with key actors in planning and heritage, selected for their role in decision-making or mobilization processes; and (3) a spatial and documentary analysis of planning instruments, regulatory gaps, and transformations of emblematic sites. These materials were analyzed thematically, focusing on how actors negotiate legitimacy and how heritage value is constructed or undermined in speculative contexts.

To contextualize the intensity of speculative dynamics, the study also reviewed land price trends from 2015 to 2024, based on listings, agency reports, and professional interviews. Given the opacity of the market, these figures were treated as indicative and triangulated with qualitative observations. The sharp price increase observed (42% in key areas) serves not as statistical proof but as an indicator of the scale of disconnection between market values and preservation frameworks.

Ultimately, this methodological strategy seeks to illuminate how fragmented governance, market incentives, and institutional loopholes converge to redefine both heritage value and urban space.

3. Theoretical framework

The analysis of land dynamics in Casablanca draws on a critical urban theory approach, at the intersection of urban political economy, the right to the city, and heritage studies. It starts from the premise that heritage is not a neutral object of conservation, but a field of conflict where actors negotiate meanings, legitimacy, and uses. This conflict is particularly visible in the tension between speculative dynamics and heritage mechanisms, two key notions that structure this study.

By *speculative dynamics*, we refer to the set of strategies and anticipatory behaviors aimed at capturing land value gains through retention, rezoning, or strategic demolition, often disconnected from actual use or need. This notion is grounded in David Harvey's work on the urbanization of capital (1985; 2012), which shows how urban space becomes a vehicle for capital accumulation. In contrast, *heritage mechanisms* refer to the formal and informal tools used to identify, classify, and preserve heritage elements. Following Davallon (2023), these mechanisms include inventories, safeguard plans, expert commissions, and institutional designations.

Henri Lefebvre's theory of the production of space (1974) provides an essential lens to understand this dynamic. Urban space is not a passive backdrop, but a social product shaped by power relations. Heritage, in this sense, becomes a contested representation of collective memory, subject to selection, erasure, and commodification. Laurajane Smith (2006) deepens this critical perspective by arguing that heritage is always a process of authorization, often aligned with dominant economic interests. In the context of Casablanca, symbolic enhancement through rehabilitation coexists with the silent

destruction of less profitable buildings, reinforcing a heritage landscape shaped by rent-seeking rather than collective memory.
This framework allows us to interpret the observed gap between urban planning documents and actual land practices, not as administrative incoherence, but as the symptom of a broader structural contradiction between value creation and spatial justice.

4. Land speculation: a dynamic intrinsic to the city's history :
Casablanca's urban history is related to the speculative dynamic that accompanied its development, long before the official establishment of the French Protectorate in 1912. From the end of the XIXe century, the still modest city attracted growing attention from Europeans, particularly the French, seduced by its strategic position on the Atlantic and its economic potential[4] . This process of capitalist acceleration was rooted in a local reality: an emerging city in contact with the global economy, with an expanding port and cheap labor.

Figure 2. First advertising billboards for housing subdivisions, Casablanca. (source: Cohen, J.-L., & Eleb, M. (1998). *Casablanca: Myths and figures of an urban adventure*.)

On the eve of the formal establishment of the protectorate, the city was already invaded by a population from all over Europe: "*Officers, engineers, businessmen, small traders, capitalists who go to 'see', workers, cocottes: it's a swarm of our humanity from Europe that crosses the sea to land on the west coast of Morocco*."[5] . This migratory flow is explained by the anticipation of rapid enrichment, fuelled by demographic growth and the prospects of land development. "*The population of this city was growing by two thousand souls a month*"[6] , which stimulated demand for urban land and unbridled speculation, long before the regulatory foundations of colonial urban planning were laid.
In this context, land speculation became one of the visible signs of economic colonization in progress. Casablanca became a veritable laboratory for colonial urban rent, where land became a commodity, freely exchanged in an unregulated market. The city's cafés served as informal exchanges where prices soared: "*Such and such a plot of land on the road to Rabat, bought for 400,000 francs last Saturday, resold for 500,000 yesterday evening*"[7] . This phenomenon is not marginal: it structures the city, guides investment and accelerates spatial segregation.

[4] Académie d'Architecture (ed.). L'Œuvre de Henri Prost: Architecture et Urbanisme. Paris : Académie d'Architecture, 1960. 243 p.

[5] Lavaud, A. (2003). Casablanca: Années 20: récits de voyages. Casablanca: La Croisée des chemins, page 18.
[6] Idem, page 22.
[7] Idem, page 36.

This speculation is underpinned by two major dynamics: the first is economic. Casablanca became a major export port, linked to a fertile hinterland[8] . The modern infrastructure attracted capital, while the large, low-paid local workforce guaranteed high returns for European investors[9] . The second dynamic was political and ideological: on the eve of the Protectorate, France was preparing to integrate Casablanca into its colonial system. Land ownership thus became an anticipated sovereignty issue. Buying land meant gaining a foothold in the future colonized territory. What's more, it's crucial to note that Casablanca was bombed and occupied by France in 1907, five years before the Protectorate was signed in Fez in 1912. This military occupation can be interpreted as a major political and strategic action by France to establish its hold on the city [10].

The Medina itself is no exception to this commercial logic. Although described as a dilapidated area, it is also perceived as a *"reservoir of labor" and an "exceptionally dynamic commercial space"*[11] . Europeans see it as a strategic commercial hub, but also as a reservoir to be urbanized. This duality, between economic enhancement and social relegation, contributes to making the Medina a transitional area, gradually encircled by modern projects.

Colonial history only amplified this trend. The Prost plan (1917) and then the Ecochard plan (1952) aimed to channel this growth and organize the city's expansion through hierarchical urban planning[12] . But they never succeeded in completely containing the speculative logic. The first plan covered only a small portion of the urban territory, giving free rein to a multitude of unregulated peripheral housing estates. Indeed, Prost himself points to the inability of the French urban planner and administration to contain the maneuvers of speculators, who "took control of the city"[13] as soon as the first settlers arrived.

On his arrival in Morocco, Mr. Ecochard was confronted with an "urban landscape" marked by two major dynamics: speculative pressure on land and the uncontrolled expansion of shantytowns[14] . His development plan, although more comprehensive, still had to come to terms with the realities of the land market: *"major purchases by the Domaines services had made it possible to build large housing estates for the Moroccan population"*, but often in areas *"built outside the urban perimeter without control"*[15] .

[8] Scientific Mission of Morocco. Cities and tribes of Morocco: Casablanca and its region. Tome II : Châouïa. Paris: Éditions Ernest Leroux, Casablanca: Éditions Frontispice, 1915, 338 p.

[9] Idem.

[10] Adam, A. (1968a). Casablanca: essai sur la transformation de la société marocaine au contact de l'Occident (Tome 1). Paris: Centre National de la Recherche Scientifique.

[11] Dernouny, M., & Léonard, G. (Date unknown). Casablanca: La parole & la trace , Casablanca, p.76.

[12] Cohen, J.-L., & Eleb, M. (1998). *Casablanca: myths and figures of an urban adventure*. Hazan.

[13] Urbanisme, n. 88, 1955, quoted by J. Dethier, 1970, p. 15.

[14] Aljem, S.,Bkiri.I (2019). Limitations of the 'Plan' as a Public Policy Instrument in the 'Urban Fabric' of Major Moroccan Cities: The Case of Casablanca and Rabat. African and Mediterranean Journal of Architecture and Urbanism, [S.l.], n. 1, pp. 35-45, ISSN 2665-7953.

[15] Dernouny, M., & Léonard, G. (Date unknown). Casablanca: La parole & la trace , Casablanca, p.56.

Figure 3. The Prost plan (1917), Casablanca. (source: Cohen, J.-L., & Eleb, M. (1998). *Casablanca: Myths and figures of an urban adventure*.)

Many authors point out that the legislative and regulatory arsenal introduced by Ecochard in Casablanca, based on a system of permits, authorizations and bans, was primarily aimed at curbing land speculation and containing the expansion of shantytowns. The stakes were as much sanitary as urban planning. Ecochard himself makes no secret of the radical nature of his observation: *"In Casablanca, after the war, speculators were indeed running the streets (...) It's a poor disguise to use the law of supply and demand to hide speculation, to use freedom to undermine the health of inhabitants, to use individual security to confine 2/3 of a population to slums!"* .[16]
However, another interpretation is proposed, according to which *"the fact of calling on H. Prost (1917), then M. Ecochard (1946), to draw up urban planning instruments, was carried out primarily to prepare the various spaces for an extroverted capitalist economy; then to adapt this space and reorganize it to accommodate the massive arrival of capital (Ecochard's development of industrial zones)"* (Rachik, 1995, p. 129). This reading reveals an essential shift: colonial urbanism goes beyond the simple logic of planning or sanitation to become a tool for spatial organization in the service of economic profitability and investment attractiveness.
The turn of the 1940s-1950s marked the emergence of a new urban logic, driven by the growth of the modern European city of La *Villeneuve*. This dynamic ushered in a profound change in our relationship with space: it was no longer seen primarily as a living environment or symbolic support, but as an economic resource to be valued. The function of use recedes in favor of exchange value, in a context where urban planning becomes a lever for accumulation. Jacques Berque sums up this evolution when he states that "the mobilization of space becomes a value of exchange and, even more, a speculative investment" (Berque, 1958, p. 23). The city then becomes an object of speculation, structured by the logic of profit and segregation, rather than by objectives of social justice or territorial equity.

[16] Écochard, M. (1955). *Casablanca: le roman d'une ville*. Éditions de Paris, P. 109.

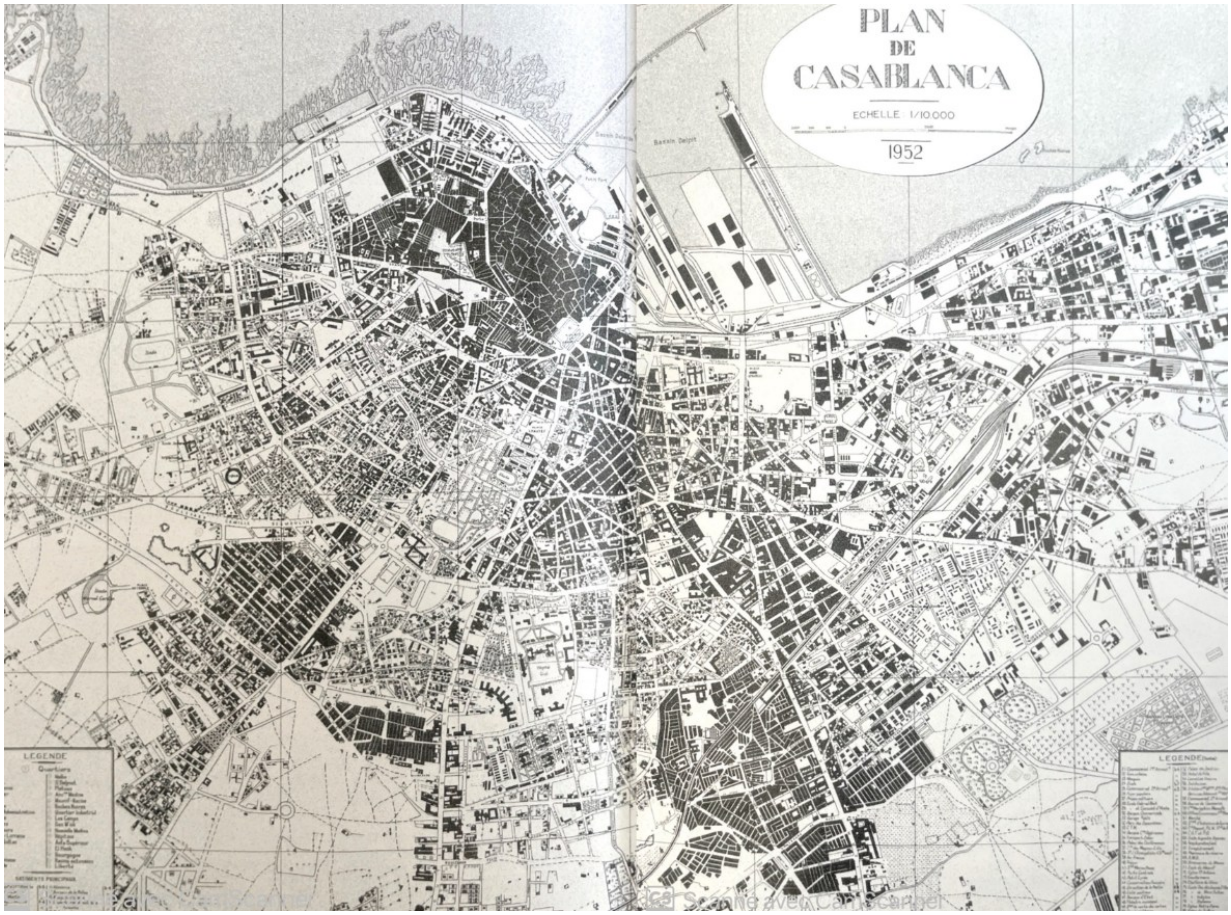

Figure 4. The Ecochard plan (1952), Casablanca. (source: Cohen, J.-L., & Eleb, M. (1998). *Casablanca: Myths and figures of an urban adventure*.)

From the outset, therefore, Casablanca was shaped by a double movement: on the one hand, a logic of land capture by European elites, attracted by a "new", open, profitable city; on the other, the gradual sidelining of local populations, who nevertheless fed the economic dynamic[17] . The city becomes a space of colonial contradictions: between planned order and speculative disorder, urban modernity and social misery, economic centrality.

Post-Protectorate: Casablanca, an identity in search of legitimacy

Far from disappearing after independence, land speculation in Casablanca intensified under the combined effect of high housing demand, limited land supply and the growing economic attractiveness of the city[18] . Despite a demographic slowdown[19] , the artificially maintained scarcity of land through retention strategies continues to fuel sustained price inflation[20] . The State, by gradually ceding its land reserves, has seen its ability to regulate eroded. As early as 1984, the SDAU warned of the absence of a coherent land policy, leaving the field open to speculative logics.

This gradual disengagement has fostered a dynamic in which urbanization is driven less by the general interest than by rent-seeking strategies. A growing number of speculators are capitalizing on land

[17] Dernouny, M., & Leonard, G. (1987). Casablanca: la parole et la trace. Afrique-Orient.

[18] Kaioua, A. (1998). *Casablanca, le sol urbain entre usage industriel et spéculation immobilière*. Études rurales, (246), 109-126.

[19] The population of the Casablanca urban area rose from one million in 1960 to 1,500,000 in 1971. This represents an average annual growth rate of 4.2%. At the September 1982 census, it reached 2263470 inhabitants, with an intercensal annual growth rate of 3.3%.

[20] Zyani, B. (1986). Habitat, land constraints and urban development in Casablanca. Éditions du CNRS, Annuaire de l'Afrique du Nord, Tome XXV.

pressure resulting from urban and industrial growth. Peripheral urbanization, which is often informal or poorly supervised, has been tolerated or even instrumentalized by the state, which has seen it as a means of containing social tensions, channelling middle-class savings and strengthening its local clienteles, as shown by the surveys carried out by numerous Moroccan researchers between the 1980s and 1990s[21] . Speculation led to the spread of illegal housing estates, the consolidation of shantytowns, and the multiplication of zoning changes, often anticipated for speculative purposes, without any mechanism for the public capture of capital gains.

Against this backdrop, land became both a safe haven and a medium for speculative appreciation, accentuated by rising construction costs and insufficient public housing supply. The rise in prices was continuous and widespread: moderate until the 1960s, it began to spiral in 1973, under the influence of several factors - ex-colonial land being put on the market, demographic growth, a revival in construction, and accelerated inflation[22] . It was at this point that major retailers, industrialists and real-estate companies began to invest massively in agricultural land on the outskirts of the city, anticipating a change in use. Market-garden land was then converted into economic housing estates or industrial zones, revealing the extent of the functional mutations affecting Casablanca's suburbs.

Land valuation also relies on zoning changes, often anticipated by investors, which cause prices to soar without any public capture of capital gains. Added to this is the perception of land as a haven, reinforced by rising construction costs. As a result, Casablanca has long suffered from an insufficient public housing supply, accentuating the dominance of the private sector and directing production towards the most profitable segments. This imbalance feeds disorderly urban sprawl and socio-spatial segregation, to the detriment of a mixed, accessible city.

Contemporary Casablanca has a clear ambition: to become an international city, with a world-class financial center, the Casablanca Finance City (CFC). This project embodies the city's desire to become part of the global economy, to attract investors, to capture flows, talents, and capital. But this ambition is part of a marked neoliberal logic: competition between territories, priority given to major showcase projects, and aggressive urban marketing[23] . Cities are shaped according to the needs of economic elites, land prices soar, and spatial disparities and social gaps are glaringly apparent. Behind the smooth façade of international competitiveness, a fragmented city is emerging, riven by inequalities and tensions.

Colonial architecture: a controversial legacy

Unlike Morocco's imperial cities - Fez, Marrakech, Meknes or Salé - where heritage is evident in the presence of medinas and historic monuments, Casablanca struggles to claim a clear heritage legitimacy. A city whose development stemmed from the colonial boom, its architectural identity is largely based on its development under the Protectorate. Long perceived as a city without history or culture[24] , marked by industry and social tensions, Casablanca has sought to forge a new image for itself by emphasizing the heritage value of its modern architecture.

"Casablanca resists the styles it reduces to mere expression. It ends up integrating them into its new culture, a dynamic expression of Modern Morocco[25] " (Ahmed Hariri). This phrase captures the very essence of the city's architectural history: a place where imported styles are absorbed, reformulated and surpassed. Casablanca doesn't just imitate, it filters, simplifies and transforms. It digests codes to make something else of it.

Rather than speak of a single "colonial style", it's more accurate to evoke the diversity of styles that permeated Casablanca during the Protectorate and beyond. Eclecticism, very much in evidence in the 1920s, imposed a classical, symmetrical composition directly derived from the Beaux-Arts. But other influences were already seeping in. The Neo-Moroccan style, for its part, draws on traditional textures

[21] Naciri, 1980 ; Ameur and Naciri, 1985 ; Ameur 1988 ; Abouhani, 1988, Lehzam 1998.

[22] Cattedra, R. (2001). La mosquée et la cité: La reconversion symbolique du projet urbain à Casablanca (Maroc) (Doctoral dissertation, University of Tours). Université François Rabelais.

[23] Aljem, S., & Strava, C. (2020). Casablanca's megaprojects: Neoliberal urban planning and socio-spatial transformations. *TRIALOG. A Journal for Planning and Building in the Third World*, 135(4), 12-19.

[24] Cattedra, R. (2001). La mosquée et la cité: La reconversion symbolique du projet urbain à Casablanca (Maroc) (Doctoral thesis, University of Tours).

[25] Zurfluh, J.-M. (1985). Casablanca. SODEN.

and decorative vocabulary without reproducing their structures. An almost diplomatic translation of local heritage into modern syntax.
Then Art Deco took hold, particularly in the new town. Geometric facades, friezes, bow-windows, zelliges on the facade, stained-glass windows and ironwork intertwine. This is undoubtedly the style most associated with Casablanca. And yet, here again, it is never pure: it hybridizes, it adapts, it flirts with Neo-Moroccan or Premier Moderne.

Figure 5. Architectural diversity of Casablanca (Source: Alexandre, N., & Neiger, E. (2019). *Reading Casablanca: A grammar of urbanism and architecture*. Zurich : Park Books*)*.

The boundaries between styles are porous. Architecture in Casablanca is fluid, shifting, difficult to confine to rigid categories. It's a city of stylistic overlaps, where buildings tell the story of passages and aesthetic negotiations.
After independence, the momentum continued unabated. The Second Moderne, sometimes lyrical, sometimes sculptural, made its mark in a number of major projects. Then came more banal forms, postmodernism and contemporary writing. What Casablanca doesn't invent, it transforms. It doesn't freeze anything; it continues to advance, absorb and recompose.

A belated and disputed patrimonialization :
In Casablanca, recognition of the heritage inherited from the Protectorate has been slow, conflictual and marked by unresolved historical tensions. From the outset, colonial urban policy was characterized by a contradiction: valorizing the Moroccan past while imposing foreign modernity. By separating European cities and medinas, Lyautey established a spatial duality that reflected an implicit hierarchy between two visions of the city - one modern and hygienic, the other traditional and symbolic. This logic of separation gave lasting structure to urban space and influenced the way in which heritage was perceived.
As early as 1912, measures to protect historic monuments were adopted[26] , modelled on foreign models, but adapted to the local context. Medinas were recognized as having a certain value,

[26] The Dahir of November 26, 1912, published in the Bulletin Officiel on November 29, marks the first legal initiative in Morocco for the protection of built heritage. It placed historical monuments, whether religious or secular, ancient or Islamic, under the

provided they were part of an As early as 1912, measures to protect historic monuments were adopted[27] , modelled on foreign models, but adapted to the local context. Medinas were recognized as having a certain value, provided they were part of an acceptable urban aesthetic. This colonial view of heritage has left its mark: even today, the very idea of preserving the architecture of the Protectorate remains controversial.

Indeed, the recognition of heritage, particularly architectural and urban heritage, depends primarily on a semantic reading of legislation and institutional practices. The use of terms such as 'monument' or 'historic monument'[28] determines not only how this heritage is perceived, but also the concrete actions taken by the authorities to protect and enhance it.

Law no. 22-80, promulgated by dahir no. 1-80-341 of December 25, 1980, is the reference text for the conservation of cultural property. However, at no point does this text mention the generic term "*heritage*". It is limited to a series of restricted legal categories: *historic monuments*, *sites*, *protected areas*, and *objects of art or antiquity*. This semantic limitation has a direct impact on the official non-recognition of certain "immovable" properties, notably those of the 20th century, whether modern, vernacular or ordinary.

This conceptual narrowing poses a fundamental problem: any protection initiative relies on being included in the lexical field defined by the law. Thus, a modernist building from the early 20th century, rich in social, historical and artistic values, can only be protected if it is recognized as a "historic monument", a notion that is legally framed and historically associated with ancient or prestigious buildings.

This shift in terminology is part and parcel of a certain "insensitivity" - or rather, structural disinterest - on the part of the relevant authorities towards more recent forms of heritage. This lack of interest is not necessarily voluntary, but stems from the absence of a suitable legal framework.

This discrepancy between the legal lexicon and the practices of heritage enhancement creates a void into which speculative dynamics engulf. A building may be recognized in a development plan as an element to be preserved, yet be legally demolished for lack of support in national legislation. It is therefore the words themselves, or rather their absence from the law, that render protection ineffective.

This is precisely where the need for far-reaching reform arises, as embodied in the draft law 33-22 on heritage protection. Unlike Law 22-80, Law 33-22 uses the term "heritage" right from its title, signalling a major conceptual reorientation. This new law aims to integrate all forms of heritage - whether tangible or intangible, ancient or modern - into a broader framework of protection. It introduces not only an overhaul of vocabulary, but also coercive provisions against damage to heritage, whatever its period of construction.

Thus, the transition from Law 22-80 to Law 33-22[29] is more than just an administrative update: it represents a semantic, and therefore legal, revolution that would finally bridge the gap between symbolic recognition and effective protection of heritage in Morocco. Law 33-22 represents a serious attempt to consolidate Morocco's heritage protection system, by broadening its scope, clarifying its vocabulary and consolidating its means of implementation.

Coveted heritage, contested memory: between the commodification of land and the mobilization of heritage :

In Casablanca, growing land pressure is combined with persistent institutional fragility. The former European neighborhoods of the early 20th century, now very central, are a magnet for property

supervision of the Makhzen, emphasizing their historical and artistic value. Driven by Marshal Lyautey's determination, this seminal text, although not immediately applied, laid the foundations for heritage preservation in Morocco.

[27] The dahir of November 26, 1912, published in the Bulletin Officiel on November 29, marks the first legal initiative in Morocco for the protection of built heritage. It placed historical monuments, whether religious or secular, ancient or Islamic, under the supervision of the Makhzen, emphasizing their historical and artistic value. Driven by Marshal Lyautey's determination, this seminal text, although not immediately applied, laid the foundations for heritage preservation in Morocco.

[28] The concept of the historic monument has been shaped progressively since antiquity, and developed in humanist circles during the Italian Renaissance, then institutionalized in 19th-century France with the first safeguarding measures.

[29] Draft Law 33-22 on heritage protection, in the process of promulgation. This law establishes general rules for the protection of natural and geological cultural heritage, its preservation, maintenance and enhancement.

developers. These densely built-up but poorly protected areas represent considerable speculative potential. Architectural heritage is seen as a land resource to be released, not as a collective memory to be preserved.

In this logic, heritage is instrumentalized, just as Laurajane Smith has shown: it becomes a selective tool, shaped by power relationships, where certain narratives and built forms are promoted while others are ignored or erased. In the absence of a binding legal framework, clear political will and sufficiently structured citizen mobilization, damage to heritage is frequent. Emblematic buildings in Casablanca, Rabat and Fez have been destroyed, despite their value being recognized by international bodies such as UNESCO and ICOMOS.

In Casablanca, the first decades after independence were marked by almost total indifference to the disappearance of these buildings, such as the Vox cinema in 1970 or the Hôtel d'Anfa in 1972[30] . These losses moved neither the authorities nor public opinion. It wasn't until the 1980s and 1990s that a turning point was reached, spurred on by the publication of fundamental works (Zurfluh, Eleb, Cohen and Ghislaine Gallenga), which legitimized a new view of modern architecture. By documenting and valorizing these buildings, these scientific productions gave modern heritage a status, a value and a history.

The emergence of CasaMémoire in 1995 marked a phase of militant appropriation of this memory[31] . Mainly made up of architects trained in France, the association asserts a Casablanca identity attached to the modernist heritage. It acts through description (fact sheets), media coverage (press, guided tours), but also through informal influence on decision-making processes. This role of mediator between expert knowledge and institutional action underlines the importance of civil society in the construction of heritage policies.

However, as Bernard Toulier reminds us[32], this mobilization is marked by certain biases. The focus on twentieth-century European architecture reveals a neo-colonial memory bias, sometimes to the detriment of the medina and working-class districts. *"It was a question of prolonging a form of neo-colonial memory, tinged with nostalgia for the "white" modernist city, often to the detriment of the medina and working-class districts*"[33] . We are witnessing a social production of selective memory, in line with Lefebvre's observations: space and heritage are not neutral entities, but products of dominant social relations.

Since the 2000s, a number of institutional advances have been made: inclusion in the national inventory, heritage mapping, safeguard plans. In 2013, the Agence Urbaine de Casablanca initiated a clearer structuring of its action tools: atlases, fact sheets, inventories, architectural recommendations. These measures reflect a shift towards the formalization of heritage policy.

But this structuring remains largely formal. In the field, destruction continues. Protection tools are not very restrictive, trade-offs are not very transparent, and economic logic predominates. *"In practice, many buildings identified as heritage continue to be threatened or transformed, for lack of a sufficiently restrictive legal framework*[34] ". As Harvey notes in *Spaces of Hope* (2000), the urbanization of capital consists precisely in transforming use values into exchange values. In Casablanca, heritage becomes an exchange value, a source of profit, often emptied of its social use and its memorial value.

Heritage associations, though dynamic, struggle to make a real impact. They are neither representative of all residents, nor do they have a strong institutional status. The authorities do not systematically consult them, even in sensitive cases such as demolitions[35] . This lack of public dialogue reinforces an opacity

[30] Article Casablanca's historic center: A renaissance underway - LesEco.ma.

[31] www.casamemoire.org official Casamémoire website, Created in 1995, Casamémoire is a Moroccan non-profit association dedicated to safeguarding the country's 20th-century architectural heritage. Its members share common values: preservation of Casablanca's unique character, promotion of architectural heritage, cultural tourism and collective memory.

[32] Bernard Toulier Archaeologist and architectural historian, Honorary General Curator of French Heritage, UNESCO expert.

[33] Interview with Bernard Toulier on March 8, 2025.

[34] Interview with representatives of the Casablanca Urban Agency conducted on April 23, 2025.

[35] Interview with Bernard Toulier on March 8, 2025.

conducive to speculation. Scientific criteria for heritage selection, although available, are applied in variable ways, or even bypassed .[36]

In the end, heritage is caught in a permanent tension: between a desire for symbolic recognition, still-weak protection tools, and aggressive land-ownership logics. This imbalance reflects a broader reality: that of a city in transformation, where urban space is the scene of a confrontation between memory, market and power.

The city center and speculation: a heritage under pressure

In Casablanca, land dynamics cannot be understood solely through technical or legal frameworks. Their analysis requires an intersection of urban political economy, the right to the city, and conflicting approaches to heritage-making (Harvey, Lefebvre, Tornatore). Heritage here is not simply a matter of preservation: it is a site of confrontation between market logics, institutional policies, and social uses. These tensions expose the deep contradictions of Casablanca's urban development.

The Master Plan for Development and Urbanism (SDAU) from the 1980s already acknowledged the heritage value of the medina and certain parts of the colonial city. But this recognition remained largely symbolic. No binding regulatory tool followed. On the contrary, the former zoning plan for the Sidi Belyout district permitted increased building heights, thereby encouraging demolition and reconstruction dynamics. Colonial-era buildings were acquired for the sole purpose of being demolished and replaced with more profitable real estate developments[37].

The contradictions between strategic planning documents (such as the SDAU) and regulatory instruments (like zoning plans) have opened the door to opportunistic land strategies. This is not merely a market drift but the result of administrative arrangements that make speculation both possible and legitimate. For example, a 1950s Art Deco building housing the national police headquarters partially collapsed. Instead of restoring it, the administration chose to rebuild, motivated not only by functional needs but also by the development opportunities made possible by the new zoning plan (higher floor-area ratios). Another common strategy is the use of technical assessments to have buildings declared as "structurally unsafe," making them easier to demolish. These procedures, ostensibly about safety, become tools of land pressure[38].

Meanwhile, revitalization projects have multiplied (building conversions, heritage trails, facade improvements), but despite their role in raising awareness, they remain insufficient to prevent demolition. The gap between official ambitions and actual transformation is striking.

Figure 5: The Lincoln Hotel Rehabilitation Project in Casablanca[39]: A Case of Heritage Enhancement and Real Estate Revalorization. (source of the images: Urban Agency of Casablanca)

In an already saturated city center, where available land is limited to old structures, pressure is mounting. By analysing real estate transaction data over nearly a decade, the average price per

[36] Idem.

[37] Interview conducted with H.B., Urban Agency, April 15, 2025.

[38] Inteview conducted with M.S, Ministry of Interior, 2022

[39] The rehabilitation project of the Lincoln Hotel, led by the Moroccan investment fund OCP and the French group Realites, aims to preserve the Art Deco façade while converting the building into a high-end hotel complex. Located opposite the central market and along the tramway line, the project exemplifies how heritage valorization can intersect with speculative real estate dynamics in central Casablanca.

square meter in Sidi Belyout rose from 13,000 to 18,500 dirhams between 2015 and 2024[40], an increase of over 42%. This inflation is driven by well-known speculative practices: land hoarding, anticipatory value extraction, zoning change rumors, and leaked information about urban plan revisions[41].
Speculation does more than distort land values; it reshapes the urban fabric. It turns heritage into a financial lever rather than a preservation tool (Smith, 2006). High-profile rehabilitations like the Lincoln Hotel or the Central Market enhance the symbolic image of the city center, but without strong land regulation, they fuel rising prices and intensify real estate pressures[42]. Laurajane Smith, in *Uses of Heritage* (2006), warns of how heritage is mobilized for economic and political ends. Far from being neutral, heritage becomes a tool for legitimizing urban neoliberalism, disguising the logic of demolition-reconstruction under the guise of rehabilitation. Several emblematic cases reflect these distortions: the demolition of Villa Mauvillier for a 14-story development; an Art Deco building on Hassan II Avenue replaced by a hotel; or uncontrolled vertical extensions in the Rachidi and Gauthier neighborhoods.

Figure 6. Land pressure on colonial buildings of high architectural value, in a context of land-use reclassification. (Source: photograph by the author.)

Thus, financial logic prevails over historical memory. Speculation acts like a brutal filter: only buildings that can be monetized survive. The others, even if inventoried, even if historically significant, disappear in silence or institutional complacency.

[40] The 2015 data comes from official statistics published in 2016 by the General Directorate of Taxes, while the 2024 data was collected through field observations and validated by publications from the YAkeey real estate website (www.yakeey.com) as well as other websites dedicated to real estate investment in Casablanca

[41] Several local newspaper articles have reported on this phenomenon. An investigation conducted by a local outlet revealed that land prices have increased fivefold in certain neighborhoods of the city: "This frenzy is fueled by leaked information regarding the new urban plans, driving land prices to record highs." Source: Hespress article — Casablanca/New Urban Plans: Land Value Multiplied by 5, published on 01/08/2024.

[42] According to Asmae Abdelaoui, a real estate agent quoted in an article by the magazine *Telquel* "in Casablanca, *new property prices always soar along the tramway route, particularly in the months following the announcement of the construction project.*" Source: "*Real estate: should you invest in Casablanca before 2030, and where?*" – Telquel.ma, 20/12/2014.

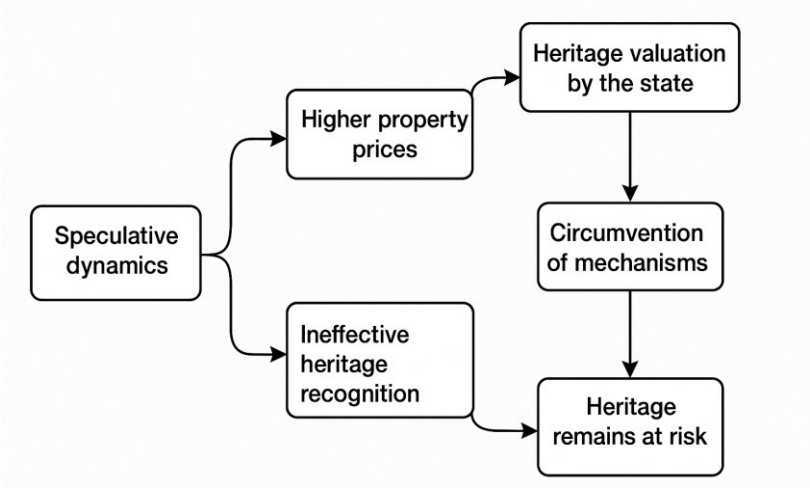

Figure 7. The impact of speculative dynamics on heritage recognition and vulnerability in Casablanca. (source: produced by the authors)

Heritage governance in Casablanca mobilizes numerous experts, arbitration commissions, and a range of institutions. This configuration may appear to guarantee methodological rigor, but it suffers from a serious lack of coordination and a dilution of responsibilities. In the absence of sanctions, decisions lose their impact.

The episode of Casablanca's withdrawn candidacy for UNESCO World Heritage status in February 2020 is a clear symptom of this dysfunction. The withdrawal occurred on the very day of the submission, after years of preparation, funding, and mobilization. The project, supported by Casamémoire, was ultimately halted by a chain of institutional breakdowns.

Nevertheless, since 2024, a noticeable semantic shift has emerged in official heritage discourse: the term "colonial heritage" is gradually being replaced by "shared heritage." This new terminology reflects a desire for openness, recognizing that this legacy does not stem from a single narrative but from an entanglement of stories, circulations, and co-productions[43]. While still fragile, this symbolic shift signals an attempt to move beyond memory-based divides and toward a more inclusive approach to heritage-making.

Conclusion:

The case of Casablanca shows that heritage development cannot be understood outside the speculative dynamics shaping the city's urban transformation. Rather than acting as a neutral or stabilizing force, patrimonialization intersects with logics of land valorization, real estate investment, and institutional fragmentation. Drawing on a mixed-method approach that combined field observations, interviews, and a longitudinal analysis of land price data, this study shows how heritage is increasingly mobilized as a financial asset. The rise in land values, notably the 42% increase in Sidi Belyout between 2015 and 2024, reflects not only market anticipation but also institutional permissiveness and planning contradictions. These mechanisms foster unregulated densification and the erosion of built heritage in strategic central areas.

The analysis reveals that heritage-led development in Casablanca often operates within a context of weak legal protections and conflicting planning instruments. While the Urban Agency has made efforts to systematize heritage recognition through inventories and safeguard plans, these tools lack enforceability. As a result, they coexist with urban policies that authorize demolitions or incentivize densification, especially in strategic central areas. This contradiction weakens the preservation agenda and reinforces selective processes of recognition, where only the most profitable buildings are protected or rehabilitated.

[43] Interview with R.E., Directorate of Heritage, Ministry of Culture of Morocco, 2025

The study's mixed-method approach—combining transaction data, urban observations, and expert interviews—helped capture both the material and symbolic effects of speculation. However, limitations remain: the quantitative sample is partial, and some spatial data rely on secondary sources. Further research could expand the empirical base, particularly by examining the role of financial actors in land transactions and the informal negotiations surrounding zoning exceptions.

These findings open up avenues for further inquiry into the political economy of heritage in fast-growing cities of the Global South. In particular, they call for critical engagement with the normative assumptions behind heritage as a development tool. Future research might explore under what conditions heritage policies can escape instrumentalization, and how public institutions can recover a strategic capacity to arbitrate between economic and cultural priorities.

In the absence of robust legal and fiscal tools to curb speculation and redistribute land value gains, patrimonial strategies risk reinforcing spatial inequalities. Protecting the architectural legacy of Casablanca will require more than technical inventories or symbolic designations. It demands political commitment, institutional coordination, and a redefinition of urban heritage as a public good rather than a market asset.

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Data availability statement

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

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.

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Biophilic Smart Cities: Harnessing Urban Green Spaces for Health and Well-being in Connected Environments

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A B S T R A C T

The concept of biophilic smart cities centers on blending advanced technologies with biophilic design to improve urban living. In this model, urban green spaces play a key role, providing aesthetic value while simultaneously supporting physical, mental, and social well-being. This study employs a qualitative approach based on literature review, analysis of international case studies, and evaluation of planning documents related to urban development in Tunisia. The research specifically explores how the principles of biophilic smart cities can be adapted to the Tunisian context, with a focus on emerging projects such as Tunisia Garden City. By comparing global strategies with local urban dynamics, this article proposes context sensitive recommendations to support healthier, more resilient, and sustainable urban environments in Tunisia.

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1. Introduction

Modern urban environments are increasingly challenged by rapid population growth, environmental degradation, and the depletion of natural resources (UN-Habitat, 2022). In response to these issues, the concept of biophilic smart cities has emerged as a compelling solution, aiming to merge biophilic design with advanced technologies to promote healthier, more sustainable, and more resilient urban living (Sung et al., 2021; Yan et al., 2022). This integrated approach recognizes the vital role of nature in human well-being and seeks to reconnect city dwellers with natural elements through intelligent, interconnected systems (Harfouch et al., 2020). Biophilic design has demonstrated significant benefits in enhancing mental health, cognitive performance, and social well-being by incorporating natural elements into the built environment (Fang et al., 2020; da Silva et al., 2021). At the same time, smart technologies offer tools for efficient urban management, including real-time environmental monitoring, resource optimization, and adaptive infrastructure (Abusaada & Elshater, 2020; Ahvenniemi et al., 2021). Despite progress in each of these domains, there remains a gap in research addressing their

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convergence, particularly concerning the strategic role of urban green spaces as both ecological and technological assets (Neirotti et al., 2020).

This paper investigates how the integration of nature and technology within the urban fabric can transform green spaces into multifunctional systems that support physical, mental, and social health. The research question guiding this study is as follows: how can the integration of biophilic design and smart technologies enhance the performance of urban green spaces in fostering well-being, sustainability, and connectivity?

The objectives of the study are to examine the current contributions of urban green spaces to public health and ecological resilience, to explore how smart infrastructures can optimize their design and functionality, and to propose a conceptual framework for the development of biophilic smart cities. Aiming to answer the central question posed in the article: "How can the integration of biophilic design and technology in urban green spaces stimulate health and well-being?", this paper develops an exploratory, analytical study of various examples of urban green spaces that incorporate biophilic principles and technological innovations in their architecture. The methodological approach combines a qualitative review of relevant literature with two in depth case studies focusing on implemented or emerging examples of smart green infrastructure in Hong Kong and Singapore, followed by a presentation of qualitative results and interpretive analysis. Although recent initiatives in East Asia have explored such integrations (e.g., Singapore, Hong Kong), studies examining the applicationor even the potential of this model in African or Middle Eastern contexts remain sparse. Existing research in these regions either addresses green urbanism or digital infrastructure, but rarely both in combination (Neirotti et al., 2020).

The findings are expected to contribute new insights into how urban green spaces can be transformed through technological integration, offering guidelines for urban planners, architects, and policymakers seeking to create cities that are both intelligent and human-centered. The paper is structured to first present the theoretical foundations of biophilic and smart urbanism, followed by the methodology adopted for the study, an analysis of key findings, and a concluding discussion highlighting the broader implications of the research. Finally, while this study draws on international perspectives and case studies, it also aims to open reflections on how the biophilic smart city model could inspire future urban development in Tunisia. In the face of increasing environmental stress, urban densification, and socio-spatial inequalities, the integration of nature and technology offers a promising direction for creating healthier, more inclusive, and sustainable urban environments adapted to the Tunisian context.

2. State of the art

2.1. Biophilic Design in Urban Spaces

Urban In recent decades, the growing awareness of the psychological and physiological impacts of the built environment has renewed interest in design approaches that reconnect people with nature. One of the most influential among these is biophilic design, a concept rooted in the broader theory of biophilia a term introduced by psychologist Erich Fromm and later popularized by biologist Edward O. Wilson (1984). Derived from the Greek bios (life) and philia (love or affinity), biophilia refers to the innate human tendency to seek connections with natural forms of life and environments. Building on this, Kellert et al. (2011) articulated a theoretical framework that operationalizes biophilia through design, advocating for environments enriched with natural elements to support health, emotional balance, and cognitive functioning. Biophilic design in urban spaces involves strategies such as green roofs, living walls, natural light access, organic materials, water features, and biomorphic spatial forms. These interventions are not merely aesthetic; they have measurable effects—including reduced stress, improved mental clarity, and stronger social cohesion (Fang et al., 2020; da Silva et al., 2021). A recent contribution to this field is the Guidelines for Greening Healthcare Spaces by Bouaziz et Tur. (2023), which, although centered on hospital settings, proposes transferable principles for urban design. These include the integration of indoor greenery, natural materials, refuge spaces, locally adapted vegetation, and daylight acces all aimed at enhancing sensory comfort, cultural relevance, and psychological well-being.

2.2. Smart Urbanism and Digital Infrastructure

The concept of smart urbanism has gained traction as cities seek to address complex challenges such as demographic growth, environmental pressures, and infrastructural inefficiencies. At its core, the smart city paradigm promotes the use of digital technologie such as IoT systems, big data, artificial intelligence, and automation to optimize urban services and enhance quality of life (Neirotti et al., 2014; Ahvenniemi et al., 2021). These technologies are applied across a wide range of urban domains, including mobility, energy management, waste collection, and public safety, enabling real-time monitoring, predictive planning, and data driven governance.

2.3. Smart Ecotechnologies and Ecological Intelligence

In response to the limitations of traditional smart city frameworks, a new direction has emerged: the integration of digital intelligence with ecological systems, giving rise to what may be called smart eco-technologies. These technologies are designed not only for efficiency but also to support ecological regeneration, environmental resilience, and human-nature connectivity.

Examples of smart eco-technologies include adaptive irrigation systems based on climate data, air quality sensors embedded in green infrastructures, smart shading systems, and responsive lighting that adjusts to daylight conditions. These systems allow urban green spaces to become dynamic, multifunctional ecosystem capable of cooling urban areas, purifying air, managing storm-water, and supporting biodiversity, all while being monitored and optimized through digital tools.

Smart city models have often emphasized efficiency, control, and infrastructure optimization. However, critics point out that this techno-centric focus frequently overlooks ecological dynamics and human well-being. As a result, the early versions of smart cities tended to function more as technologically advanced systems of control rather than inclusive and resilient urban environments.

3. Methodology

This study explores how biophilic design and smart technologies shape urban sustainability, public health, and social connectedness. Using a mixed methods approach, it begins with an in depth literature review to highlight key trends and theoretical frameworks around biophilic principles and smart urban innovation. Through real world case studies, it examines how these elements are implemented in urban settings and assesses their impact on community well-being and environmental performance. Data is gathered through surveys and field observations to evaluate effects on residents' health, social interaction, and ecological sustainability. The analysis combines thematic exploration, and comparative evaluation to draw meaningful insights from the findings.

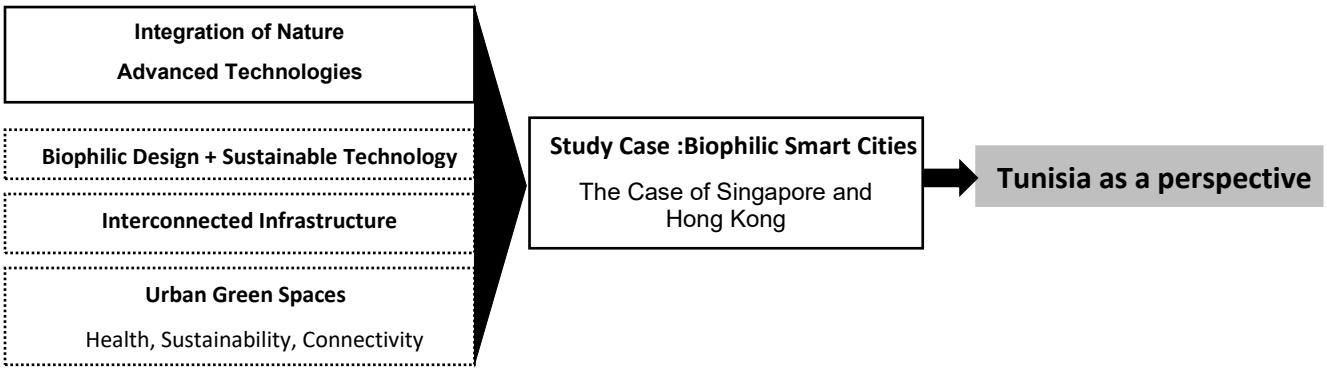

Figure 1. Structure of the study.

4. Study Design and Setting

The concept of biophilic smart cities, which integrates biophilic design principles with smart technologies, is rooted in a range of academic disciplines, including urban planning, environmental psychology, sustainability, and technology. A comprehensive literature review was conducted to establish the theoretical and empirical foundations for this study, focusing on four key areas: biophilic design, smart cities, health and sustainability, and case studies of successful urban models.

Biophilic design refers to the architectural and urban planning principles that incorporate elements of nature into built environments to promote human well-being. The term "biophilia," coined by Edward O. Wilson in the 1980s, describes humans' inherent affinity for nature and the positive impacts that nature

exposure can have on physical and mental health (Wilson, 1984). Biophilic design is based on the idea that reconnecting urban residents with nature can lead to improved psychological outcomes such as reduced stress, enhanced mood, and better cognitive function (Kellert et al., 2011).

Multiple studies have demonstrated the effectiveness of biophilic design in enhancing urban environments. For example, a study by Barton et al. (2009) emphasized that access to nature and green spaces in urban settings significantly reduces stress and promotes recovery from mental fatigue. Kaplan and Kaplan (1989) also found that exposure to natural environments helps reduce cognitive load and promotes restorative experiences. The inclusion of natural elements, such as plants, water features, and green spaces, has been shown to create environments that encourage relaxation, creativity, and social interaction (Ulrich, 1984). In the context of smart cities, biophilic design integrates these principles into urban spaces while leveraging technology to monitor and optimize the benefits of natural elements (Beatley, 2011).

Smart cities refer to urban areas that leverage advanced technologies to enhance the quality of life for residents, improve the efficiency of urban systems, and promote sustainability. Technologies like Internet of Things (IoT) sensors, big data analytics, and artificial intelligence (AI) play a key role in monitoring and managing urban environments. These technologies help cities make data-driven decisions to optimize resource use, improve air quality, and reduce energy consumption (Batty et al., 2012).

According to Harrison et al. (2010), smart cities use sensors and data systems to collect real-time information on various parameters such as traffic flow, waste management, energy use, and environmental conditions. This data allows city officials to make informed decisions that improve urban efficiency, reduce carbon emissions, and enhance sustainability. Smart grids, for instance, enable real-time adjustments to electricity consumption based on demand, improving energy efficiency and reducing greenhouse gas emissions (Murray et al., 2015).

Furthermore, smart city technologies can facilitate the integration of green infrastructure in urban planning. Smart systems can monitor urban heat islands, air quality, and energy use in real-time, thereby enhancing the ability to manage green spaces more effectively and optimize their environmental benefits (Zhou et al., 2020). Thus, the combination of biophilic design and smart technologies in urban settings has the potential to create more sustainable, resilient, and livable cities.

The concept of smart cities has evolved significantly over the past few years, with a growing emphasis on the integration of advanced technologies and data driven decision making to improve urban living. A smart city leverages technologies such as Internet of Things (IoT), big data analytics, artificial intelligence (AI), and sustainable infrastructure to enhance the efficiency, sustainability, and livability of urban environments. The integration of these technologies into urban systems aims to address the challenges of rapid urbanization, resource management, pollution, and climate change, while simultaneously enhancing the quality of life for residents.

A central feature of smart cities is the deployment of IoT sensors that collect real-time data on various urban parameters, such as traffic flow, air quality, energy consumption, and waste management. This data is processed and analyzed using big data and AI to optimize the functioning of city systems. Recent studies by Zhao et al. (2023) and Tan et al. (2024) emphasized how IoT networks in smart cities enable better urban planning by providing real-time insights into environmental conditions, transportation patterns, and infrastructure needs. These innovations allow cities to become more efficient in managing resources and responding to environmental challenges.

For example, smart grids, which use IoT sensors and data analytics, enable cities to monitor and manage electricity consumption more efficiently. By dynamically adjusting power distribution based on real-time demand, smart grids reduce energy waste and lower carbon emissions (Schaeffer et al., 2020). Additionally, smart water management systems use sensors to monitor water quality, detect leaks, and optimize irrigation schedules in urban landscapes, contributing to water conservation and sustainability (Wang et al., 2023).

Smart cities also place a significant emphasis on smart mobility systems, which aim to improve urban transportation by integrating digital technologies and innovative solutions. Autonomous vehicles (AVs), electric vehicles (EVs), and smart public transport systems are increasingly being adopted in cities to reduce traffic congestion, improve air quality, and promote sustainable transportation options (Zhang et al., 2023). A study by Sun et al. (2023) highlighted how cities like Amsterdam and Barcelona are leading the way in implementing smart transportation systems, such as electric car-sharing platforms, integrated public transport apps, and autonomous bus services.

Sustainability is at the core of smart city initiatives, with a focus on reducing energy consumption and minimizing environmental impact. Smart buildings and green infrastructure are being integrated into cities to improve energy efficiency and enhance environmental quality. Smart buildings use IoT sensors to regulate temperature, lighting, and air quality, optimizing energy use and reducing operational costs. Green roofs, solar panels, and other sustainable technologies are being incorporated into building designs to further reduce the carbon footprint of urban environments (Tian et al., 2022).

An emerging trend in smart cities is the focus on smart governance, which leverages technology to improve urban management and citizen engagement. By integrating e-governance platforms and digital citizen services, cities can streamline administrative processes and improve public service delivery. The use of open data platforms allows residents to access real time information about city services, such as waste collection schedules, air quality levels, and traffic conditions (Lee et al., 2021).

The study also explored a variety of indicators related to different urban scales and biophilic design patterns. The article by Turki, Bouaziz, Taieb, and Gargouri (2023) highlights the importance of Biophilic Design Patterns, illustrating how creating visual connections with nature and incorporating natural elements into healthcare spaces contribute to a therapeutic and calming environment. A subset of these indicators was chosen for the research, focusing on aspects such as urban resilience, disaster response, and public health, all within the context of the urban environment, as shown in Fig. 2.

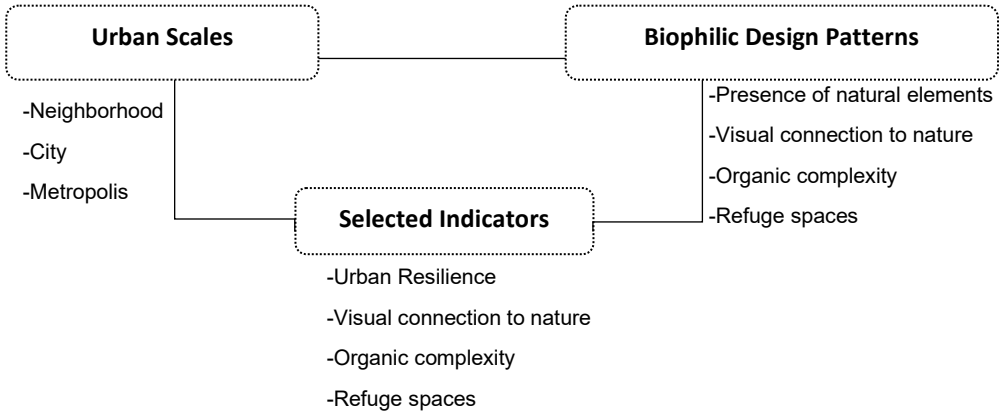

Figure 2. Connection between Urban Scales, Biophilic Design Patterns, and Sustainability Indicators.

Citizen engagement is another important aspect of smart cities. By utilizing digital platforms, smart cities foster greater interaction between local governments and residents, enabling citizens to actively participate in decision-making processes. For instance, participatory budgeting apps and smart city dashboards allow residents to vote on urban development projects and provide feedback on city services, thus improving community involvement and transparency in governance (Kumar et al., 2023).

5. Green and Smart: Transforming Urban Landscapes in Singapore and Hong Kong

Singapore has consistently been at the forefront of integrating biophilic design and smart technologies within its urban planning framework. Its approach not only enhances the quality of life for its residents but also fosters sustainability, environmental resilience, and innovative resource management. A prime example of this is the Gardens by the Bay project, along with its smart urban farming initiatives like SkyGreens. These initiatives combine natural beauty with cutting edge technology, setting a benchmark for smart biophilic cities worldwide.

The Gardens by the Bay, which opened in 2012, is a striking example of how smart cities and biophilic design can be seamlessly integrated to create sustainable and technologically advanced urban environments. As part of Singapore's larger vision to become a smart city, the project showcases how innovation can be harnessed to improve both the quality of life for residents and the resilience of the urban ecosystem.

Figure 1. The Gardens by the Bay Exterior

Figure 2. The Gardens by the Bay Interior

Biophilic design, which focuses on connecting people to nature within urban settings, is a central element of the Gardens. The sprawling complex, which includes features like the Supertree Grove, Flower Dome, and Cloud Forest, not only offers green spaces for recreation and relaxation but also fosters a deeper connection with the natural world. These elements serve to improve well-being, reduce stress, and enhance the mental and physical health of residents and visitors alike. As Andrew Grant, director of Grant Associates, the landscape architects for the project, stated: "The Gardens by the Bay is about reimagining what an urban park can be. Blending natural beauty with advanced technology to create a space that's both sustainable and uplifting for the community." (Grant Associates)

The design of the Gardens was led by Wilkinson Eyre Architects, with Grant Associates responsible for the landscape architecture. Together, they created a visionary blueprint that balances aesthetics, sustainability, and functionality. Simultaneously, smart city technologies have been embedded into the design of the Gardens. These include energy-efficient systems, climate responsive architecture, and smart lighting, which ensure that the space operates sustainably while offering visitors a technologically enhanced experience. For example, the Lumenbeam LBX Color Changing lights used to illuminate the waterfall within the Tropical Rainforest Conservatory are part of a sophisticated lighting system that responds dynamically to the movement of the water, contributing to the immersive experience. The ability to monitor and control lighting and energy usage ensures that the project remains environmentally responsible and efficient. User experiences also highlight the Gardens' impact. Many visitors have praised the site for its ability to evoke a sense of tranquility in the heart of a bustling city. As one visitor shared, "It's a place where you can truly escape the stress of city life, reconnecting with nature while still being surrounded by innovation. The seamless integration of the greenery and technology makes the experience feel both refreshing and futuristic."(TripAdvisor)

Through this combination of biophilic design and smart city principles, Gardens by the Bay serves as a model for other cities seeking to integrate nature with technology. The project highlights how smart technologies can be leveraged not only for operational efficiency but also to enhance the human experience within urban landscapes. By blending the best of both worlds, nature and technology, Singapore continues to set the standard for future urban developments that prioritize sustainability, innovation, and well-being.

Similarly, Jewel Changi Airport in Singapore exemplifies this harmonious blend, seamlessly combining biophilic elements with cutting-edge smart technologies to redefine urban spaces. Designed by Safdie Architects (2019), its iconic Rain Vortex—the world's tallest indoor waterfall—is not merely an architectural marvel but also a symbol of biophilic innovation, designed to evoke a sense of tranquility and connection to nature. Surrounding the waterfall is a lush indoor forest featuring over 2,000 trees and 100,000 shrubs from around the world, offering visitors an immersive experience in a natural setting.

The biophilic design of Jewel Changi Airport fosters well-being by creating a serene and refreshing environment, reducing stress for travelers and visitors. This connection to nature is further enhanced by smart technologies that ensure operational efficiency and sustainability. For instance, the Rain Vortex is part of an advanced water management system that collects and recycles rainwater for irrigation, reducing water waste while maintaining the lush greenery. The structure also incorporates energy efficient lighting and climate control systems, optimizing the indoor environment while minimizing environmental impact.

Figure 5. Jewel Changi Airport Exterior

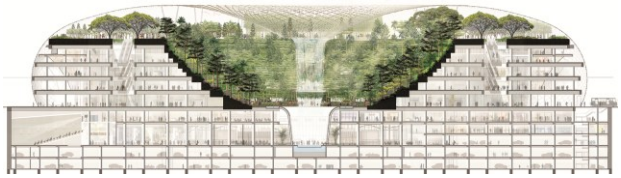

Figure 6. Interior Section of Jewel Changi Airport

Jewel Changi Airport demonstrates how smart technologies can work in tandem with biophilic principles to create spaces that are not only functional but also deeply engaging. By integrating technology to enhance the sensory experience—such as dynamic lighting that adjusts with natural rhythms and interactive installations that engage visitors the space goes beyond being a transit hub to become a destination in itself. Through projects like Gardens by the Bay and Jewel Changi Airport, Singapore continues to lead the way in urban innovation, setting a global benchmark for sustainable, nature centric developments that prioritize human well-being (Tan et al., 2020).

Hong Kong, a city known for its iconic skyline and high population density, faces numerous challenges when it comes to implementing biophilic design principles. The rapid pace of urbanization, coupled with limited land availability, creates significant obstacles for integrating nature into the urban environment. One of the primary difficulties is the city's extreme density, with over 7 million people living in a relatively small area, which places considerable pressure on available space for green infrastructure (Census and Statistics Department, 2023). This challenge is further exacerbated by the city's reliance on vertical urbanization, where high rise buildings dominate the landscape. While this vertical development offers potential for rooftop gardens and green walls, the challenge lies in designing these spaces in a way that maximizes human interaction with nature while maintaining their environmental benefits (Cheung, 2019).

In addition, Hong Kong suffers from significant air pollution, primarily due to industrial activity, vehicle emissions, and dense construction. This makes it more difficult to foster a healthy, nature integrated urban environment. Although biophilic design can play a role in mitigating some of these issues, substantial investment is required in green infrastructure and sustainable technologies, which can often be overshadowed by the city's economic priorities (Chan & Leung, 2017). Hong Kong also faces the delicate task of balancing rapid development with the preservation of its natural landscapes. Despite having numerous country parks and natural reserves, the city's rapid urban expansion has often encroached on these green spaces, creating tension between development and conservation. Ensuring that natural areas are preserved while still accommodating a growing urban population is a challenge that urban planners must address carefully (Lai, 2020).

Moreover, integrating smart technologies with nature poses additional difficulties. Hong Kong has already introduced various smart solutions aimed at improving sustainability, such as air quality sensors and energy efficient systems, but successfully combining these technologies with biophilic elements in a dense urban environment requires careful planning. The design of smart systems must complement and enhance nature based solutions rather than detract from their aesthetic or ecological value (Yung & Chan, 2020).

Despite the constraints posed by high urban density and limited land availability, Hong Kong has actively pursued the integration of biophilic principles into its urban development strategy. A flagship initiative in this regard is the Hong Kong Wetland Park, opened in 2006 in the New Territories. Spanning over 60 hectares, the park functions both as a conservation site and an educational center, offering residents access to a rich mosaic of ecosystems including wetlands, mangroves, and reedbeds within close proximity to the urban core. Although not originally conceived as a "smart" facility, the Wetland Park is embedded within a wider urban agenda that increasingly leverages technological tools for

environmental management. For example, real-time monitoring systems managed by the Environmental Protection Department are deployed in adjacent protected zones to track water quality, air conditions, and biodiversity fluctuations. These systems allow for early detection of ecological disturbances and support informed conservation efforts (Environmental Protection Department, 2021).

Figure 3. Hong Kong Wetland Park Interior Site

Figure 4. Plan of Hong Kong Wetland Park.

From a user perspective, data from 2024 underscore the park's continued relevance and popularity: with over 410,000 visitors, including 8,100 international tourists, and more than 2,500 guided tours and programs conducted, it remains a key biophilic destination in the city (Hong Kong Wetland Park, 2024). Visitors consistently highlight the park's restorative ambiance and immersive natural experience, frequently describing it as a peaceful retreat from urban life. Digital exhibits and educational installations enhance this experience, using interactive technologies to foster greater awareness of local ecosystems and climate challenges. By blending natural design with technological innovation, the Hong Kong Wetland Park illustrates how urban environments even in hyper dense metropolises can be reimagined to promote ecological literacy, well-being, and sustainable coexistence between humans and nature.

In addition to large scale ecological initiatives, Hong Kong has begun to implement biophilic interventions even within its most infrastructure-heavy projects. A notable example is the Central-Wan Chai Bypass, an extensive urban expressway completed in 2019, which includes the development of green decks—elevated landscaped platforms that link key urban infrastructure with accessible green spaces. These decks not only serve as aesthetic buffers but also play an important ecological and psychological role, offering residents and commuters a more nature integrated experience in otherwise heavily built up zones (Hong Kong Highways Department, 2019).

Moreover, the Central-Wan Chai Bypass integrates several smart technologies aimed at reducing environmental impact and improving the quality of urban life. For instance, the tunnel system is equipped with automated ventilation that adjusts airflow based on real-time data on air quality, traffic conditions, and temperature, optimizing energy use and maintaining a healthy indoor environment (Hong Kong Highways Department, 2019). Additionally, IoT sensors monitor the quality of air and noise levels within and around the tunnel, providing continuous feedback for system adjustments to reduce pollution and improve urban comfort (Tang & Ho, 2018). The green decks also benefit from smart irrigation systems, which use weather and soil moisture data to efficiently water plants, helping maintain greenery while minimizing water waste (Environmental Protection Department, 2021).

Beyond infrastructure retrofitting, the city is also exploring innovative strategies to reclaim vertical surfaces for nature, including green rooftops, living walls, and urban farming projects. Given Hong Kong's limited horizontal space, these vertical green solutions have gained momentum as a way to increase biodiversity, mitigate urban heat islands, and support local food systems. Pilot programs have already been launched in schools, public buildings, and commercial towers, with some rooftops converted into automated smart farms that utilize IoT sensors to monitor soil moisture, sunlight, and temperature allowing for optimized and sustainable food production in dense urban contexts (Tang & Ho, 2018).

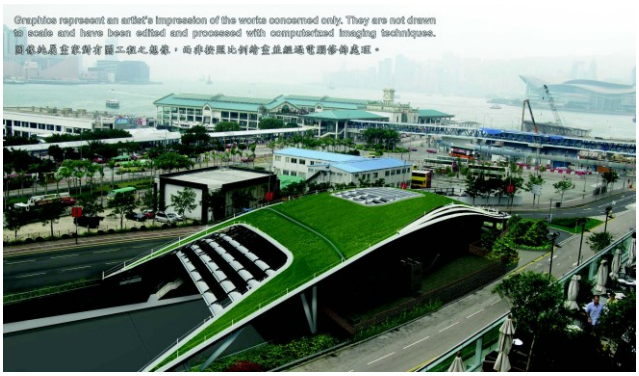

Figure 9. Aerial view of the Central Wan Chai Bypass

Figure 10. Front View of the Central Wan Chai

While the path to becoming a fully biophilic and smart city is inherently complex particularly in a metropolis defined by verticality and high land value Hong Kong is gradually redefining its urban fabric. The city's efforts to integrate nature into the built environment, supported by data driven technologies and forward thinking urban planning, represent important steps toward resilience and livability (Hong Kong Urban Renewal Authority, 2022).

Rather than viewing nature and development as opposing forces, Hong Kong is pioneering a model where urban growth coexists with ecological regeneration. Through careful spatial design, policy innovation, and smart technology integration, the city is beginning to transform its dense urban form into a more nature connected and human centered environment, ultimately paving the way for a smarter, greener, and healthier future for its residents (Environmental Protection Department, 2021).

A survey conducted by the Hong Kong Highways Department (2019) and supplemented by qualitative interviews with users reveals a positive perception of the Bypass's environment. Respondents emphasized the value of "visual openness," "green relief," and "quiet transitions" as aspects that contribute to reduced commuting fatigue and improved daily satisfaction.

For many residents, the ability to engage visually or physically with nature during routine movements is a critical factor in urban well-being. Moreover, the predictability and cleanliness of the space, enabled by connected monitoring systems, foster a sense of security and trust in public infrastructure.

6. Results

This section presents the key findings of the study, focusing on the integration of biophilic elements and smart technologies in Connected Environments. It highlights their influence on the health and well-being of residents and visitors by analyzing four notable projects: Gardens by the Bay, Jewel Changi Airport, Hong Kong Wetland Park, and the Central–Wan Chai Bypass. These cases illustrate how nature and technology can coexist in complex urban environments, offering restorative experiences and contributing to sustainable development.

Gardens by the Bay in Singapore is a large-scale urban ecological park that exemplifies how biophilic design can transform a dense city into a green sanctuary. The project integrates advanced environmental engineering, such as the cooled conservatories and the iconic Supertree Grove, which function as vertical gardens, solar energy collectors, and air exhaust systems. The Cloud Forest and Flower Dome maintain optimal temperature and humidity levels through smart climate control systems, creating comfortable microclimates year-round. Visitors report high levels of psychological comfort, reduced stress, and an enhanced sense of connection to nature. The immersive design fosters environmental awareness while providing an escape from the surrounding urban intensity. Similarly, Jewel Changi Airport in Singapore offers an innovative model for integrating nature into a high-traffic transit hub. At its center is the Rain Vortex, the world's tallest indoor waterfall, surrounded by a lush indoor forest that spans multiple levels. Smart technologies regulate light levels, indoor air quality, and temperature, creating a stable and soothing environment for travelers. These biophilic and digital systems work together to transform the airport from a purely functional space into a therapeutic environment. Visitors often describe their experience as calming and uplifting, highlighting the psychological benefits of biophilic design in non-traditional contexts such as airports. In Hong Kong, the

Wetland Park represents a successful integration of ecological preservation and public engagement. Located in the northern New Territories, this project combines natural wetlands with smart environmental monitoring systems that track biodiversity, water quality, and weather conditions. The park is both a conservation site and an educational center, where visitors are encouraged to engage directly with nature through elevated walkways, observation areas, and interactive exhibits. Feedback from users highlights the park's role in fostering mindfulness, relaxation, and environmental stewardship. By making ecological systems visible and accessible, the Wetland Park promotes both physical and mental well-being. The Central–Wan Chai Bypass, also in Hong Kong, represents a different typology, where biophilic strategies are applied to major transport infrastructure. This urban expressway includes elevated green decks and vegetated roofs that mitigate the visual and environmental impact of the tunnel system. Although primarily a mobility corridor, the bypass incorporates smart ventilation systems that respond to air quality and traffic conditions, as well as IoT sensors that monitor noise and pollution levels in real time. The landscaping above the tunnel serves as a green buffer, improving urban aesthetics and offering passive rest zones in a dense urban setting. Users and local residents benefit from enhanced air quality, lower noise levels, and visual access to greenery, all of which contribute positively to health and well-being.

Together, these four projects demonstrate that the integration of biophilic design and smart technologies can significantly enhance the quality of life in urban environments. Whether through immersive gardens, reimagined transportation infrastructure, or conservation-based public spaces, these interventions provide both ecological benefits and psychological value. They suggest that the future of urban development lies not only in high-tech innovation but also in the reconnection of people with nature through thoughtful, multisensory spatial experiences. The study shows that biophilic and smart strategies are not mutually exclusive but are, in fact, complementary tools in creating connected environments that support resilience, sustainability, and human well-being.

7. Tunisia as a Future Horizon for Biophilic Smart Cities

While global cities such as Singapore and Hong Kong have implemented advanced models of biophilic and smart infrastructure (National Parks Board Singapore, 2022; Hong Kong SAR Government, 2021), Tunisia is still in the early stages of exploring this convergence. However, the emergence of visionary projects like Tunis Garden City reflects a growing awareness of the need to reintegrate nature into urban planning and signals a broader shift toward more sustainable, human-centered development.

Although still under construction and lacking fully operational smart systems, Tunis Garden City is designed with future-oriented principles, including reduced energy consumption, promotion of walkability, and generous integration of green public spaces (Mabrouk Group, 2025). These foundational elements suggest a readiness to embrace smart ecotechnologies in future phases, positioning the project as a strategic prototype for Tunisia's transition toward biophilic-smart urbanism.

The choice of Tunisia as a focus for this perspective is not incidenta it is based on the country's urgent urban challenges and untapped potential. Rapid urbanization, water scarcity, environmental degradation, and socio-spatial inequalities have placed increasing pressure on Tunisian cities, particularly Tunis, Sfax, and Sousse. These challenges demand a rethinking of conventional planning models in favor of more resilient, inclusive, and ecologically embedded approaches.

1.At the same time, Tunisia offers fertile ground for innovation:

2.A Mediterranean climate that favors biodiversity and passive design;

3.A heritage of vernacular architecture deeply rooted in climatic and cultural intelligence;

4.A growing ecosystem of startups and designers interested in smart city solutions and green innovation;

5.Emerging public-private initiatives and international support (European Commission, 2021) for sustainable development.

By leveraging these contextual strengths, Tunisia holds the potential not only to adapt global biophilic-smart models, but also to localize them in ways that reflect its cultural identity, environmental needs, and social priorities. Projects like Tunis Garden City, even in their conceptual phase, demonstrate both the feasibility and desirability of nature-integrated, tech-enhanced urban planning.

In summary, while Tunisia's biophilic-smart infrastructure is still in its infancy, the country is well-positioned to lead regional innovation in this field. By capitalizing on its climatic advantages, architectural heritage, and emerging technological capacity (European Commission, 2021), Tunisia can pave the way toward

a resilient, connected, and biophilic urban future—not only for itself, but also as a model for other North African and Middle Eastern cities.

Figure 11. Urban façade of the Tunis Garden City

Figure 12. Walk WATER and Green Boulevard.

Based on this context, supported by the literature (Kellert et al., 2008; Beatley, 2016) and the analysis of international precedents such as Gardens by the Bay and Jewel Changi Airport in Singapore (National Parks Board Singapore, 2022; Changi Airport Group, 2020), and the Central Wan Chai Bypass in Hong Kong (Hong Kong SAR Government, 2021), this study proposes a guide for integrating biophilic-smart design into Tunisian urban spaces drawing from both global expertise and local innovation capacity.

This is why, based on the literature review (Kellert et al., 2008; Beatley, 2016) and the analysis of international case studies such as Gardens by the Bay and Jewel Changi Airport in Singapore (National Parks Board Singapore, 2022; Changi Airport Group, 2020), and the Central–Wan Chai Bypass in Hong Kong (Hong Kong SAR Government, 2021), we have proposed a guide for the integration of smart biophilic design in urban spaces in Tunisia.

Table 1: A guide for the integration of smart biophilic design in urban spaces in Tunisia.

Category	Indicators/ Principles	Description/Recommandations	Application to Tunisian Context
Biophilic City	Direct Connection to Natu	Integrate local vegetation, water feature shaded areas, and natural light.	Use drought-resistant Mediterranean plants (olive trees, palms). Create green spaces ir city centers.
	Natural and Sustainable Materials	Favor local materials such as stone, wood, and raw earth.	Revitalize traditional Tunisian architecture (medinas).
	Organic Patterns and Forms	Incorporate natural patterns (fractals, curves) into urban furniture and architecture.	Draw inspiration from traditional Islamic an Berber motifs.
	Urban Biodiversity	Diversify plant species to support urban fauna (insects, birds).	Promote species adapted to Mediterranec climate.
	Accessible Green Spaces	Ensure equitable and easy access to natural areas for all residents.	Create neighborhood parks in underservec districts.
Urban Resilience	Climate Adaptation	Reduce urban heat islands with vegetation and water reuse systems.	Install green roofs and walls in dense urban areas.
	Sustainable Resource Management	Optimize water and energy consumptior recycle waste.	Implement rainwater harvesting systems.
	Flexibility and Redundancy	Design multifunctional spaces that can adapt to different uses during emergencies.	Develop modular public squares and open spaces.
	Citizen Participation	Engage residents in the design and management of urban spaces.	Organize co-design workshops and ecological awareness programs.
Smart City	Environmental Monitoring Systems	IoT sensors to measure air quality, temperature, humidity, and noise.	Install sensors in parks and sensitive urban zones.
	Intelligent Infrastructure Management	Automate lighting and irrigation based on real-time conditions.	Use sensor-driven drip irrigation in parks an gardens.
	Connected Sustainable Mobility	Integrate electric transport, connected bike lanes, and shared mobility apps.	Develop bike stations and local carpooling apps.
	Smart Energy Management	Smart grids and local renewable energy production (solar).	Install solar panels on public buildings and parking lots.
	Data Collection and Analy	Digital platforms for real-time urban datc collection and analysis.	Establish open data platforms for the city.

By following these steps, it is possible to successfully integrate smart biophilic design into urban spaces in Tunisia. This approach offers a holistic response to contemporary urban challenges by combining the restorative power of nature, the adaptability of resilient planning, and the efficiency of smart technologies. Through context-sensitive strategies that embrace Tunisia's Mediterranean climate, cultural heritage, and social dynamics, cities can evolve into healthier, more inclusive, and future-ready environments. The integration of greenery, intelligent systems, and community engagement not only improves urban well-being but also fosters a stronger connection between people and nature in the heart of Tunisian cities.

8. Conclusion

Biophilic-smart cities represent a new generation of urban ecosystems that aim to reconcile technological innovation with ecological intelligence, placing human well-being and environmental resilience at the core of urban transformation. Far from being limited to high-tech interventions, these models propose hybrid infrastructures where digital tools serve to enhance the regenerative capacities of natural systems and foster inclusive, adaptive public spaces.

Through the integration of urban green spaces as multifunctional nodes—combining environmental services, social interaction, and data-driven responsiveness—biophilic-smart cities operate at the intersection of nature, community, and technology. These spaces are not merely aesthetic amenities but act as micro-infrastructures for urban health, offering: restorative environments that promote mental and physical well-being,, platforms for environmental monitoring and adaptive urban management and frameworks for participatory use, where communities can engage with, and benefit from, intelligent and green systems.

In contexts like Tunisia, where urbanization coexists with climatic vulnerability and socio-spatial fragmentation, such an approach holds transformative potential. The development of context-sensitive, scalable prototype as seen in the conceptualization of Tunis Garden City can serve as both functional infrastructure and symbolic transition toward a more resilient and connected urban future.

As environmental infrastructure, biophilic-smart solutions support biodiversity, mitigate urban heat islands, and enable efficient management of water and air quality. As social infrastructure, they foster belonging, interaction, and accessibility, especially in neighborhoods where public space is fragmented or underdeveloped.

Future research should explore how these hybrid models can be adapted to diverse urban morphologies, particularly in the Global South. It will be essential to assess their long-term ecological performance, their integration with vernacular knowledge, and their capacity to generate socio-economic value through inclusive governance and technological equity.

Ultimately, the biophilic-smart paradigm invites us to rethink the city as a living system—one that not only responds to data but regenerates its own ecosystems, enhances the quality of urban life, and reconnects citizens to the rhythms and benefits of the natural world.

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Data availability statement

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

Ethics statements
Studies involving animal subjects: No animal studies are presented in this manuscript.
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The author declares no conflict of interest.

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Developing Design Strategies within Vernacular Context: A Social Responsibility-Based Approach to Architectural Education

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A B S T R A C T

Although architecture is inherently shaped by social, cultural, and environmental factors, contemporary practices often limit architects' engagement with broader societal responsibilities. Integrating "social responsibility" concept into architectural education provides a framework to address this gap, emphasizing ethical responsibilities, sustainability, and community involvement. Architectural Design Studio 3 at Abdullah Gül University, conducted during the 2022 and 2023 academic years, explored this idea by focusing on culturally significant sites, Divriği/Sivas and Büyükada/Istanbul, to study human-environment interactions and local habitat sustainability. Students conducted multidimensional design research to develop strategies at urban, neighborhood, and building levels. This study evaluates how well their design concepts reflect social responsibility principles. For this, a mixed-methods approach was used: first, a systematic literature review and thematic analysis were employed to define social responsibility principles in architecture; then, students' concept statements were analyzed through content and thematic analysis. The findings show that these principles effectively guided students in developing inclusive spatial strategies responsive to cultural and environmental contexts. This highlights the importance of incorporating social responsibility principles into architectural education to enhance students' ethical awareness, contextual understanding, and inclusive design thinking.

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1. Introduction

While architecture is increasingly losing its influence in addressing complex societal and environmental challenges, concepts such as "ethics" and "social responsibility" have re-emerged as vital frameworks to redefine the architect's role. This decline in architecture's societal impact has led to greater interest in design approaches that address social issues beyond just aesthetics or technical concerns. In this context, "social responsibility," which derives its broader principles from the "Corporate Social Responsibility (CSR)" concept, focuses on the ideal relationships between global corporations, governments, citizens, and stakeholders (Crowther & Aras, 2008). Based on CSR, social responsibility in architecture encompasses themes like sustainability, accountability, transparency, community engagement, and responsiveness, all

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supporting sustainable development by addressing environmental and societal issues alongside economic factors (Chapple & Moon, 2005; Crowther & Aras, 2008; Organization for Economic Co-operation and Development (OECD), 2001). Historically, a major turning point occurred when architecture became fully responsible for shaping the built environment, requiring architects to consider broader ethical and societal aspects of design (Tanju, 2003). In light of this shift, incorporating social responsibility into architectural education and discourse has become essential for training professionals capable of creating sustainable, ethical, and inclusive built environments.

In this context, architectural education plays a crucial role in developing socially responsible designers who can address current societal and environmental challenges. A key component of this educational process is the design studio, where students are expected to develop conceptual frameworks that demonstrate ethical and contextual understanding from the early stages of design. Kyropoulou (2024) argues that there is a significant gap between the concept of sustainability and architectural education, mainly due to the lack of clear methods and tools that help students effectively incorporate sustainable principles into their design processes. Supporting this view, Burton and Salama (2023) focus on integrating "Sustainable Development Goals (SDGs)" knowledge into architectural education at both global and national accreditation levels. They emphasize the need for theoretical frameworks, validated strategies, and interdisciplinary teaching and learning experiments to embed SDGs into curricula and studio practices. In line with this concern, Qiu et al. (2023) developed a situational teaching framework for a third-year architectural design studio at Zhejiang University, incorporating investigations of historical background, economic and social structures, public services, and human needs to create an effective framework for improving students' ability to address social needs through design. Similarly, Calikusu et al. (2023) assessed how design studios influence students' knowledge, skills, and awareness of social, economic, and environmental sustainability through quantitative hypothesis testing and thematic qualitative analysis. Their findings show that both studio courses and theoretical lectures significantly enhance students' understanding of sustainability concepts. Complementing these perspectives, Mazalán et al. (2022) advocate for integrating social science methodologies such as sociology, anthropology, environmental studies, and behavioral psychology into architecture education curricula to promote participatory and user-centered design methods. These approaches help develop students' analytical, empathetic, and collaborative skills, enabling them to incorporate social dynamics into architectural practice. Collectively, these studies highlight the importance of equipping architecture students with the conceptual and methodological tools necessary to address sustainability and social responsibility throughout their architectural design education. Since the early stages of the design process are essential in shaping effective and responsible solutions to design problems, social responsibility can serve as a foundation for achieving creative, original, and high-quality results through structured frameworks.

On this basis, several scholars emphasize that enhancing students' ability to navigate complex design problems remains a key challenge in design education (Casakin & Goldschmidt, 1999). Structuring the problem is crucial for developing meaningful frameworks, while design concepts act as guiding ideas that shape spatial strategies and influence early design decisions (Eckert & Stacey, 2000; Mumcu & Düzenli, 2018). As Goldschmidt (1997) notes, these concepts are often uncertain at first and evolve through interaction with the problem space, where designers generate and refine partial ideas. Conceptual development is closely connected to sources of inspiration, personal interpretation, and shared cultural references, ultimately forming a unique design language (Eckert & Stacey, 2000). Despite the central role of the design studio in architectural education, a lack of structured understanding regarding how conceptual modeling helps develop students' creative and problem-solving skills remains a significant gap (Akalin & Sezal, 2009).

Building on this theoretical approach, this study argues that integrating social responsibility principles into the early design stages can provide a stronger pedagogical foundation for fostering critical thinking, contextual awareness, and value-based decision-making in architectural education. Therefore, to reflect this perspective, the Architectural Design Studio 3 at Abdullah Gül University (AGÜ), conducted during the 2022-2023 and 2023-2024 academic years, was explicitly structured around social responsibility principles in architecture. The studio aimed to explore how social responsibility concept can be integrated

into architectural design education, with a particular focus on studio-based learning. As a result, this study examines a studio course centered on social responsibility principles to achieve this goal, analyzing how these principles influence students' approaches to design problems. By tracking how students developed their conceptual frameworks in response to a framed design brief focused on social responsibility, the research highlights the educational potential of embedding the social responsibility concept within architectural design. Architectural Design Studio 3 was selected for this purpose since third-year students had completed core compulsory courses in architectural design and theory, building and construction technologies, and urban design outlined in the architecture department's curriculum at AGÜ. Additionally, they had finished university-level elective courses focused on SDGs. As Bektaş (2001) indicates, vernacular structures within traditional settlements are authentic and direct reflections of life, representing a common ground between culture and architecture. Therefore, vernacular settlements were chosen as project sites to discuss cultural issues related to social responsibility, especially focusing on the sustainability of local habitats. For this purpose, two distinct areas, Divriği/Sivas and Büyükada/İstanbul, were selected as project sites over the following years, since they offer traditional and geographically diverse environments. Students conducted multidimensional design research during on-site visits to these areas, including historical documentation, field observations, mapping, and stakeholder interviews to analyze socio-cultural, natural, and built-environmental contexts. Based on their findings, they developed design strategies through architectural concepts and usage scenarios at urban, neighborhood, and building scales. These proposed design concepts were then evaluated within this study using a mixed-methods research approach, including thematic and content analyses and a systematic literature review, to demonstrate how third-year architecture students integrated social responsibility principles into the design concepts of their project proposals.

2. Materials and methods

This study employed mixed-methods research to examine how social responsibility principles are reflected in the design concepts developed by students. The study consisted of two steps: defining social responsibility principles in architecture and analyzing students' design concept proposals within the social responsibility perspective (Figure 1). First, a systematic literature review was conducted using the Web of Science database, and thematic analysis was used to identify social responsibility principles in architecture. Next, concept-statements created by students in two design studios, "Socially Responsible Architecture: Alternative Scenarios for Divriği" and "Social Gathering Space at Büyükada," were analyzed using thematic and content analysis methods to assess the extent to which these principles appeared in their design concepts. Therefore, a systematic literature review was used for data gathering, while thematic and content analyses were used for data analysis within the study's framework.

A systematic literature review refers to a research method used to identify, evaluate, and synthesize existing studies related to a specific research question, involving collecting and critically analyzing data drawn from those studies (Kitchenham, 2004; Liberati et al., 2009). This process follows a structured, transparent, and repeatable approach designed to reduce bias and ensure comprehensive coverage of the literature, resulting in trustworthy findings that support sound conclusions and informed decisions (Kitchenham, 2004; Moher et al., 2009). A systematic review seeks to find all empirical studies that meet predetermined inclusion criteria to address a particular research question or hypothesis (Moher et al., 2009). These reviews include clear objectives, predefined inclusion and exclusion criteria, and systematic search strategies applied across selected databases. As Petticrew and Roberts (2006) explained, systematic reviews differ from traditional literature reviews because they follow an explicit protocol, which improves reliability and allows for critical evaluation of the included studies. This method enables researchers to combine findings from multiple studies to generate evidence-based insights and identify knowledge gaps within a specific field.

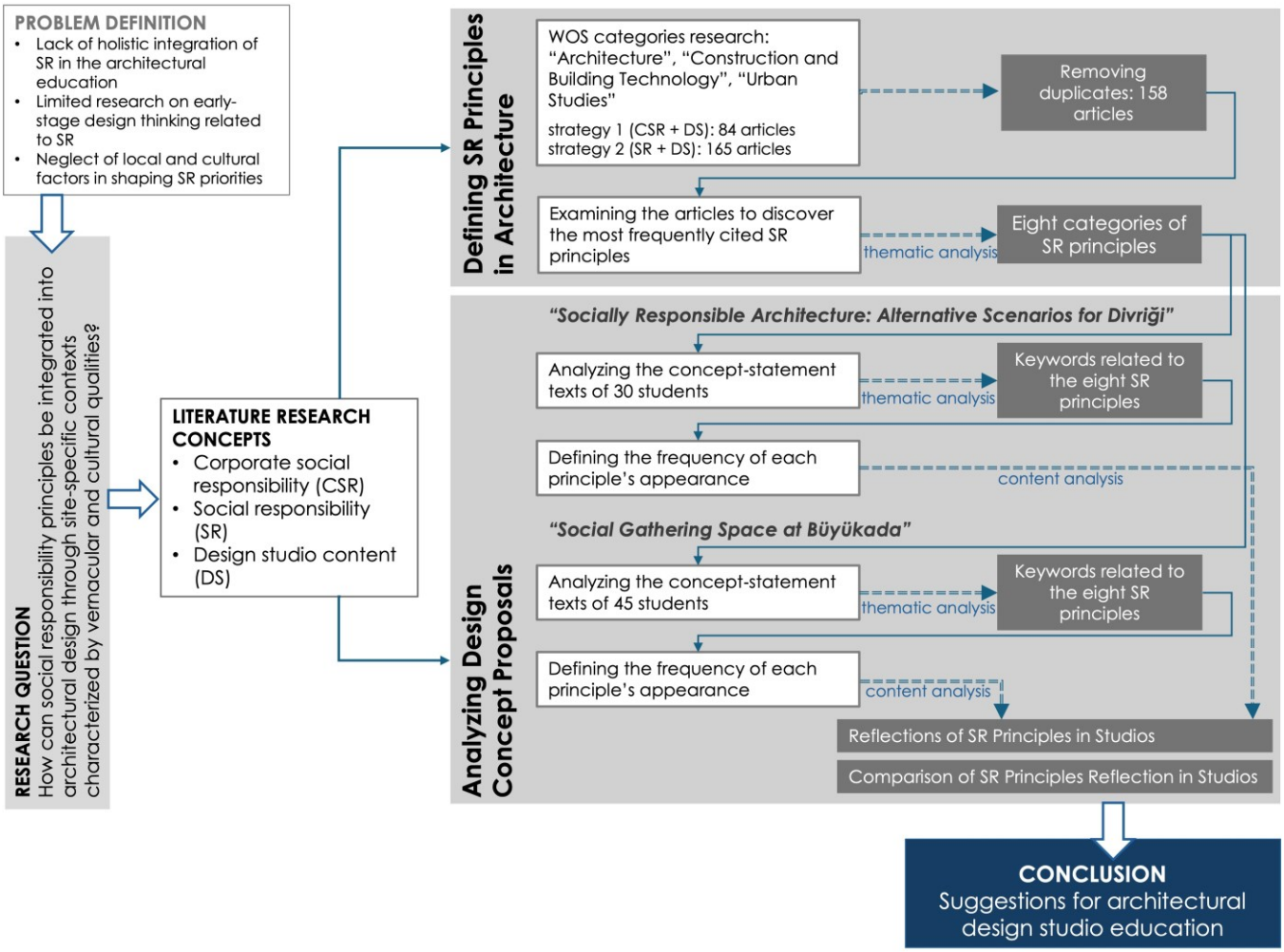

Figure 1. Research design of the study

Thematic analysis is a widely used qualitative method and independent analytical approach for identifying, analyzing, and reporting patterns called themes within data (Braun & Clarke, 2013; Guest et al., 2014). It can be used either inductively or deductively, depending on the researcher's theoretical framework (Braun & Clarke, 2013). Braun and Clarke (2006) describe thematic analysis as an approach rather than a strict method, highlighting its flexibility across different research designs and epistemological perspectives. This approach helps researchers organize and describe detailed datasets while also interpreting their deeper meanings (Braun & Clarke, 2006). Its flexibility enables researchers to explore viewpoints among participant groups, identify similarities and differences, and uncover unexpected insights from extensive or unstructured datasets (Maguire & Delahunt, 2017). The coding process is essential in thematic analysis because it simplifies complexity by identifying key features within the data. Researchers assign labels to significant data segments that represent specific topics or themes, creating a clear framework of interconnected concepts (King, 2004). Thematic analysis is particularly useful for understanding socially constructed meanings and narratives in their context, making it highly relevant in fields like education, psychology, cultural studies, and architectural heritage. It also improves methodological rigor through transparent coding processes, theme development, and reflexive interpretation (Nowell et al., 2017). In the end, thematic analysis helps researchers to summarize and generate theories from data, resulting in conceptually rich and methodologically sound findings.

Content analysis, on the other hand, refers to quantifying different types of documents, which involves classifying written, visual, or spoken material into distinct categories and analyzing how often these categories appear (Simon & Burstein, 1985). This process measures frequencies quantitatively while also aiming to understand the texts' structural characteristics and their underlying conceptual frameworks. This approach is convenient for exploring how specific topics, concepts, or ideologies are represented and highlighted across various media. Content analysis enables the identification, summarization, structuring, comparison with other datasets, and analytical interpretation of existing data (Smith, 1975). Through identifying recurring themes or symbolic expressions, this method goes beyond surface content to reveal deeper values and intentions in the material. Researchers like Ericsson and Simon (1985), Kassarjian (1977), and Neuendorf (2002) emphasize that content analysis involves not just the message of the texts but also the reasons and methods behind their particular structures. The approach is widely used across many fields, serving as a fundamental tool in discourse analysis in areas such as sociology, education, communication, architecture, and cultural heritage. The analytical process usually begins by selecting a set of texts or documents. Next, a systematic coding scheme is developed to record the presence and frequency of specific concepts or themes. Within this framework, key terms or themes are quantified, and the findings are often represented visually with tables or charts for interpretation (Neuman, 2009). Thus, content analysis functions as both a qualitative and quantitative method, offering objectivity and replicability. As noted by Mayring (2010) and Erdoğan and Semerci (2021), content analysis emphasizes not only individual concepts but also the larger structures and contexts in which they exist, leading to richer and more detailed insights. Therefore, content analysis goes beyond simple counting; it assesses how concepts function within their context and how they relate to each other. Specifically, qualitative content analysis enables a deeper exploration by examining similarities and differences encountered during classification.

3. A social responsibility-based architectural design studio experience

Architectural design education at AGÜ aims to foster the ability to critically question and reinterpret the connections between architecture and disciplines such as culture, art, science, society, environment, and technology. Students are expected to develop essential skills in design, inquiry, abstraction, critical evaluation, and decision-making based on multiple criteria during their first and second years. Additionally, AGÜ emphasizes sustainability by requiring students to complete five elective courses on global issues from various departments, focusing on the SDGs. The curriculum promotes a balanced and sustainable approach to both built and natural environments, including an emphasis on heritage and ecology. It also aims to raise awareness of urban design and landscape architecture in relation to local and global values, planning strategies, and cultural, economic, and political factors. By the third year, students should incorporate the technical knowledge gained from courses on structural systems, building materials, and architectural detail design into their projects. Consequently, Architectural Design Studio 3 is organized around students' accumulated knowledge, with a focus on the urban-rural interface, construction systems, and vernacular architecture. Having previously completed architectural design projects on individual housing units and repetitive building clusters, third-year students are expected to design a public space at the intersection of urban and rural environments. In this context, discussions about sustainability, nature, human interactions, and geographical conditions are integrated into the studio, creating a platform for active exploration of these themes.

Based on this framework, two design studios were conducted during the fall semesters of 2022–2023 and 2023–2024 academic years, named "Socially Responsible Architecture: Alternative Scenarios for Divriği" in Divriği/Sivas and "Social Gathering Space at Büyükada" in Büyükada/İstanbul, both focusing on social responsibility in architecture. The studio brief encouraged students to develop new visions for gathering spaces within the urban cores of the selected project sites, emphasizing inclusive design and the use of natural building materials and techniques. Students developed programmatic solutions that included, but were not limited to, workspaces, meeting rooms, multi-functional spaces based on specific user scenarios, collective production areas, recreational zones, accommodation units, administrative offices, storage, stationery, and service areas. The studio also involved designing open and semi-open spaces, as well as landscape elements that respond to the existing landscape character and production systems. To support this studio design, three faculty members with expertise in building and construction

technology, urban and environmental design, and cultural heritage, along with research assistants from related fields, co-instructed the studios. Their interdisciplinary collaboration enhanced the teaching approach and helped integrate building details and landscape design into the projects.

The social responsibility-focused architectural design studio was structured to include discussions, site visits, and analysis studies, leading to concept development based on the synthesis of these analysis studies. This was followed by a design development phase, concluding with the final product (Figure 2). Throughout each semester, social responsibility principles were clarified through lectures, readings, and follow-up discussions to provide students with a structured foundation. Additionally, students conducted comprehensive literature reviews before the site visits, analyzing conceptual frameworks, documents, and maps in detail. During the site visits, students worked in groups based on assigned analysis topics from an interdisciplinary perspective. In these visits, interviews with municipalities and non-governmental organizations were conducted, providing students with insights into the spatial and socio-cultural contexts of the area. Similar projects were examined on-site during the visits, with analyses discussed interactively among student groups.

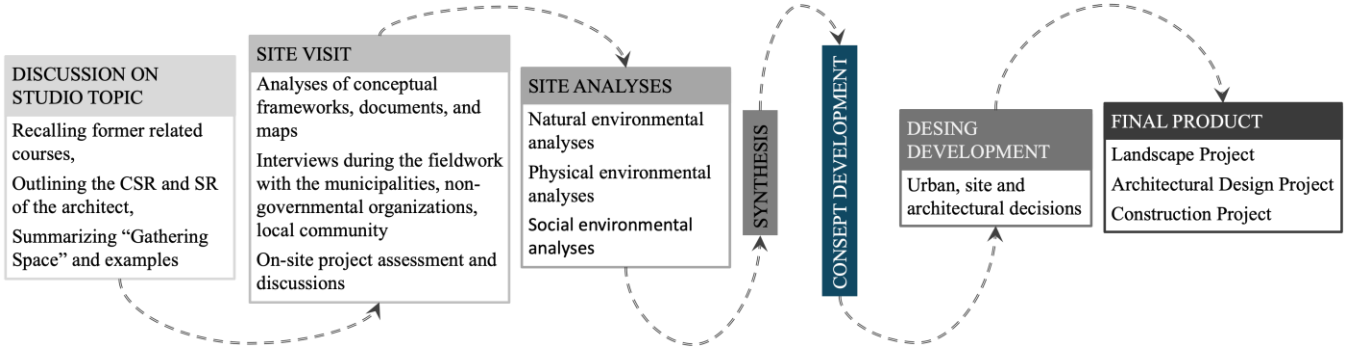

Figure 2. Phases of the social responsibility-based architectural design studio

In both the Divriği and Büyükada studios, site analyses were conducted across natural, physical, and social environment categories to understand the multi-layered character of the site. The natural environment category includes the area's physical and ecological features, from topography to environmental characteristics. The physical environment category describes the site's spatial layout and structural elements, such as street patterns, neighborhood units, building facades, architectural details, construction techniques, material use, and artisan culture. The social environment category considers historical development along with socio-economic structures, demographic distribution, cultural traditions, ethnic groups, production practices, and daily activities. These analyses were then integrated into comprehensive syntheses of the natural, physical, and social environments, serving as the basis for the concept design and guiding design decisions. Synthesis studies, which included field analysis and context assessment, were conducted using written descriptions, diagrams, visuals, collages, and models to explore the relationships uncovered through site analysis and synthesis. The spatial, social, and cultural connections that the design aims to establish with the site are communicated through a multi-layered approach that uses these visual and written narratives. Finally, students developed their concept proposals based on the synthesis findings (Figure 3 and Figure 4). Throughout this process, students received guidance to develop their conceptual frameworks grounded in principles of social responsibility and related values, which subsequently informed their design choices.

As a result, in both studios, students developed inclusive design visions rooted in local traditions of social life and architecture. They collaborated with local experts to explore vernacular techniques, which shaped their socially responsible design strategies. This process improved their understanding of traditional architecture as a means to achieve contextual and ethical design, encouraging innovative methods that combine historical knowledge with contemporary requirements. Ultimately, the studios provided a platform for students to examine the architect's role in developing resilient, site-specific environments using local and natural materials.

Figure 3. Examples of concept development from the Divriği/Sivas Studio

Figure 4. Examples of concept development from the Büyükada/İstanbul Studio.

4. Results and discussion

To examine how third-year architecture students reflected social responsibility principles in their project proposals' design concepts in two design studios, "Socially Responsible Architecture: Alternative Scenarios for Divriği" and "Social Gathering Space at Büyükada," social responsibility principles in architecture were first defined, followed by an analysis of the concept-statement texts developed by the students for their design proposals.

4.1. Defining social responsibility principles in architecture

As the first step of the study, the principles of social responsibility (SR) in architecture were identified. Although lectures were given and readings assigned in the studio to provide students with a general overview of social responsibility principles, it was necessary to systematically identify these principles to understand how much they were reflected in the design concepts. Therefore, a comprehensive literature review was conducted using the Web of Science database. For this review, a search strategy was developed to cover the "social responsibility" principles addressed in the studio, as well as the broader concept of "corporate social responsibility" and related themes from various scales and scopes that align with the studio's theme. To achieve this, keywords related to "corporate social responsibility," "social responsibility," and "design studio content" were established (Table 1).

Table 1. Keywords for the literature search.

Concepts	Keywords
Corporate social responsibility	Corporate social responsibility, Corporate social responsibility strategy, Corporate social responsibility principle, Corporate social responsibility principles, Principles of corporate social responsibility, Strategies of corporate social responsibility
Social responsibility	Social responsibility, Social responsibility strategy, Social responsibility principle, Social responsibility principles, Principles of social responsibility, Strategies of social responsibility, Social responsiveness
Design studio content	Architect, Architecture, Design, Building, Construction, Urban, Urban design, Built environment, Heritage, Cultural heritage, Sustainable, Sustainable built environment, Sustainable design, Sustainable architecture, Sustainable urban design, Sustainability, Sustainable development

The literature search was conducted in two stages to expand the range of sources collected. In the first stage, articles that included at least one "corporate social responsibility" keyword and one "design studio content" keyword were collected. Then, in the second stage, articles containing at least one "social responsibility" keyword and one "design studio content" keyword were gathered. To keep the search focused, only original research articles in the categories of "Architecture," "Construction and Building Technology," and "Urban Studies" were included, and the keywords had to appear in the title, abstract, and keywords. During the first stage, 84 articles were identified, with one excluded due to missing an abstract. In the second stage, 165 articles were identified, and six were excluded for the same reason. After removing duplicates from both stages, 158 articles remained. These articles were then analyzed using thematic analysis to identify the "social responsibility in architecture principles." The initial analysis, supported by OpenAI, was validated through manual review. As a result, eight categories of social responsibility principles were identified, as defined below.

- **(SR1) Community Development** emphasizes the support and improvement of local communities through corporate social responsibility initiatives, aiming to foster social cohesion and sustainable community growth (Xie et al., 2020).
- **(SR2) Economic Development and Poverty Reduction** highlights corporate efforts to boost economic prosperity and reduce poverty within society (Othman, 2009; Winkler, 2012; Yáñez, 2015).
- **(SR3) Education and Capacity Building** focuses on promoting education, skill development, and capacity-building programs to empower individuals and communities (Chakrabarty, 1998; Manav, 2016; Othman, 2009; Pentireddi et al., 2024; Yáñez, 2015).
- **(SR4) Environmental Responsibility** involves corporate commitments to environmental protection, sustainable resource management, and mitigation of climate change impacts (Ajibike et al., 2023; Akotia & Sackey, 2018; Chang et al., 2017; Ng et al., 2018; Pentireddi et al., 2024; Somachandra et al., 2023; Tunji-Olayeni et al., 2020; Ye et al., 2022; Zhang et al., 2024).
- **(SR5) Ethical Governance and Transparency** stresses the importance of ethical behavior, transparency, and accountability in corporate governance practices (Brunetta, 2016; Collinge, 2020; Kar & Jha, 2021; Ng et al., 2018; Pentireddi et al., 2024; Somachandra et al., 2023; Xie et al., 2020).
- **(SR6) Human Rights and Social Justice** advocates for the protection of human rights, promotion of social equity, and advancement of social justice within corporate practices (Chakrabarty, 1998, 2001; Kaatz et al., 2005; Karaca et al., 2024; Winkler, 2012).
- **(SR7) Public Health and Well-being** targets the enhancement of public health, safety, and overall well-being through corporate initiatives and programs (Ernest et al., 2022; Kaatz et al., 2005; Kar & Jha, 2021; Ng et al., 2018; Tunji-Olayeni et al., 2020; Williams et al., 2024; Xie et al., 2020).
- **(SR8) Stakeholder Engagement** involves active engagement and participation of stakeholders in corporate decision-making processes to ensure inclusiveness and responsiveness (Collinge, 2020; Kaatz et al., 2005).

4.2. Analyzing design concept-statements

After defining the social responsibility principles in architecture, students' concept-statement texts from two design studios, "Socially Responsible Architecture: Alternative Scenarios for Divriği" (Divriği/Sivas) and "Social Gathering Space at Büyükada" (Büyükada/İstanbul), were analyzed to identify keywords they used to reflect social responsibility principles in their projects. For the Divriği/Sivas studio, one project lacked a concept statement and was excluded, resulting in an analysis of 30 projects; for the Büyükada/İstanbul studio, one project without a concept statement was similarly excluded, resulting in 45 projects for analysis. The selected concept statements were then subjected to thematic analysis to extract all keywords related to the predefined principles (Table 2 and Table 3). Throughout this process, manual coding was complemented by OpenAI-assisted validation to improve the accuracy and depth of the findings.

In the Divriği/Sivas studio, students' concept statements covered a range of keywords, most of which related to "(SR1) Community Development," followed in descending order by "(SR4) Environmental Responsibility," "(SR3) Education and Capacity Building," "(SR2) Economic Development and Poverty Reduction," "(SR6) Human Rights and Social Justice," and "(SR7) Public Health and Well-being" principles. On the other hand, the keywords associated with "(SR8) Stakeholder Engagement" and "(SR5) Ethical Governance and Transparency" were more limited. When the concepts developed for the Divriği/Sivas studio were further analyzed, it was evident that elements such as urban memory, production culture, and social interaction were central, and the designs were organized around five main themes. The first theme emphasizes reviving craft and handicraft culture, revitalizing traditional forms of production like carpet making, motif processing, and woodworking through modern reinterpretations. The second theme, rural gastronomy and natural health, highlights community-based kitchens and therapeutic spaces utilizing local herbs, traditional recipes, and alternative treatment methods. The third theme focuses on preserving cultural heritage, including minstrelsy, square dances, and the representation of local musical traditions in public spaces. The fourth theme promotes social meetings and sharing spaces that support rural socialization through public markets, squares, and interaction areas. Lastly, a climate-sensitive and culture-bound architectural approach has emerged by reinterpreting local materials, such as adobe, stone, wood, and rammed earth, using modern building techniques. Therefore, the thematic analysis highlights Divriği's rural characteristics, where priorities focus on fostering community cohesion through economic and educational initiatives, respecting local building traditions, and preserving cultural identity, resulting in a strong emphasis on community and environment-related principles.

In the Büyükada/İstanbul studio, students' concept statements mainly focus on keywords aligned with "(SR1) Community Development" and "(SR4) Environmental Responsibility," followed by "(SR3) Education and Capacity Building" principles. Then, this was followed by "(SR6) Human Rights and Social Justice," "(SR7) Public Health and Well-being," and "(SR2) Economic Development and Poverty Reduction" principles. On the other hand, none of the students included keywords related to "(SR8) Stakeholder Engagement." Further analysis of the concepts reveals four main themes that holistically address the island's natural, cultural, and social fabric. First, the idea of living in harmony with nature is emphasized through elements such as local flora, olive groves, flowers, forest textures, and aromatic plants, supported by sustainable building techniques and the use of natural materials. Second, social participation and inclusiveness are expressed through spaces dedicated to collective production, gastronomy, art, and learning areas that prioritize multicultural island identity and social justice. The third theme focuses on revitalizing cultural heritage by creating new narratives through elements like island memory, literature, music history, and craft traditions. Lastly, sensory and experiential spatial designs aim to deepen individuals' connection to space through festivals, interactive experiences, and designs that engage all five senses. Overall, the pattern gathered from the thematic analysis highlights Büyükada's rich natural and architectural heritage, encouraging projects that foster community cohesion, environmental responsibility, and learning through built interventions. Additionally, its well-established economic base, governance structures, and social-health frameworks may have led students to assume that stakeholder collaboration and ethical transparency mechanisms are already in place and thus require less attention.

Table 2. Keywords gathered from the Divriği/Sivas studio design concepts.

SR Principles	Reflected Keywords
(SR1) Community Development	active open area, activity square, amphitheater, areas for families, children, young people, bring people together, celebrate, chatting, come together, cultures brought together, exhibition areas, games offered by local people, gardening, gathering area, gathering space, green areas, introduce bees and products, keep culture alive, market, meeting, meeting areas, musical cafes, network to producers, open spaces, people gather around folk music, people of all ages, people produce together, place for wood hobby, playgrounds, preservation of memory, public forums, public space, resting, seed swaps, semi-open bazaar, sense of community, share, shared place for everyone, social events, socialization, socialize, spend time together, square, walking, weaving
(SR2) Economic Development and Poverty Reduction	Divkoop market, herbal markets selling plants, herbalist-cafe selling plants, bazaar, cafe, restaurant, commercial return, community-based tourism, earn money, efficient operations, exhibit and sell, exhibition area, exported to surrounding provinces, increase income sources, market, exhibition section, market produced works, marketing and promotion building, marketing by regular events, online sales, organic cafe, sales unit, sell own products, semi-outdoor seating, shop building
(SR3) Education and Capacity Building	adobe workshops, apitherapy applications, classes, creativity training, decor workshops, design workshop, dyeing workshop, education meetings, hydrotherapy, instructive area for formation process, interactive education, learning by cooking, master-apprentice training, meditation/yoga halls, museum-promotion-education, musical workshops, musicotherapy, organic production workshop, phytotherapy, specialized workshops, spinning, studios, technology workshop, therapy studios, trainings, weaving workshop, wood workshop, workshops
(SR4) Environmental Responsibility	adobe, adobe and wood facade, adobe blocks, andesite stone masonry, breathable walls, climatic conditions, cordwood technique, wood structure, laminated wood system, laminated wooden beams, landscape elements, materials specific to natural region, natural materials, natural stone, natural stone masonry, rammed earth, rammed earth walls, stone masonry, sustainability, traditional construction techniques, wood, wood columns and flooring, wood construction techniques, wood structural system, wooden facade, wooden floors, wooden structure
(SR5) Ethical Governance and Transparency	less bureaucracy
(SR6) Human Rights and Social Justice	accessibility, accessibility of all people, appeal to all ages, disabled access, elderly knowledge transfer, inclusive design, inclusive design idea, inclusive design principle, inclusive design principles, inclusive user definition, inclusive user profile, people from all groups, people of all ages, genders and genres, same level access, wide target audience
(SR7) Public Health and Well-being	apitherapy, aroma therapy, care applications, collective meditation, hydrotherapy, massage, massage parlor, music relaxes people, psychological and spiritual health, relax with alternative activity, spa, stress relief
(SR8) Stakeholder Engagement	games offered by local people, invited to event, socially responsible architects

Then, the content analysis method was employed to determine how frequently students' concept statements referenced each principle of social responsibility in architecture. This was based on the ratio of students in the studio referencing each concept, using keywords gathered from the thematic analysis. The reflections of social responsibility principles in the design concepts of Divriği/Sivas and Büyükada/İstanbul studios are interpreted according to the site contexts as follows (Figure 5):

Table 3. Keywords gathered from the Büyükada/İstanbul studio design concepts.

SR Principles	Reflected Keywords
(SR1) Community Development	activities, activities and awareness, activity areas, botanical mock-up area, bring people together of all age groups, bring people together through art, bring societies together, city tours, closed spaces, collaborative discussions, come together, common gathering area, communal learning, communal spaces, community center, community connection, community engagement, community kitchen, cultural exchange, cultural protection, ease of gathering, events, olive harvest, exchange ideas, festival, festival area, flowers, cultural play, forest-specific activities, garden gatherings, gather and express thoughts and ideas, gather people, gather people of all ages, genders, cultures, gathering center, gathering space, gatherings, gathers people with music, inclusive space, interaction with people, interactive setting, involve local community, maintain heritage, make, share and eat foods, memorial forest, modernize weaving culture, open air market, open spaces, open-air concert area, participant activities, platform for artistic expressions, popular area by people, private gardens, produce together, provide occupation, relax, rest, restaurant, semi-open spaces, sense of pride and continuity, share experiences, share observations, social gathering area, social interaction, square, strengthens community ties, tea parties, unite community, vibrant atmosphere, workshops
(SR2) Economic Development and Poverty Reduction	employment environment, jam, production, and sale of pet food, products from resin, recycling, syrup, sell here
(SR3) Education and Capacity Building	activity areas, archive library, aromatherapy, art and cooking workshop, art therapy, atelier, botanical cosmetics workshops, collaborative visual arts-based activities, collective kitchen, community kitchen, cooking workshops, culinary workshops, design, education on health benefits, drama therapy, educational component, educational programs, exhibition areas, exhibitions, greenhouse, interactive, interactive cooking sessions, interactive reading experiences, literary-related activities, live performances, market, meeting hall, multi-purpose hall, music sessions therapy, painting therapy, participatory production atelier, participatory workshops, production, production studios, published magazines, selling block, seminar, therapy, tissue culture lab, training, training and application areas, virtual events, weaving workshops, workshop areas, workshops, workshops crafting essences
(SR4) Environmental Responsibility	oak wood, active green area, biodiversity, building techniques, cordwood, glass brick, green energy, green texture for open and semi-open events, harmony with planet, hemp, hybrid construction, masonry stone, hybrid structure, irrigation canals, masonry, masonry stone, masonry walls, natural building techniques, natural landscapes, natural materials, natural stone and wood, rain gardens, rain harvesting, rammed earth, recyclable materials, recycling, renewable energy, roof extensions, rubble stone walls, slip straw walls, solar and wind analyses, stacked stone, stone, stone and wood, stone and wood carriers, stone masonry, sustainability, sustainable agriculture, sustainable living, sustainable rammed earth, sustainable wooden construction methods, timber, timber frame, traditional construction techniques, traditional facade cladding, traditional wood, traditional wood and masonry, traditional wood methods, traditional wooden frame, traditional wooden methods, traditional wooden structure with openings, traditional wooden walls, upcycle, wood, wood and stone, wood and stone masonry, wooden construction, wooden structure
(SR5) Ethical Governance and Transparency	cultural cooperative, collaborative discussion
(SR6) Human Rights and Social Justice	accessibility, accessibility and convenience for all people, accessibility for diverse communities, accessibility of all people, accessible to all, accessible to everyone, barrier-free area appealing to all, catering to all age groups and abilities, disabled, inclusive, inclusive design, inclusive structure, inclusivity
(SR7) Public Health and Well-being	emotional well-being, felinotherapy, mental and physical well-being, psychological health, relaxing feature, therapeutic activities, therapies
(SR8) Stakeholder Engagement	-

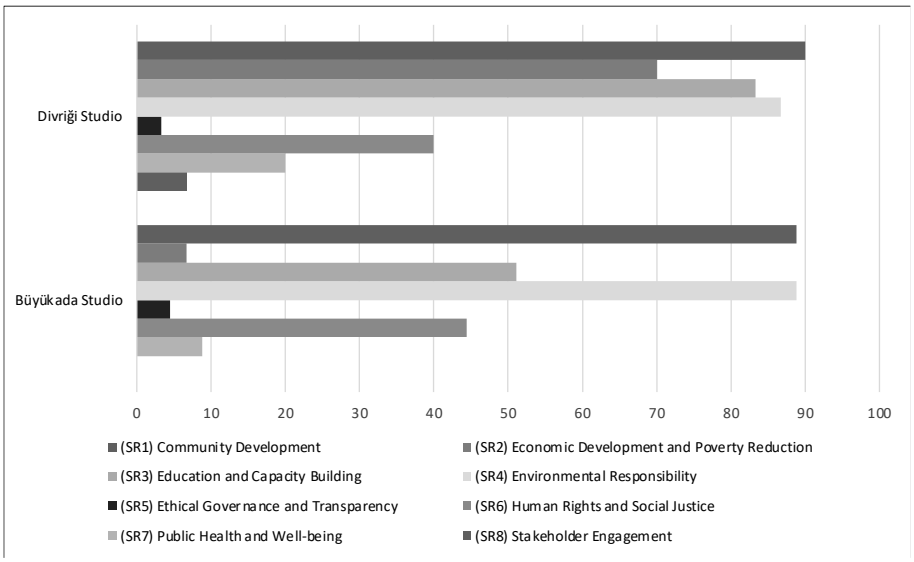

Figure 5. Reflections of social responsibility principles in the Divriği/Sivas and Büyükada/İstanbul studios.

In the Divriği/Sivas studio, students primarily focused on "(SR1) Community Development" (90%) principle, followed by "(SR4) Environmental Responsibility" (87%), "(SR3) Education and Capacity Building" (83%), and "(SR2) Economic Development and Poverty Reduction" (70%) principles with higher rates. On the other hand, while 40% of students addressed "(SR6) Human Rights and Social Justice," only 20% dealt with "(SR7) Public Health and Well-being." "(SR8) Stakeholder Engagement" (7%) and "(SR5) Ethical Governance and Transparency" (4%) received the least interest. Since Divriği has a rural context enriched by its cultural characteristics, nature, local traditions, building practices, as well as its demographic conditions, the interpretations of the design concepts related to the social responsibility principles in architecture make sense. Although elements of community participation were integrated into other principles, they were rarely addressed as a standalone focus in the design concepts. Similarly, issues related to ethics, governance, and transparency were not highlighted as separate themes.

In the Büyükada/İstanbul studio, students placed equal emphasis on "(SR1) Community Development" and "(SR4) Environmental Responsibility," with each reflected by 89% of the students. The students also paid moderate attention to "(SR3) Education and Capacity Building (51%)" and "(SR6) Human Rights and Social Justice (44%)." In contrast, "(SR7) Public Health and Well-being (9%)," "(SR2) Economic Development and Poverty Reduction (7%)," and "(SR5) Ethical Governance and Transparency (4%)" received less focus. None of the students addressed "(SR8) Stakeholder Engagement." This pattern reflects Büyükada's strong traditions of community participation, communal living, and daily cultural practices, along with its educated population, which most clearly influence approaches to social justice and capacity building. Conversely, the island's vibrant tourism-driven economy, proximity to the urban periphery, and well-established public health and governance practices seem to lessen the focus on other principles.

When the students' approaches to their design concepts were interpreted in both studios, it can be argued that regional characteristics and their initial analyses directly influenced the outcomes. Students drew inspiration not only from analyses of the natural, physical, and social environments, where they examined the existing urban fabric, but also from historical studies of the project areas. These studies supported their understanding of social responsibility principles and enabled the development of context-sensitive solutions within this perspective.

Then, the reflections of social responsibility principles in design concepts for Divriği/Sivas and Büyükada/İstanbul studios were compared and interpreted for each principle as follows (Figure 6):

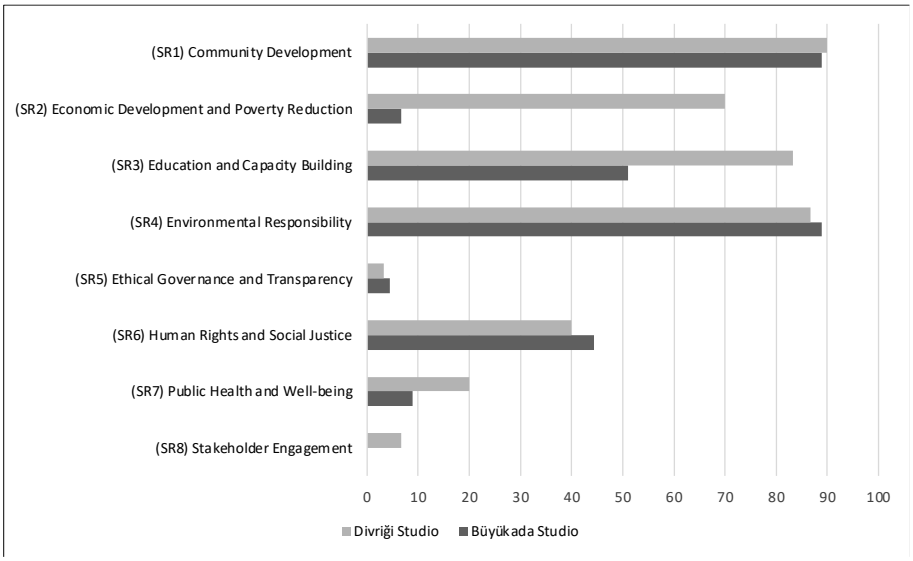

Figure 6. Comparison of social responsibility principles in the Divriği/Sivas and Büyükada/Istanbul studios.

The "(SR1) Community Development" principle was incorporated into the design concepts by 90% of students in the Divriği/Sivas studio and 89% in the Büyükada/Istanbul studio. These high and nearly identical rates suggest that the studio's core theme of "gathering space" significantly influences the focus on developing and sustaining the local community. In both studios, students employed similar concepts (see Table 2 and Table 2) to highlight gathering opportunities at various scales and within different functional frameworks.

The "(SR2) Economic Development and Poverty Reduction" principle was a focus for 70% of students in the Divriği/Sivas studio, while only 7% of students in the Büyükada/Istanbul studio addressed it. This difference is attributed to the different rural-urban dynamics and economic development levels in the two project sites. In their design concepts, Divriği/Sivas students proposed solutions focused on local production and the economic circulation of locally made goods. In contrast, Büyükada/Istanbul students concentrated on issues like the labor environment and recycling.

The "(SR3) Education and Capacity Building" principle was most emphasized in the Divriği/Sivas studio, with 83% of students focusing on it. In comparison, 51% of students emphasized this principle in the Büyükada/Istanbul studio. Although students used more detailed keywords in the Büyükada/Istanbul studio to reflect this principle than those in the Divriği/Sivas studio (see Table 2 and Table 3), rural-urban dynamics significantly influence this outcome. Students' focus on incorporating site-specific cultural richness and natural resources into their projects as a means of education and capacity building, rather than solely for economic purposes, explains this result.

The "(SR4) Environmental Responsibility" principle was addressed by 87% of students in the Divriği/Sivas studio and 89% of students in the Büyükada/Istanbul studio. The natural environmental conditions of both project areas and sustainable construction practices that focus on using local materials were prominently integrated into the design concepts as part of this principle.

The "(SR5) Ethical Governance and Transparency" principle was reflected by 3% of students in the Divriği/Sivas studio and 54 students in the Büyükada/Istanbul studio. Although they met with local officials and community members during fieldwork and received feedback, the design concept proposals did not reflect this principle.

The "(SR6) Human Rights and Social Justice" principle was similarly addressed by students, with 40% of those in the Divriği/Sivas studio and 44% in the Büyükada/İstanbul studio incorporating it into their design concepts. They achieved this by embedding accessible and inclusive design strategies, adopting a universal approach to accommodate all ages and ability levels.

The "(SR7) Public Health and Well-being" principle was primarily emphasized in the Divriği/Sivas studio by 20% of the students, while 9% focused on it in the Büyükada/İstanbul studio. Although Divriği's healing traditions and the historic buildings associated with them can serve as sources of inspiration for students, it can be said that, in Büyükada, the opportunities and potential offered by the natural environment were only reflected to a limited extent in the design concepts.

The "(SR8) Stakeholder Engagement" is addressed by only 7% of students in the Divriği/Sivas studio and by none of the students in the Büyükada/İstanbul studio. Regarding the design-concept approaches developed by students, it can be interpreted that this principle was related to other principles, mainly in "(SR1) Community Development," rather than being treated as a separate focus.

5. Conclusion

This study examines how social responsibility principles can be incorporated into architectural design studio education through site-specific contexts characterized by vernacular and cultural qualities. By analyzing students' concept statement texts from two geographically and contextually distinct studios, the research explores how design thinking evolves under different local dynamics. First, eight core social responsibility principles were identified through a systematic literature review and thematic analysis, creating a structured framework for evaluating students' design concepts. Applying this framework to the Divriği/Sivas and Büyükada/İstanbul studios revealed both overlapping and site-specific patterns within the social responsibility framework. In both contexts, "Community Development" and "Environmental Responsibility" emerged as the most frequently referenced principles, highlighting social cohesion and ecological awareness. However, significant differences appeared in "Economic Development" and "Public Health and Well-being," with Divriği's rural character encouraging deeper engagement with local production and healing traditions, while Büyükada's urban-touristic environment resulted in more modest attention. On the other hand, "Ethical Governance" and "Stakeholder Engagement" were the least addressed principles, indicating a need for greater emphasis on participatory and transparent processes within studio content.

The findings highlight the importance of incorporating social responsibility principles into architectural design education to enhance students' ethical awareness, contextual understanding, and inclusive design thinking. The studio provided a comprehensive framework that integrated context-specific, research-based, and interdisciplinary approaches for embedding social responsibility principles into architectural design education. Results also suggest that introducing social responsibility in the early stages of design process can shape students' conceptual thinking, affecting both creative ideas and critical assessments. Differences observed between studio outcomes further highlight the need to tailor social responsibility education to particular social, economic, and environmental contexts. Through engagement with diverse geographic and cultural settings, students gained a deeper understanding of architecture as a practice influenced by local traditions, environmental conditions, and social dynamics. This experience fostered critical thinking, collaborative exploration, and the capacity to translate complex analyses into meaningful design solutions. Ultimately, the studio served as a pedagogical model illustrating the architect's growing responsibility to address today's societal challenges through inclusive, sustainable, and culturally aware design strategies. Overall, these results support the main idea of the study: that embedding social responsibility principles into architectural education improves students' ability to approach complex design issues ethically, contextually, and inclusively. By providing a comparative view based on two distinct environments, the study shows how a structured social responsibility framework can influence both conceptual development and spatial strategies in student work. In this way, it enriches current architectural education literature by introducing a thematic and evaluative model that connects early design thinking with broader social, environmental, and ethical responsibilities.

Building on these insights, this study contributes to architectural education by proposing a thematic approach to assess how social responsibility principles can be integrated into design studio pedagogy. Through the integrated application of thematic and content analysis, it provides a replicable framework that educators can adapt to evaluate student outcomes. While the findings are based on a specific institutional and cultural context, the methodological framework and educational strategies developed

in the studio offer transferable insights for other architectural education settings, especially those focusing on vernacular heritage, sustainability, and ethical design. The comparative analysis of distinct geographic and cultural sites further illustrates how local conditions influence students' engagement with social responsibility, emphasizing the importance of context-responsive pedagogy. These findings aim to help educators and curriculum developers better embed ethical, cultural, and environmental themes into architectural design education, guiding future teaching strategies and studio practices. Future research should expand this approach to additional pedagogical settings, include tracking students' design-thinking development, and examine the effects of explicit instruction in underrepresented principles like governance and stakeholder engagement. Ultimately, systematically incorporating social responsibility into the architectural design education curriculum can help develop practitioners who are technically skilled, creatively driven, and highly conscious of their social and environmental responsibilities.

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Natural Solutions to Combat Urban Heat and Noise Islands: Investigation of Earth-Sheltered Buildings, Green Roofs and Urban Plantations

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A B S T R A C T

This review article presents a structured set of building and city-scale solutions that simultaneously mitigate the impacts of Urban Heat Island (UHI) and Urban Noise Island (UNI). 61 peer-reviewed articles published between 1981 and 2025, were examined in terms of their thermal and acoustic performances. Articles were selected by systematic keyword searches in databases with defined inclusion/exclusion criteria. In the article, building-scale strategies like green roofs, green walls, earth-sheltered buildings and blue-green infrastructures such as parks, forests, rain gardens, water bodies were considered together. According to quantitative data, green roofs and green walls can reduce surface temperatures by up to 26.9°C, indoor air temperatures by up to 11.3°C, and urban noise by 9.5 dB. When afforestation is added to these strategies, air temperatures in densely populated urban areas can be reduced by 5.48%. In addition to environmental benefits, nature-based solutions also have benefits related to energy efficiency, urban aesthetics, and public health. This study highlights research gaps and problems encountered in practice with a new dual-focus approach and offers suggestions for future studies. At the same time, it contributes to a framework that supports science-based, scalable urban planning approaches by bringing together thermal and acoustic benefits in a new synthesis.

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1. Introduction

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Today's cities require resilient designs that offer solutions to environmental problems at urban and building scales. UHI and UNI often occur simultaneously in the same place and negatively affect human health and comfort. Although UHI and UNI originate from different causes, they are affected by common variables such as existing land cover, structure, and the intensity of anthropogenic activities. The joint impact of these two problems reveals the importance of integrated mitigation strategies.

UHI, a significant environmental problem that exists in many metropolitan areas of the world, refers to the higher urban ambient temperature relative to the nearby undeveloped rural regions.UHI formation is directly related to climate change and global warming (Zinci & Santamouris, 2019). While anthropogenic activities, large thermal masses of buildings, low evaporation and low wind speed, and increased atmospheric pollution are the main sources of the UHI (He, 2019), motor vehicle use, increasing construction areas, and the decreasing green areas have significant contributions to this formation.

As a result of man-made noise caused by increasing population density in urban centers (Pijanowski et al., 2011), dense and high-rise construction, and increased traffic congestion (Yuan et al., 2019), city centers become noisier than surrounding rural areas. According to recent studies, a relationship has been found between UNI and preeclampsia (Auger et al., 2018), sleep problems (Douglas & Murphy, 2016),and the risk of stress-related cardiovascular disease (Moudon, 2009).

Figure 1 depicts a conceptual scheme summarizing the reasons why these two problems often occur together and simultaneously. Although UHI and UNI have separate causes, they share same underlying factors such as high-density construction, the use of impermeable surfaces such as asphalt and hard concrete in urban centers, and the lack of green-blue infrastructure. This overlap between the concepts emphasizes the suitability of holistic strategies rather than intervening in problems separately.

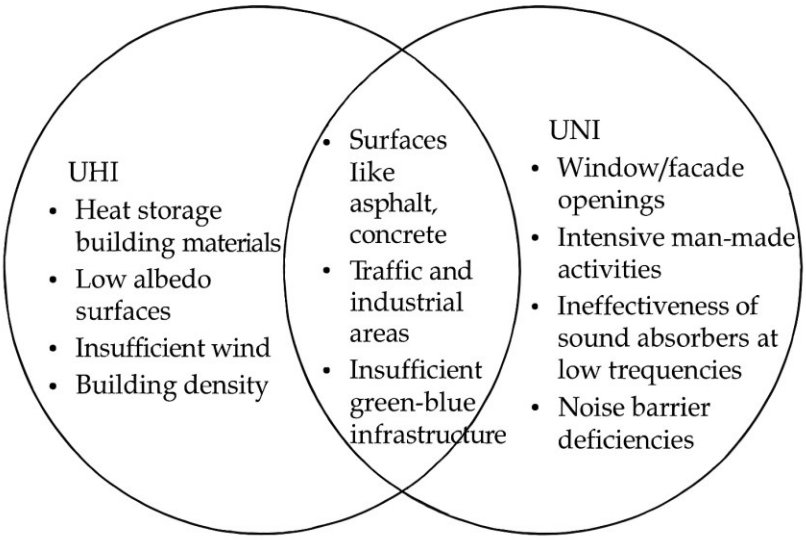

Figure 1. Conceptual scheme of UHI and UNI formation (Author, 2025).

While The Paris Agreement, aims to keep global warming below 2 ◦C, it has been recorded that central temperatures in many large cities are 2-5 ◦C, and in some extreme cases 12 ◦C higher than surrounding rural areas (He, 2019; Zinzi & Agnoli, 2012). UHI, not only increase energy and water consumption but also brings health risks related to the vulnerable populations (He, 2019). In 2003, nearly 70,000 deaths in Europe were associated with rising temperatures, and such data reveal the need for urgent intervention in UHI formation (Mitchell et al., 2016).

Since buildings, which cover the largest area in cities, are the main cause of high temperatures in city centers, measures to be taken in building envelopes are of special importance in UHI mitigation (He, 2019; He et al., 2019; Zhao et al., 2017). It is possible to change the albedo of city surfaces by using materials that have higher solar reflectivity (albedo) and high infrared heat emission capacity instead of using traditional materials (Santamouris et al., 2008; Synnefa et al., 2007). The use of innovative materials

and implementations in building facades and pavement surfaces to mitigate the UHI effect presents significant opportunities for sustainable and resilient urban design.

Although UNI is often controlled by using high sound absorbing materials in building envelopes, especially low frequency noise control is quite difficult. The use of acoustic metamaterials, which are still in the research phase for the control of low-frequency sounds, is quite limited due to their low efficiency, high cost and unsuitability for mass production (Kumar & Lee, 2019). Since highly reflective materials generally have low sound absorption capacity, it is possible to mitigate the UHI and UNI separately with the building envelope materials to be selected, but creating dual functional smart surface designs that mitigate both environmental problems at the same time brings with it significant challenges. However, there are also natural and innovative solutions that can mitigate both problems. Green roofs, green walls and earth sheltered buildings may simultaneously mitigate UHI and UNI.

Today, three different strategies are followed to reduce noise: reducing noise at the source, reducing it in the propagation path, and reducing it at the receiver (Bellucci et al., 2023).According to the United Nations and Environment Directives update prepared by the World Health Organization, traffic-related noise should be less than 53 dB during the day and 45 dB at night for human health.

The dangerous process that the whole world is facing with the COVID-19 pandemic has revealed that the comfort of life in public areas needs to be re-evaluated in many areas, and today it emphasises the importance of controlling UHI and UNI together.

Research Questions

(1) What are the building and city-scale strategies that can simultaneously mitigate UHI and UNI?

(2) How can these strategies be integrated into building envelopes and urban designs to increase thermal and acoustic comfort?

UHI and UNI, which were generally addressed separately in previous studies, are addressed simultaneously in this study, filling an important literature gap and offering a single, nature-based and scalable approach to these problems. This study is divided into three logical sections. In the first section, measures to be taken at the city scale for UHI and UNI mitigation are discussed, in the second section, measures at the building scale are explained. In the third section, the results of the study and its contributions to the field are discussed.

2. Methodology

There are sufficient studies on UHI mitigation, but the studies on UNI mitigation are relatively limited. The number of studies that address the solution of both environmental problems simultaneously is extremely limited. This review article aims to fill the gap in the literature by systematically addressing solutions that address both environmental problems within the framework of nature-based strategies. Table 1 depicts the database, keywords, and inclusion criteria for the article, with the aim of ensuring transparency and repeatability of the study.

Within the scope of the study, priority was given to English publications that simultaneously focused on UHI and UNI problems, addressed nature-based sustainable approaches, and were published especially in the last fifteen years, and were peer-reviewed. Google Scholar was chosen as the main search engine because it includes peer-reviewed, scientifically reliable publications and grey literature. Keyword combinations were determined by taking into account their frequency of use in previous publications in the literature.

Two separate search strings consisting of different keyword combinations were used for UHI and UNI. The studies identified in the first stage were filtered using abstracts, full texts, and prospective snowball scanning. Quantitative results in studies on temperature and noise reduction were compared in ◦C and dB units. Studies that did not include quantitative result data or were unclear in their methods were not included in the study. In the final evaluation, 47 UHI and 14 UNI articles were selected. Three studies addressing both issues simultaneously were included in the UHI. The inclusion criteria for the study were as follows;

(1) Type of study (compilation, experimental, observational)

(2) Language of the article (English)

(3) Date of publication (1981-2025)

Table 1. Followed methodology of the research.

SCOPING OF LITERATURE	
UHI SEARCH	**UNI SEARCH**
("urban heat island" OR "urban overheating") AND ("mitigation" OR "natural solutions" OR "forests" OR "Miyawaki" OR "landscape" OR "green space" OR "urban planning" OR "parks" OR "cool surfaces" OR "tree" OR "urban farming" OR "water bodies" OR "cool roofs" OR "green roofs" OR "vegetation" OR "green infrastructure" OR " green wall " OR "vertical garden" OR " earth sheltered" OR "earth bermed" OR "underground building")	("urban boise island" OR "noise pllution") AND (" mitigation" OR "natural solutions" OR "noise absorption" OR " sound absorption" OR " transmission loss" OR "forests" OR "Miyawaki" OR "landscape" OR " green space" OR " urban planning" OR " parks OR " porous surfaces" OR "green roofs" OR "vegetation" OR " green infra structure" OR "green wall" OR "vertical garden" OR "earth sheltered" OR " earth bermed" OR "underground building")
SERACH ENGINES	
Google scholar	Google scholar
CRITERIA	
1. Type of the study, 2. Language of the study, 3. Date of the study (last 5 years priority)	
520	405
ABSTRACT SCREENING	
469	354
MANUSCRIPT SCREENING	
65	33
SNOWBALL SCREENING (exclusion)	
18	19
FINAL SELECTION	
47	14

The study was structured in accordance with the method followed in the literature research. Figure 2 summarizes the typology of strategies investigated in this study, categorized according to scale and function. Miyawaki forests, parks, water bodies, green roofs, green walls, earth sheltered buildings under these categories were discussed in terms of their potential to mitigate UHI and UNI. In this study, "dual-function strategies" are used to describe materials and practices that provide holistic environmental benefits by simultaneously mitigating UHI and UNI problems. Among many possible strategies, earth sheltered buildings, which are reported in the literature to provide dual benefits regarding heat and noise control, were included in the study. Cool pavements or cool building envelope materials at the urban scale were excluded because they were not nature-based.

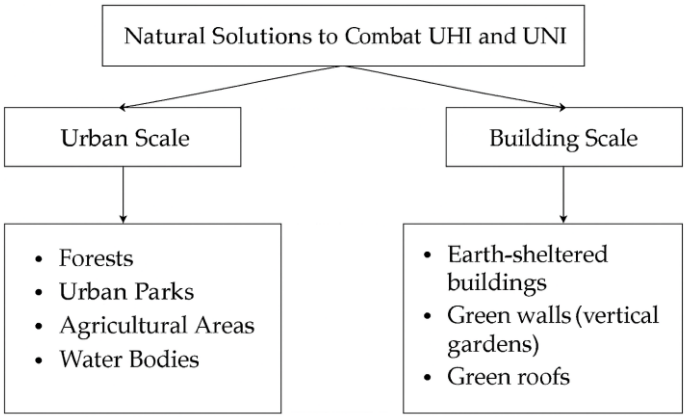

Figure 2. Classification of nature-based solutions at the urban and building scale.

Since this review article consists of peer-reviewed English publications, studies in other languages may have been overlooked. Additionally, studies without quantitative data were not taken into account, so there may be gaps in qualitative findings.

3. Urban scale solutions

3.1. Forests, parks and agricultural areas

UHI effect can be reduced by fragmenting impermeable surfaces and bare lands in city centers (Sun et al., 2022). Urban green areas consist of forests, parks and agricultural areas of various sizes. The association between UHI and urban landscape has been examined in different seasons in cities of different sizes using Landsat data. Many studies have shown that UHI density varies according to the size of common green areas in the city (Maimaitiyiming et al., 2014), and that generally clustered and large green areas are more efficient in reducing UHI than small and fragmented ones (Chang et al., 2007; Dugord et al., 2014). Therefore, large landscape areas in cities offer important opportunities to mitigate UHI impacts at the city scale. Large forested areas mitigate the UHI effect through shading, evaporation and carbon sequestration while also reducing carbon emissions by diminishing the quantity of cooling energy (Akbari et al., 2001). However, the type of vegetation or trees in large green areas plays a major role in UHI efficiency. In general, choosing trees with high shading in afforestation always gives better results (Sun et al., 2022).

Ziter and friends (Ziter et al., 2019) conducted a research in Madison, a city with a population of 255,000 in the United States, in 2016. In this research, they investigated the effect of the association between tree canopy cover and hard, waterproof surfaces on air temperature in the summer months. According to the results, daytime air temperature varied by 3.5 °C depending on the distribution of urban landscape regions. Furthermore, the tree canopy effect reached the highest cooling efficiency when the vegetation cover exceeded 40%. The greatest cooling effect was obtained in the 60-90 meter radius. In 2020, a study was conducted by Arulbalaji and his colleagues (Arulbalaji et al., 2020) in the Akkulan-Veli Lake basin of India. Between 1988 and 2019, the built-up areas in the study area increased from 10 km^2 to 68 km^2, while the vegetation cover decreased from 125 km^2 to 71 km^2. As a result, it was observed that the average land surface temperature increased from 26.5 °C to 28.1 °C. The results of this study underline the requirement to increase green areas to reduce UHI effect caused by rapid urbanization.

Miyawaki forests are of particular importance when it comes to UHI. Introduced by Japanese botanist Akira about four decades ago, Miyawaki forests offer an effective and rapid solution for climate change. The selected tree species are planted in a very dense and mixed manner. After fertilization and weeding for three years after planting, a self-sufficient Miyawaki forest is formed that does not require any further maintenance for 20-30 years (Miyawaki, 2004). In this method, local trees and vegetation are researched, and the most suitable species for the region are selected for planting. Miniature forests created in narrow areas with the Miyawaki method can be planted even in strips if needed (Miyawaki, 2008). Since they can be created in very narrow areas in dense forms, it is possible to establish them in domestic and commercial areas in the city. Another feature of Miyawaki local forests is that they are multi-layered. They consist of moss, herbaceous layer, shrub, lower tree and upper tree layers, respectively (Miyawaki, 2014). Figure 3 shows the layers of the Miyawaki forests. Maintenance-free Miyawaki forests are the fastest solution for mitigating UHI and UNI effects at the same time.

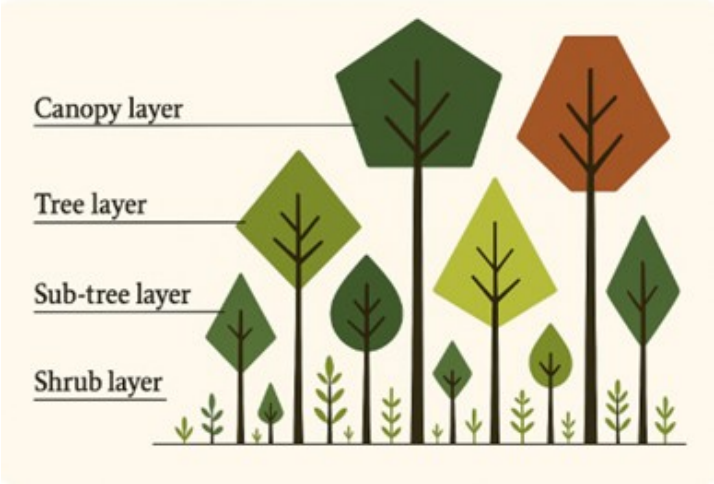

Figure 3. Layers of miyawaki forest

Apart from forests, other green areas at the city scale are parks and agricultural lands. Investigations on the UHI mitigation influence of city parks have shown that efficiency varies according to the types of plants and trees used in parks, the shape of the parks, the area they cover and the altitude within the city. It has been reported that the heat mitigation impact of irregularly shaped and linear parks is lower than that of compactly shaped parks. However, the heat island mitigation effect increases with the increase in area. Eucalyptus, Olea, and, to some extent, Acacia trees have been found to be more effective in heat mitigation than Cupressus and Grevillea trees. Based on this research, it can be inferred that the UHI effect can be decreased by carefully selecting the trees and plants used and optimizing the size and form of the parks (Feyisa et al., 2014). Various scale agricultural activities taking place in cities are called urban agriculture, and in addition to providing food, these irrigated lands have the capacity to change the urban climate.

Green infrastructure like forests, parks and agricultural lands also help to mitigate UNI by absorbing sound, creating physical barriers and preventing sound from spreading by regulating airflow. In a study conducted in southern Canada in 2022 (Gaudon et al., 2022) the effects of seasonal differences and frequency on sound insulation were investigated in temperate forest, tall grass meadow and agricultural land areas. The study was conducted at frequencies of 250 Hz, 500 Hz and 1000 Hz in summer, autumn and winter. The findings of the study revealed that noise absorption was affected by season, terrain characteristics and sound frequency. While forest and shrub areas showed significant performance in sound absorption, tall grass meadows also contributed to noise control.

3.2. Water bodies

Water bodies cool the air by evaporation. In this way, they absorb heat and remove it from the environment (Khare et al., 2021). It may be possible to mitigate the ambient temperature by 2-6 ◦C through heat flow among the surrounding air and the water surface (Khare et al., 2021; Manteghi et al., 2015). Lakes, rivers, streams, pools, water channels, and artificial lakes are natural and artificial water sources found in cities. The temperature-reducing effects of water bodies vary according to size, form, environmental land use, climate conditions and local vegetation. Urban water bodies can reduce air temperatures through mechanisms such as evaporation, air flow regulation, and shading effects through reflection. The use of blue infrastructure together with green regions increases UHI mitigation efficiency. Generally, large and regular-shaped water bodies show higher performance (Jandaghian & Colombo, 2024).

The presence of hard and impermeable surfaces, such as concrete near water bodies reduces the UHI mitigation effect. Water bodies that perform well in hot and dry climates due to higher evaporation may have a heating effect at night, particularly in the end of summer. Long-term studies on water bodies in different seasons are needed. Moreover, the effects of the cooling effect provided by water bodies in extremely hot weather on the health and well-being of vulnerable populations, especially the elderly and infants, should be examined (Jandaghian & Colombo, 2024). How cities are designed at the

urban scale affects their climate. Therefore, it is possible to mitigate UHI by using smart urban design principles (Sun et al., 2022). In the redesign of the Transvaal neighbourhood of Rotterdam, Netherlands, seasonal water was used to water trees. Using permeable pavements together with water storage areas is a useful strategy to prevent flooding and drought. By storing rainwater in channels, trees provide maximum cooling and contribute to UHI mitigation (Kleerekoper et al., 2012). Additionally, in addition to their major role in controlling urban water cycles, rain gardens also contribute to UHI mitigation by increasing urban evaporation. A study conducted in Gdansk, Poland, investigated the relationship between rain gardens and UHI mitigation. The research found that rain garden surface temperatures were 7°C lower than surrounding pavement and asphalt surfaces on cloudy days and 20°C lower on sunny days (Kasprzyk et al., 2022).

In the event of UNI, researche has shown that the sound of moving water bodies can mask loud and unwanted noises, such as airplane noise, by creating a more powerful noise source. With successful planning, vegetation used in conjunction with a moving water source can be used to improve the acoustic environment of residential and commercial areas where noise intensity varies (Lugten et al., 2018).

As a result, parks, agricultural areas and water bodies offer significant opportunities to simultaneously mitigate UHI and UNI effects at the city scale. Miyawaki forests and compact densely treed parks are effective in passive cooling. Water bodies can increase the cooling effect by evaporation while simultaneously masking unwanted sounds. However, the effectiveness of different methods varies according to the design, vegetation, local climatic conditions and urban context. Therefore, dual-functional results can be achieved with an integrated approach where green-blue infrastructure adapted to local conditions and climatic conditions is used at the urban scale.

4. Building scale solutions

4.1. Green roofs

Green roofs are nature-based constructed ecosystems that offer benefits such as mitigating UHI and UNI, ensuring energy efficiency, purifying the air, and protecting biodiversity. Green roofs are generally examined in two types: extensive and intensive. Extensive green roofs are thin and light-structured green roofs with a soil layer of 6-20 cm. These types of green roofs do not require much maintenance, have low initial investment costs, and generally do not require irrigation. Intensive green roofs have a soil layer thicker than 20 cm, which contains shrubs and small trees. Initial investment and maintenance costs are usually high (Aboelata, 2021).

According to the research results, green roofs are effective in mitigating UHI, but their performance depends on many variables. For example, irrigated green roofs are more efficient in lowering surface temperatures than non-irrigated green roofs. Since the benefits vary relying on numerous variables such as the density of the buildings in the area used, the height at which they are located, the types of plants used, whether or not irrigation is done, climate conditions, and the type of green roof (extensive/intensive), they should be used with good planning and optimization in urban design (Li et al., 2014).

Although the noise mitigation capability of green roofs is known, there has been insufficient investigation on the acoustic impacts of green roofs consisting of substrates and vegetation. The general acceptance in the literature is that sound absorption increases as the substrate layer increases.

4.2. Green walls (vertical gardens)

Green walls, alternatively called living walls, bio-walls or vertical gardens, usually consist of vegetation grown in supported vertical systems mounted on an interior or exterior wall. There are also green walls that are freestanding without being mounted anywhere. Green walls, which have a very aesthetic appearance, contribute to the insulation of the building by providing effective and direct shading on the wall surface. They provide benefits such as improving air quality, creating a cool microclimate and growing plants in places where there is not enough space for growing plants. In green walls, where a wide variety of plants can be used, herbaceous plants and small shrubs are usually used (Balany et al., 2020).

The performance of green walls, which are natural based solutions to mitigate UNI, is influenced by variables like plant density, substrate and humidity. Among the green wall types, hydroponic green walls, which are green walls where no soil is used and plants are grown in nutrient-rich water, provide both aesthetic and environmental benefits. Their noise reduction performance is quite high due to providing continuous vegetation and optimizing the substrate porosity (Shushunova et al., 2022). In summary, green walls can offer aesthetic solutions with the potential to mitigate UHI and UNI.

4.3. Earth sheltered buildings

Earth-sheltered buildings are a term used to describe structures where the soil is used in various proportions to reduce heating and cooling requirements, they can be divided into two basic categories in terms of architectural planning. For example, the most commonly used type of earth-sheltered housing is a structure covered with soil on three sides but with an open southern façade. They can have roofs covered with soil (green roofs) or well-insulated traditional roofs. Although earth-sheltered structures can be placed on flat land, they are more suitable for sloping land. When suitable conditions are provided, they can be applied on land with a slope of up to 50%. Another category that can be exemplified on a residential scale is courtyard-type structures, in which the spaces are arranged around a courtyard (Sterling et al., 1981). All earth-sheltered dwellings with roofs covered with soil and greenery have the UHI and UNI mitigation benefits of green roofs. Figure 4 depicts the most common types of earth sheltered buildings.

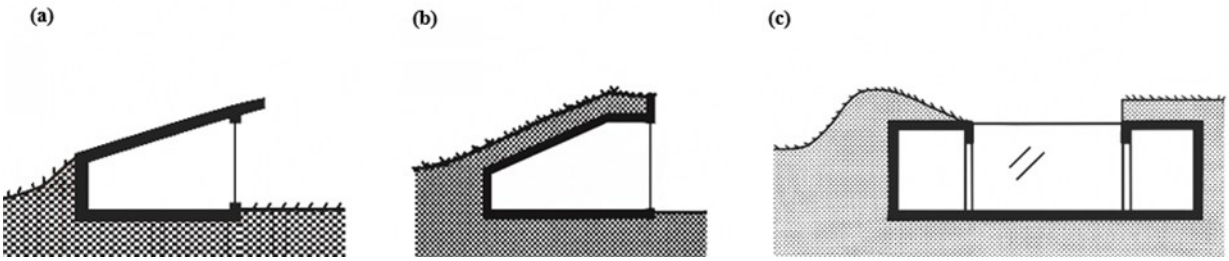

Figure 4. Types of earth-sheltered buildings on the residential scale a) Section of elevational type with conventional roof b) Section of elevational type with soil roof c) Section of atrium type.

Throughout history, the use of underground for residential construction has been applied in the villages of Matmata (Tunisia), Cappadocia (Turkey), Sassidi Matara village (Italy), Santorini (Greece) and Guadix village (Spain). Although using underground for buildings is a sustainable green approach and has been implemented in various regions of the world in the past, it is far from today's modern design culture. In recent years, the focus has been on earth-bermed structures due to the understanding that completely underground housing is unclean, unsafe, dark, damp and unusual, and therefore not accepted (Benardos et al., 2014).

Due to the thermal insulation provided by the earth, less heat is transmitted into the soil-protected structure, as the ground temperature rarely reaches the outside air temperature, even at shallow depths and under typical environmental conditions (Carmody & Sterling, 1984). The thermal mass of the soil reduces the daily and annual variations in the temperature of the interior of the building, keeping it relatively constant. In this way, the thermal mass of the soil acts as a heat source in winter and a cooling source in summer. Studies on earth sheltered buildings have shown that energy efficiency increases as the surfaces of the facades in contact with the soil increase (Benardos et al., 2014). Earth-sheltered buildings, which are not preferred much today due to their unusualness, can be used as an alternative solution in the context of UHI and UNI mitigation. Most earth-sheltered structures are found in hot, dry climates due to their cooling efficacy.

Earth-sheltered buildings have the potential to mitigate UHI through mechanisms such as heat insulation, evaporation, shading and microclimate creation provided by the soil. However, due to their not being widely implemented, studies on the UHI mitigation performance of earth-sheltered buildings are insufficient despite their high energy efficiency. Regarding UNI, the soil layer in earth sheltered buildings

helps mitigate noise by dampening vibration and sound. On the other hand, there is also not enough research in the literature on the UNI performance of earth-sheltered housing.

5. Findings

Forests (especially Miyawaki Forest) and green parks offer significant opportunities for UHI mitigation at the urban scale, while green roofs and green walls offer effective solutions at the building scale. Each of the strategies presented in the article reduces the UHI effect using different mechanisms. Table 2 shows the mechanisms by which different solutions mitigate UHI effect. Green roofs, which are artificial ecosystems based on nature, provide benefits such as energy efficiency, air purification and biodiversity protection, as well as an aesthetic solution that mitigates UNI. There are studies showing that green roofs may mitigate the cooling demand of buildings by up to 70% and indoor temperature by up to 15 °C. In addition to green roofs, green walls, another aesthetic solution where plants are grown in vertical systems, also have the potential to absorb noise and mitigate UHI. Although sufficient research has not been conducted on UHI and UNI performances, earth sheltered buildings offer significant opportunities thanks to their green roofs and soil layers that provide thermal and sound insulation.

Table 2. UHI Mitigation Mechanisms of Natural Solutions.

NATURAL SOLUTIONS OF URBAN HEAT ISLAND MITIGATION							
	MECHANISM	**FORESTS**	**URBAN PARKS**	**WATER BODIES**	**EARTH-SHELTERED BUILDINGS**	**GREEN WALLS**	**GREEN ROOFS**
UHI MITIGATION MECHANISMS	**Shading**	√ (Balany et al., 2020)	√ (Balany et al., 2020)		√ (Cascone et al., 2019)	√ (Susca et al., 2022)	√ (Cascone et al., 2019)
	Evaporation	√ (Balany et al., 2020)	√ (Balany et al., 2020)	√ (Lin et al., 2020)	√ (Cascone et al., 2019)	√ (Susca et al., 2022)	√ (Cascone et al., 2019)
	Transpiration	√ (Balany et al., 2020)	√ (Balany et al., 2020)		√ (Cascone et al., 2019)	√ (Susca et al., 2022)	√ (Cascone et al., 2019)
	Albedo effect	√ (Balany et al., 2020)	√ (Balany et al., 2020)	√ (Lin et al., 2020)	√ (Cascone et al., 2019)	√ (Susca et al., 2022)	√ (Cascone et al., 2019)
	Microclimate regulation	√ (Balany et al., 2020)	√ (Balany et al., 2020)	√ (Lin et al., 2020)			
	Thermal insulation with soil				√ (Cascone et al., 2019)		

As nature-based artificial solutions, green roofs, green walls and earth-sheltered buildings discussed in this article show the highest performance in UHI mitigation in hot and dry climates. The main reason for this is that there are high sunshine duration, high evaporation, and temperature differences in these climates. Thus, the highest cooling effect can be achieved. Table 3 lists the UHI mitigation effects obtained in different climate conditions. For example, in the hot-dry climate of Iran, green walls lowered indoor temperature by 9%, relative humidity by 32%, and outdoor temperature by 0.36 °C (Daemei et al., 2021). Underground structures in the same climate type increased indoor comfort by reducing temperature differences by 6.4 °C (Khaksar et al., 2022). In tropical climates such as Malaysia and Thailand, green roofs provided surface temperature reductions of 23.8°C and 12 °C, respectively (Kachenchart & Panprayun, 2024; Rahman et al., 2022). In temperate and cold climates, the UHI mitigation effect of nature-based artificial solutions is relatively limited. For example, in the temperate climate of Berlin, irrigated roofs reduced temperatures by only 0.71°C during the day and 0.26°C at night (Wang et al., 2022). This is because temperature differences and sunshine duration are less than in hot, dry climates. These findings can also be seen in Table 4, where the thermal and acoustic performances of different strategies are compared. Although some case studies from the Mediterranean climate report extreme surface temperature reductions, the most consistent and multifaceted benefits in indoor, surface and air temperature reductions and comfort increases are seen in hot-arid climates. Therefore, the use of such solutions should be evaluated on a climate-specific basis.

Green roofs and green walls can significantly mitigate urban noise levels by increasing sound absorption and reducing sound reverberation. The data in Table 3 supports this view. For example, a study by (Barriuso & Urbano, 2021) showed that urban noise can be reduced by 9.5 dB with the utilization of green roofs and green walls, and a 9.3 dB reduction can be achieved at the 500 Hz frequency, which is the speech frequency. A study by (Mihalakakou et al., 2024) in 2024 revealed the noise absorption

potential of earth sheltered buildings. The researches conducted by Bakker et al. and .,Carlucci et al. (Bakker et al., 2023; Carlucci et al., 2023) reported that green walls reduce both surface temperature and sound pressure. According to these results, nature-based artificial solutions offer sustainable solutions by mitigating the UNI effect, especially in densely populated urban areas.

Concerning table 3, quantitative data obtained from different studies were compared using °C and dB units as included in the studies. Due to methodological differences, no normalization was applied except for converting the result to degrees in one study using Kelvin.

Table 3. Recent studies on the use of UHI mitigation (2019-2025) .

Study	Year	Focus	Outcomes
(Hassan & El Kotory, 2019)	2019	The usability of earth-shielded buildings in the Egyptian deserts	The soil layer can reduce UHI effects by providing constant temperature throughout the year.
(He et al., 2020)	2020	Comparing green and cool roofs in Shanghai climate	Cool roofs: -3.3°C in summer, +10.4% heating load in winter. Green roofs: -2.9 °C in summer, -6.2% heating load in winter
(Asadi et al., 2020)	2020	UHI reduction capacity of green roofs in Austin	-1.96 °C the land surface temperature, by 3.2% of the overall roof area being green roof
(Arghavani et al., 2020)	2020	Green roof UHI mitigation effect under different scenarios in Tehran	In low-density areas, green roofs -0.86 °C reduction in daytime In high-density areas (with greening) resulted in -0.85 °C reduction in daytime and a 0.63 °C increase in nighttime temperatures.
(Herath et al., 2018)	2018	Different scenarios for UHI mitigation tested in Sri Lanka	Highest benefit: achieved in combination of trees on pavement + 50% green roof + 50% green wall (1.9°C (5.48%) decrease in air temperature)
(Zhong et al., 2021)	2021	Comparing green roof and cold roof UHI mitigation effect in Shanghai	Green roof and cold roof provided approximately 1.5 °C reduction in surface temperature with different mechanisms
(Daemei et al., 2021)	2021	Thermal efficiency of green wall in Rasht/Iran was investigated	Green wall mitigated indoor temperature by 9% and relative humidity by 32%. Outdoor air temperature decreased by 0.36°C and relative humidity increased by 1.04%.
(Sahnoune et al., 2021)	2021	İnvestigating green roof (GR)/urban green infrastructure (UGI) ratio and UHI mitigation in Constantine	When GR/UGI=0.0063, air temperature decreased by 1.24 °C and surface temperature decreased by 4 °C.
(Barriuso & Urbano, 2021)	2021	Investigating the thermal and acoustic performances of green roofs and green walls	Green roofs and green walls can reduce air temperature by 11.3°C, urban noise by 9.5dB, can reduce 500 Hz speech sound by 9.3dB, and reverberation time by 81%.
(Khaksar et al., 2022)	2022	Evaluation of thermal performances of underground structures in Meymand village, Iran	Earth sheltered housing reduced temperature fluctuations by 6.4 °C
(Wang et al., 2022)	2022	Comparing cool roofs and green roofs in terms of UHI mitigation in Berlin	Cool roofs with the highest albedo reduced temperatures by 0.80 °C during the day and 0.65 °C at night, while irrigated green roofs reduced temperatures by 0.71 °C during the day and 0.26°C at night
(Rahman et al., 2022)	2022	Comparing traditional roof and green roof in terms of UHI mitigation in Maleysia	Surface temperature was measured as 22.9 °C on the green roof, while it was measured as 46.7 °C on the traditional roof
(Shushunova et al., 2022)	2022	Sound absorption comparison of modular, hydroponic and container green walls	The highest performance: hydroponic type The highest sound absorption performance was measured in hydroponic green walls. The sound absorption coefficient changed

			between 0.5-1 depending on the layer structure.
(Mihalakakou et al., 2023)	2023	Assessing the thermal and acoustic performances of green roofs	Green roofs can mitigate the cooling demand of buildings by up to 70% and indoor temperatures by up to 15°C. They can significantly reduce urban noise.
(Bakker et al., 2023)	2023	Evaluating traffic noise absorption performance of vertical green systems	Vertical green systems act as porous sound absorbers in absorbing sounds at 200 Hz and above
(Carlucci et al., 2023)	2023	Thermal and acoustic performance evaluation of modular green wall in semiarid Mediterranean climate	Green wall reduced air temperature by 7.9 ◦C, surface temperature by 26.9 ◦C, and sound pressure by 5.1 dB
(Kachenchart & Panprayun, 2024)	2024	Comparing traditional roof and green roof in terms of UHI mitigation in Thailand	Green roofs reduced surface temperature by 12 ◦C compared to conventional roofs, reducing heat transfer by 84%
(Mihalakakou et al., 2024)	2024	Investigating the thermal and acoustic efficiency of earth-sheltered structures	Earth-sheltered buildings provided energy efficiency by keeping indoor temperatures constant, and also provided effective protection against external noise.
(Tadeu et al., 2024)	2024	Measuring the effect of green roof plant type, density and different soil types on acoustic performance	It was understood that the vegetation layer and substrate was effective in sound absorption
(De Cristo et al., 2025)	2025	Evaluation of green roof thermal performance in the Mediterranean region	In summer, green roofs provided 7.4 ◦C in outdoor temperature and 0.2-2.3 ◦C in indoor temperature. Annual energy savings were 10-34.7%, cooling efficiency reached 50% in highly developed layered roofs.
(Lu et al., 2025)	2025	Measuring the acoustic efficiency of green roofs	In the research conducted at Nanjing University, China, green roofs reduced rooftop noise levels by 2.1-4.3 dB (on the roof) and 0.6-1.2 dB (around the roof), and drought-tolerant mixed planting was recommended for improved performance.
(Attal & Dauchez, 2025)	2025	Comparing green wall and green fence in terms of UNI reduction	As leaf thickness and density increased, noise transmission decreased, but in case of green fence application, reflection increased, while in case of green wall, reflection decreased

6. Discussions

Controlling UHI and UNI is crucial for resilient and sustainable cities. This study has been prepared to add to the development of comprehensive strategies for the solution of these two problems that require urgent intervention. Solutions that can be taken at the city and building scale to UHI and UNI, which have an important place among environmental problems, are collectively discussed. Table 4 comparatively depicts the thermal and acoustic performances of different natural based strategires, from the UHI and UNI mitigation poinf of view (Arulbalaji et al., 2020; Barriuso & Urbano, 2021; Carlucci et al., 2023; He et al., 2020; Herath et al., 2018; Kasprzyk et al., 2022; Khaksar et al., 2022; Khare et al., 2021; Manteghi et al., 2015; Mihalakakou et al., 2024; Sahnoune et al., 2021).

Table 4. Comparing the thermal and acoustic performances of nature-based strategies.

Strategy	Heat Mitigation (°C)	Noise Mitigation (dB)	Special Notes
Green Roof	up to 15°C (inside), 26.9°C (surface)	up to 9.5 dB	Irrigation is preferred
Green Wall	up to 7.9°C (air temp.)	up to 9.3 dB	hydroponic systems give best results
Earth-Sheltered	6.4°C (less fluctuation)	Excellent insulation by soil	Constant indoor temp + noise barrier
Cool Roof	up to 3.3°C	–	May cause winter penalty
Trees and Forest	up to 3.5°C	Indirect masking	Combined strategies are preferable- Miyawaki is the best
Rain Gardens	7°C(cloudy days)-20°C(sunny days)	–	Compared to asphalt and pavement
Water Bodies	2–6°C	Noise masking (flowing)	Depends on design
Combined Systems	~2°C	up to 9 dB	Combined Synergistic results can be reached

6.1. Implementation challenges and policy recommendations

There are some disadvantages and limitations of green walls, green roofs and earth-sheltered buildings. Despite its many advantages, nature-based solutions cannot become widespread due to reasons such as high initial investment, maintenance costs and urban policy deficiencies. Green roofs and green walls have higher initial investment and maintenance costs than traditional roofs and walls. Their long-term performance varies according to local climatic conditions, selected plant species and irrigation needs. Such systems suppress atmospheric mixing processes and may cause air pollutants such as ozone to accumulate in areas close to the surface. Moreover, they may cause moisture accumulation, which may increase the UNI effect (Zhong et al., 2021). Earth-sheltered buildings have technical problems such as lack of natural air, natural light and humidity control. Nature-based approaches should be evaluated within a holistic approach and long-term planning appropriate to the local context and climatic data. Future studies should focus on UNI mitigation and the combined effects of UHI and UNI mitigation of natural solutions, primarily green roofs. Academic knowledge needs to be supported by on-site case studies and measurements. In the future, financial incentives, appropriate building codes, and informing and training architects, engineers and city planners are important for integrating nature-based solutions into urban planning.

7. Conclusions

This review article provides an original contribution to fill an important gap in the literature by systematically examining nature-based approaches that address UHI and UNI problems together. Forests, water bodies and agricultural areas, referred to as green-blue infrastructure at the city scale, have great potential to mitigate UHI and UNI effects. However, the success of these solutions depends on variables such as local climatic conditions, spatial form, plant species and the amount of water used. Therefore, such solutions must be considered contextually. In addition, the use of dense green vegetation, which is one of the nature-based applications, may increase nighttime heat or may not provide sufficient benefit in absorbing sounds at different frequencies. For this reason, in this article, dual-functional solutions are examined within the system, spatially scaled and comparatively. The findings of the article emphasize the importance of a multifunctional and context-focused perspective for the simultaneous management of these two problems in the urban design process. Future studies can expand this framework by addressing the long-term effects of the solutions described in this article in different climatic zones and social cost-benefit studies. To optimize thermal and acoustic comfort, urban planners and architects should integrate nature-based approaches that are adaptable in terms of climate, space, and scale into their designs in densely populated urban areas.

This paper comparatively examines the effects of nature-based strategies on UHI and UNI. The benefits of various strategies like green roofs, green walls, Miyawaki forests, rain gardens in reducing these two problems simultaneously have been demonstrated. In particular, it has been observed that thermal and acoustic efficiency increases when several strategies are used together (green roof, green wall, tree

and water element). The results obtained from this study are of a guiding nature for decision makers and professionals for dual-function urban planning.

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Conflicts of Interests
The authors declares no conflict of interest.

Data Availability Statement
All data generated or analysed during this study are included in this published article and its supplementary files.

Institutional Review Board Statement
The research involved publicly available datasets and thus did not require ethical approval.

CRediT Author Statement
All authors have read and approved the final version of the manuscript.

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Pillars of Community Development: A Study of Al-Asmarat District

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ABSTRACT

The topic of community development for marginalized communities has evolved significantly in the last eight years worldwide, following the United Nations' (UN) establishment of the Sustainable Development Goals in 2015. Under this umbrella, Egypt has set a development vision and targets to improve the standards of living conditions in the country. One of the targets is to minimize the problem of informal settlements through a series of action plans, such as creating new districts that aim to offer a better quality of life for the people who used to live in the various informal settlement areas. This prompted the state to spend exorbitant sums on these development projects, amounting to six trillion Egyptian pounds according to the prime minister's declarations in the "Decent Life" Initiative Conference 2021.

The thesis aims to develop an analytical tool to understand the pillars of community development. The aim was completed by collecting the main pillars of development from the point of view of many organizations, like the UN, and many individuals, like economists, sociologists, and architects. This results in having the five main pillars, which are knowledge, psychological, social, economic, and urban pillars.

The tool was implemented in a local case study, which is the Al-Asmarat district, to assess and evaluate the project as a community development project. This was achieved through site visits to collect primary qualitative data from the interviews and through observation, mapping, and photo documentation to come up with a conclusion and action plans for the already existing phases in Al-Asmarat and future recommendations to Al-Asmarat phase four, and the other futuristic community development projects.

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1. Introduction

1.1. Overview

The world now is directed to set development plans which act as a target that should be achieved within a specific range of years; they call it a vision for a better community and quality of life. One of the most prominent examples of this approach is the United Nations Sustainable Development Goals (SDGs) and its 2030 vision. The vision consists of seventeen goals that can be categorized into economic, social, educational, health, and environmental aspects, which help to understand the different development pillars.

On the other hand, Egypt follows this development plan and has started to put its vision for the year 2030. The plan focuses on three main development pillars: the economic, social, and environmental, which stress the importance of those pillars. "For instance, key components of Egypt's Vision 2030 and 2050 - emphasizing justice and social integration, such as sustainability and the creation of a competitive, balanced, diversified, and knowledge-based economy" (Kadry & Husain, 2025).

The topic of community development has become the topic of every era and area. Despite that, there is no collaborative tool that can be used as a guide for developers and planners, so in this dissertation, We will talk about varies dimensions of community development adding the urban and architectural perspective, by conducting a tool that can be used as an analytical tool to analyze already existing communities or as a design tool highlighting the aspects that should be taken in consideration in the design process.

This assessment tool can be used to assess any development project, or it can be used as a design tool to guide the decision maker in the design decisions.

In this thesis, we use this tool to analyze Al-Asmarat district as an example of a community development project, and study all the aspects of a current local case study and assess it.

1.2. Aims

- The thesis aims to develop an analytical tool to understand the pillars of community development and investigate the overlap between them.
- The tool aims to help the decision maker in design decisions, as it acts as a checklist for the most critical aspects of developing any community.

1.3. Objectives

- To provide and propose specific criteria and guidelines to deal with the complexity of the overlaps between the main community development pillars.
- To assess this tool on a local case study in Egypt.

1.4. Methodology

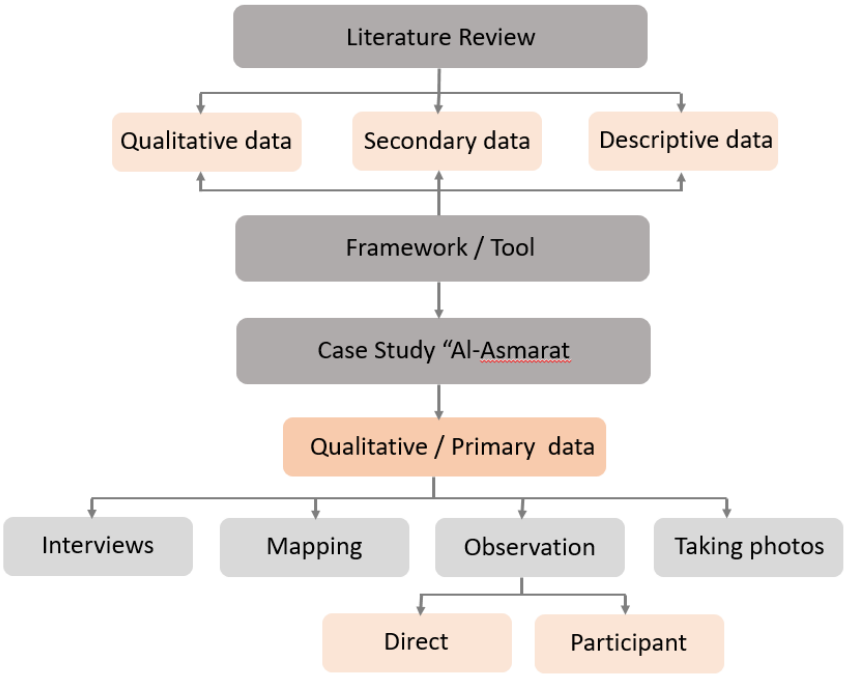

Figure 1. Research Methodology (source developed by Author, 2022)

The research methodology was about collecting qualitative, secondary, and descriptive data in the literature review; those data have been transferred to an analytical framework/tool. This tool has been tested and applied to the case study, which is "Al-Asmarat district".
The case study and been analyzed through interviews with people living there, mapping different activities, direct and participant observation, and taking photos. Finally, we came up with a conclusion in the form of a SWOT analysis technique applied in the analytical tool and future recommendations.
Through the photos of the case study, I try to record the following three aspects:

- Displays of self: the different kinds of adaptation to the existing situation and the ways of personalizing specific spaces.
- By-products of use: the leftovers and the traces of humans using the spaces and dealing with the current features.
- Context: by trying to read the present signs and indications.

The observation methods I used in the case study are:

- Cognitive observation: by observing human behavior in social interaction places.
- Interpretive observation: observing the relationship between human behavior and the built environment.

1.5. Research problem

The government in Egypt started an initiative to minimize the informal settlement problem and lift the citizens' quality of life through several community development projects, started seven years ago all over Egypt as development projects; this initiative cost around six trillion Egyptian pounds, according to the Prime Minister's declaration in the "Decent Life" initiative conference 2021. This amount of money should be used through a studied plan to come up with tangible results for the users.

2. Literature review

What is community development? "Community" is defined by Boothroyd as "A human system of more than two people in which the members interact personally over time, in which behaviour and activity

are guided" Boutilier, M.A., Rajkumar, E., Poland, B.D. et al (2001),on the other hand, "Development" is defined as 'The objective of moving to a state relatively better than what previously existed, a good change", getting more in the definition of "community development" as a whole, Butterfield, A., & Chisanga, B. (2013, June 11) Describes it as a planned approach for improving well-being among disadvantaged groups through capacity building, participation, integration, and community organizing—with asset-based and community-building methods as growing trends. While Green, J. J. (2016) frame community development as collective social action toward agency and solidarity, sometimes connecting across communities or feeding into broader movements.

2.1. Social development

Talking more specifically about the effect of the social and cultural aspects on community development and showing how it is essential to consider it to have an effective outcome, Pawar talked more about the social development approach saying that "while community development is defined as a participatory people-cantered process that involves bringing together, mobilizing and organizing people, keeping them together and enabling them to work together to address their needs and issues and thus to facilitate their own, their communities, and society's comprehensive development as par the social development approach" (Pawar, 2014).

To address poverty in rural areas, both development partners and national governments have launched enterprise development programs that emphasize the need for participatory frameworks. These frameworks aim to empower rural entrepreneurs to identify the specific Business Development Services (BDS) they need to foster economic growth and social transformation. To ensure that participation goes beyond rhetoric. Nordjo, E., Boadu, E. S., & Ahenkan, A. (2023)

Social community development is defined by various aspects that should be taken into consideration or thought of before undertaking community development programs; some of these aspects are traditions, values, culture, mores, and altitudes; Stepney & Popple(2008) specify this more and sum the concept of community in terms of five characteristics which are commonality among people, size of the population, sense of belonging and identity, attachments, primary relationships and finally the local culture, They argued that these five aspects must be considered while working on social community development.

Focusing on one of the critical aspects of social development is the effect of community organizations and the interventions they make in the community. Referring again to Mohd. Shakil, who strongly relates community organization to community development, argues that "community organization is one of the primary methods of the social work profession, it deals with intervention in the communities to solve the community problems. Community organization and community development are interrelated as two sides of the same coin" (Shakil, 2015).

2.2. Economic development

Economic development, in a broader perspective, could be defined as a dynamic process involving the country's interaction with the people and their environment through changes in the quality of productive factors in the growth process, which will lead to an increase in the individual income and this will not happen until women be a part of this development, This was ensured by the economist Karl Marx (1855) in his argument saying that "The participation of women is a mean to achieve the goals of development, through gender awareness, more efficient economy-wide policies. It will contribute to achieving economic growth, but it will also help identify the social goals the society is willing to pursue" that is why Onu (1998) opined that "women are at the heart of the development; they control most of the non-money economy (subsistence agriculture, bearing and raising children, doing domestic labour) and taking an important part in the money economy (trading, the formal sector, and the wage employment)."

Women and men need economic empowerment to reach the community's economic development, and many aspects could achieve this. One of them is microfinance. Muhammad Yunus, who is called the "father of micro-finance" and best known as the founder of the grassroots Grameen Bank, uses this

approach to uplift the villagers in Bangladesh by encouraging them to do small businesses that could help get their livelihood back on track. (Saxena, 2022)

Neither the less, the importance of providing job opportunities to the Youth. Hence, they argued that "youth leadership and skills development can contribute to lifting individuals out of poverty by improving access to work, increasing productivity, and fostering sustainable economic growth" (Saxena, 2022).

2.3. United Nations Sustainable development goals

The United Nations argued that "community development is a process designed to create conditions of economic, social progress for the whole community with its active participation and fullest possible reliance on the community's initiative (Lotz, 2019.)

In 2015, the UN (United Nations) set a vision for the next fifteen years till the year 2030; this vision aims to serve the whole world to help develop all developing countries to end poverty and fulfil human needs by reaching an entire sustainable planet. (United Nations, 2015) This vision will be implemented by working on seventeen goals that the UN targets; those goals fall under the umbrella of economic, social, and environmental development. The seventeen goals are translated into actual action plans and different project types in various countries all over the world, aiming to reach a satisfactory result of this agenda by the year 2030; many conferences and summits are held to help in achieving the seventeen goals, which are:

- Goal 1. End poverty in all its forms everywhere
- Goal 2. End hunger achieve food security and improved nutrition, and promote sustainable agriculture
- Goal 3. Ensure healthy lives and promote well-being for all at all ages
- Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
- Goal 5. Achieve gender equality and empower all women and girls
- Goal 6. Ensure availability and sustainable management of water and sanitation for all
- Goal 7. Ensure access to affordable, reliable, sustainable, and modern energy for all
- Goal 8. Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all
- Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation
- Goal 10. Reduce inequality within and among countries
- Goal 11. Make cities and human settlements inclusive, safe, resilient, and sustainable
- Goal 12. Ensure sustainable consumption and production patterns
- Goal 13. Take urgent action to combat climate change and its impacts*
- Goal 14. Conserve and sustainably use the oceans, seas, and marine resources for sustainable development
- Goal 15. Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
- Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels
- Goal 17. Strengthen the means of implementation and revitalize the global partnership for sustainable development. (United Nations, 2015).

Figure 2. United Nations. (2015). The 17 goals. https://sustainabledevelopment.un.org/sdgs

3. Analytical tool

As a result of the literature review, the main pillars conducted are five pillars which are Knowledge, Psychological, Social, Economic, and Urban, Those five main community development pillars are highlighted by most of the people who tackle the topic of development of the communities; also, they are the core of the Seventeen Sustainable development goals of the United Nations to the year 2030, Each pillar is divided into Sub-factors that should also be taken into consideration while working on the community development topic.

This part aims to conduct a tool tackling the five main pillars of development and their sub-categories in more detail; this tool is to be used as a design tool for new community development projects or as an analytical tool to analyse the projects that are already done and need more development.

3.1. Knowledge pillar

Knowledge and education are fundamental pillars in development; they enable community members to make decisions, Especially when it is about the most important values, like freedom, respect, peace, democracy, human rights, diversity, or gender equality; they enlighten their thoughts and make a big difference in their behaviour, to understand a community to develop it you should focus on all the knowledge resources within the community and work on them.

3.1.1. Formal Education

- Schools: Schools are the first gate of knowledge a person can access; they are considered to be the base of any future learning; in some communities, people don't get the proper school education because of the quality of the schools, according to Omodan, T. C. (2023). most of rural schools across the globe are often described as disadvantaged or under-resourced, typically marked by inadequate facilities, shortages of qualified teachers, and limited access to both educational and social services, which leads to a massive deficiency in the development of those communities.

- Universities and academies: According to, Hindes & Bakker "higher education institutions perform well in the provision of the relevant multidisciplinary knowledge base, but falter when it comes to developing the competencies essential for effective application of that to the world; of work." (Hindes & Bakker, 2004).
- Vocational schools: Vocational training is a precondition for countries to transition from low to high value-added production, directly affecting the community's economic level.
- Libraries: While studying the knowledge dimension, you should tackle the accessibility of the community people to books or knowledge resources in general, which should be available in different library typologies. Studying the knowledge resources such as libraries will give you an overview of the knowledge dimension.

3.1.2. Non-formal education

Non-formal education plays a vital role in addition to formal education in enhancing the skills and knowledge of the community. According to UNESCO (2006), "Non-formal education has always been part of the solution for marginalized and vulnerable population groups because programs are based on an integrated approach that takes into account all the factors influencing the opportunities and life-chances of different population groups, and the role played by education systems themselves in the process of social inclusion and cohesion." (Kotzé, D. A. 2012).

- Training centres: Training centers are where adults can get knowledge; the quality and availability of those centers will ensure a complete knowledge system within the community.
- Art and Crafts centres: Some communities can be developed upon exciting talents; art and crafts centers are where these talents can be discovered and expanded; the location and quality of those arts and crafts centers and their productivity will indicate the knowledge and creativity level within the community.

3.1.3. Technology

- Internet access: In a rapidly changing world, primary education is essential for an individual to access and apply information. Nevertheless, ICTs in the global village should be included. The Economic Commission for Africa has indicated that the ability to access and use information is no longer a luxury but a necessity for development. Unfortunately, the use of ICT in many developing countries, especially in Africa, is still low (Adomi, E. E., & Kpangban, 2010).

3.1.4. Equality

- Gender equality: In some communities and as a result of poverty, some families give more education preferences to the males than the females, and others prevent females from having access to any source of knowledge; they believe that females will end up as housewives and they better get married, which lead to undeveloped communities.
- Social equality: Unfortunately, the quality of education is directly related to the quality of schools in the community, and not all the community can afford those types of schools, so it is essential to uplift the quality of education in the governmental school to ensure that all social categories have a similar or nearby level of knowledge.

3.2. Psychological pillar

3.2.1. Physical activity & public health

Recent studies have carefully considered public health while designing, and urban planners have started to emerge in the public health field in their work, especially in the relationship with chronic diseases like depression and obesity.

Obesity is correlated with low physical activity; one of the moderate types of this activity is walking or biking, so if the city is well prepared for walking or biking, it has an apparent effect on the public health of the people living there.
Frank, L., Engelke, P., & Schmid, T. encourage creating a physical activity-friendly environment by analyzing three main aspects: the transportation system, the urban design characteristics, and the land-use patterns. (Frank, L., Engelke, P., & Schmid, T, 2003).
Earlier meta-analyses have shown that depression tends to be more common in urban areas than in rural areas among adults and older adults in developed countries. (Xu C, Miao L, Turner D, DeRubeis R., 2023).

3.2.2. Lifestyle

The design of the community has an evident influence on human behaviour; the way that towns, cities, and suburbs are designed and built significantly impacts the people working and living in them. The physical elements that shape the community have a noticeable influence on their daily lifestyle, the problems they face, and what amenities they enjoy are a direct product of how communities are designed (Frank, L., Engelke, P., & Schmid, T, 2003).

3.2.3. Maslow's hierarchy of needs

Abraham Maslow (1954) worked on a large body of research on human motivation; He suggested a hierarchy of human needs based on two groupings: deficiency and growth needs. Each lower need must be met within the deficiency needs before moving to the next higher level. Once each of these needs has been satisfied, a deficiency is detected, and the individual will be able to deal with and solve this deficiency. It is often illustrated as a pyramid with the survival need at the broad-based bottom and the self-actualization need at the narrow top. This five-stage model can be divided into basic (or deficiency) needs (e.g., physiological, safety, love, and esteem) and growth needs (self-actualization). Therefore, we need to analyse community development according to those dimensions (McLeod, 2007).

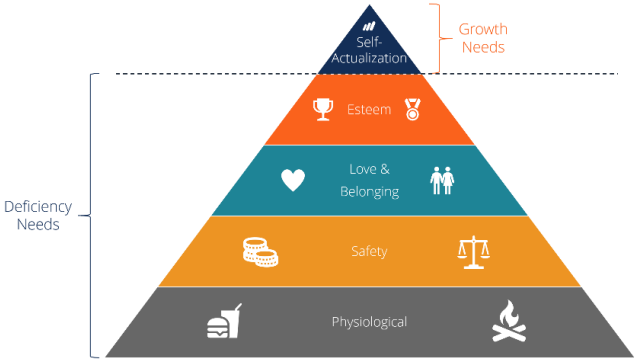

Figure 3. Corporate Finance Institute. (2018). Maslow's hierarchy of needs. Corporate Finance Institute. https://corporatefinanceinstitute.com/resources/management/maslows-hierarchy-of-needs/

3.3. Social pillar

"Persons who are socially engaged with others and actively involved in their communities tend to live longer and be healthier physically and mentally" (Leyden, K. M., 2003). The social dimension is one of the main dimensions that should be considered while trying to understand/ analyse a community to develop it.

3.3.1. Ideologies

Each community has its traditions which are inherited from the elders; some communities are affected by those traditions, which lead to particular beliefs and thoughts within the community and the neighboring ones; this culture may include a specific outfit or unique food recipes which can be used as a dimension for community development, to approach any community with the aim of development you should understand and take into consideration those social aspects.

3.3.2. Social Structure

Studying the social structure of a community helps to understand the social setting that influences collective actions in development. Analyzing this point should be covered for all the social scales, starting from the family scale and moving to the community scale. For example, a community with charge persons is much easier to develop than one that is not structured. Understanding the family structure will help you decide on the potential family member to work on more for development.

3.3.3. Equality

Women should be on equal feet with men; while developing a community, we should study and maintain this equality through actions and choices; some communities neglect the role of women; they believe that women are by nature less intellectually and physically incapable than men. This belief affects the development of the community. On the other hand, other communities understand and appreciate the role of women in development and start some small women empowerment movements and projects.

3.3.4. Social life

Social life is one of the main dimensions that should be considered while working on social development; it helps to understand how life within the community goes. For example, is it more outdoor or indoor-oriented? , it is also essential to study the nature of the places which encourage more social interaction in the community.

3.4. Economic pillar

3.4.1. Job opportunities

- Workplaces are the main economic and productive spots in any community. Therefore, to understand the economic conditions of any neighborhood, you should check the quality and distribution of the workplaces and their productivity.
- The existence of international companies indicates whether this community is economically developed; also, you can measure the community's economic development by observing the startups and small business opportunities in it.
- Most people living in poverty lack access to the resources or knowledge needed to start microbusinesses, so communities that provide these opportunities will be more economically developed than others.

3.4.2. Poverty Rate

- Average income
- Goods prices
- Subsidized products
- Access to microloans

The WMI (Women Microfinance Initiative) applied the microloans concept in Tanzania, Uganda, Kenya, and many other African countries; they mainly provide microloans to women to start a small business to help them improve their economic state; after each project, they annually do a statistic tackling the effect resulted from those loans, and they found that.

- Incomes increase 100 - 400% after the first six months.
- Savings increase by 500%.
- Women prioritize spending their income on education, food, and healthcare for their families.
- 75% of women report improved reading, writing, or arithmetic skills.
- Women in rural Uganda are buying land and building permanent houses.
- They are opening bank accounts and using ATM cards.
- Domestic violence has decreased - husbands and wives are working together (Women's Microfinance Initiative, 2008)

3.5. Urban pillar

As the urban features of the community highly affect the residents' quality of life and daily routine within this community, it is essential to study each aspect of the community to understand and have a clear impression of the community. Also, it will help in many design decisions.

3.5.1. Land uses

- Residential: UN habitat ensures that "everyone has a fundamental human right to housing, which ensures access to a secure, safe, affordable home" they have another perspective on housing as they see that housing is not just a roof but its grantees better live and better future, as housing is more precondition for education, social services, and even employment (UN-Habitat, 2012).
- Landmarks: Urban space has signified elements like a landmark. Landmarks are defined as a reference to people to help them to orient themselves in an unfamiliar environment. There are many typologies of landmarks like historical, skyscrapers, city landscapes, etc.
  The distribution and quality of those landmarks affect the perception of the community and its development; landmarks can be one of the sources that bring money to the community if this landmark is very well known, also it considers as an image to the community.

3.5.2. Mobility

- Infrastructure: Streets are the link between the different parts and activities of the city; they also connect the private with the public domain. These linkages encourage social interaction and exchange. The street design significantly contributes to the quality and characteristics of the community; hence appropriately designed streets create healthy, safe, and quiet environments.
- Walkability: People living in walkable communities can build social bonds, have better health, and have a more secure environment. Walkable cities provide a network of walkable streets with enough furniture, suitable sidewalks, and activities and services. As a result, those walkable communities offer a better lifestyle for their residents.

3.5.3. Quality of public life

In their book How to study public life, Jan Gehl recaptures it as an essential planning Dimension. Jan Gehl defined public life as "everything that takes place between buildings, to and from school, on balconies, seated, standing, walking, biking, etc. it is far more than just street theatre and café life." (Gehl & Svarre 2013).

Tools to study public life:

a) Direct observation

It is easy to document people's behavior by naked eye observation; you can also use a camera or any other aids to focus on specific situations or freeze some moments to analyze the case more deeply.

b) Asking basic questions, "what, who, where, how many?"

These fundamental questions can help you understand and get documentation about a specific activity and give you substantial knowledge about who goes where or not in assigned public spaces.

For example, asking the "who" question can help you know if women usually use this public place, which can hint at the sense of security in this place, if a specific age range uses a particular area, and so on.

c) Mapping, Tracing, and tracking

This is an example of how working in public spaces can improve public life, improve people's way of life, and create more job opportunities and entertaining activities in the city.

3.5.4. Urban Density

Urban Density is usually measured as the ratio of housing units and people over a unit of land, such as hectares, square miles, or acres; it can also be counted as floor area ratio (FAR).
According to the book The Urban Design, density determines the accessibility of people to work, services, recreation, and even the accessibility of people to people; it fosters urban relationships. Interaction with a large number and variety of people is the core of communities. Indeed, the interactions are the basis for the existence of social organizations (Macdonald, 2007).

- Density of people
- The density of the built environment
- Agglomeration of services and public facilities.

Eduardo Lozano argued that "proponents of denser and more compact cities suggest that greater densities have positive spillover effects in supporting transit, reducing car usage, providing various environmental benefits, enhancing local economic development, and promoting greater social interaction." (Richard T. LeGates, Frederic Stout, Michael Larice, 2012).

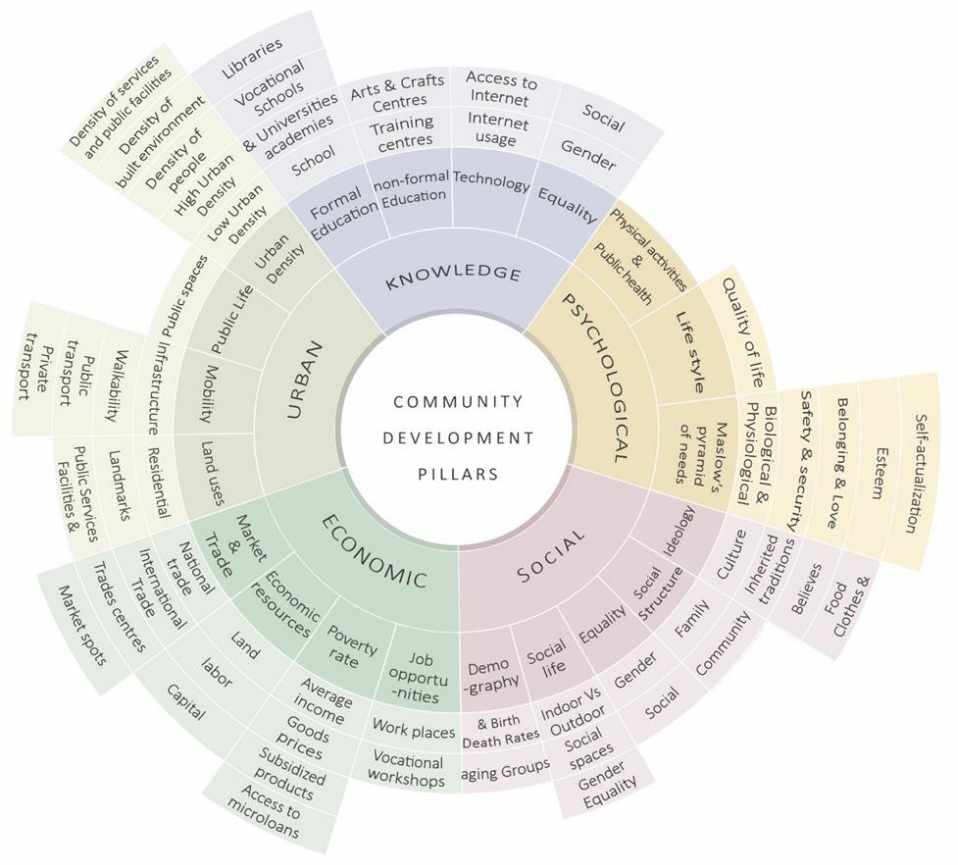

Figure 4. Community Development Pillars (source by Author 2022)

Figure 4 shows the collective analytical tool in its final form with all the subdivisions and aspects that should be studied in any community that needs to be developed covering the most critical dimensions, the five pillars are interdependent, and the improvement of one affects the others; for example, the modification of public space affects the social life of the neighboring residents and creates more job opportunities in the area.

4. Al Asmarat district Case Study

4.1. General Information about Al-Asmarat

Al Asmarat district is a residential project inaugurated by President El-Sisi in 2016; it is part of the government initiative to end the problem of the slums in Egypt. It's located in the El Mokhatam area in Cairo between the Martyr's axis and the ring road; the total size of the project is 188 acres, divided into three phases Asmarat 1, 2, And 3, Asmarat phase one is approximately 65 acres in an area containing 6258 housing units, one primary education school and 240 commercial shops till date, Asmarat phase two is about 61 acre with having 4722 housing units and 110 retail shops, and Asmarat phase tree is approximately 62-acre offering 7440 housing unit.

Asmarat is a resettlement area; the competent executive authorities decided to provide housing in Asmarat for those affected by the demolition of their homes in their original areas. This allocation was determined by the Unified Building Law and its executive regulations and Law No. 10 of 1990 on expropriation (Ezzeddine, I. (2024, July 18). It hosts about 20000 families; the target residents of the project are the people who were living in the slums of Ezbet Khair Allah, Tal Al Aqareb, Mansheyet Nasser, Al Doweiqa, Qaleat Al Kabsh, Al Mawardy, Istabl Anter, and Maspero Triangle.

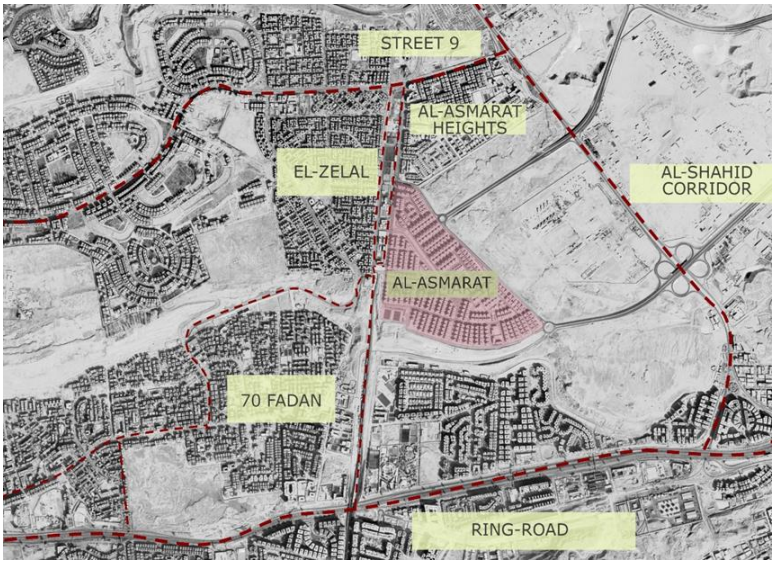

Figure 5. Al-Asmarat Location and surroundings. Source (google earth, edited by Author)

4.2. Knowledge pillar

4.2.1. Formal education

- Long live Egypt schools:

It has five branches in Al Asmarat district. Long live one was turned to be for kindergarten and primary students, and Long live two is now hosting female preparatory students only.

a) Quality: Each school has an average of ten classes that host an average of 550 students; as per the interviews conducted, the parents are not satisfied with the education quality offered, as they claim that this is because the teachers are not well paid.

b) Typologies: They are government schools that serve all age groups.

c) Availability: The schools were founded and started working in 2016; all the students who live in Al Asmarat area have the right to join different schools according to their age and gender.

d) Affordability: The fees vary from 200 to 500 L.E. according to the school grade.

The school also hosts different types of educational activities and events like, Al-Qara'iyya project مشروع القرائية: It was implemented in coordination with the Ministry of Education to address the weakness of writing and reading for students in the first grades of the elementary stage in Long Live Egypt School in Asmarat district. (Elmasri, 2020), Also, many reading and writing empowerment initiatives for women take place in school classes.

4.2.2. Non-Formal education

- Training centers: The ready-to-wear Chamber established a permanent training center for women in Al Asmarat. The Chamber had earlier announced a plan to train girls from the age of 18-30 from the residents of the Asmarat neighborhood, who have the desire to obtain a job opportunity in the ready-made garment sector through a program that lasts for two weeks only, but generally, the residents there complains that there is no enough workshops to accept them, which will be considered in the planning of Al- Asmarat phase four. (Salah, 2021), Quality: Dr. Mohamed Abdel Salam, President of the Chamber of Readymade Garments and Furniture Industries, said that the training given to girls would qualify them to work in factories according to the numbers and specializations required (Salah, 2021).

4.3. Psychological pillar

4.3.1. Physical activity & public health

There are many types of physical activities in the district; one is walking exercise. The residents prefer to talk to save transportation money, but the experience is not so pleasant, as there is no urban public furniture and no shading.
And as noticed from the interviews, the government is trying to pay more attention to the kids and the coming generations; they offer sports activities to both genders, and they are trying to engage them in so many activities and champions like kung-Fu, karate, and football.

4.4. Social pillar

4.4.1. Social life

- Social interactions spaces: Through observation and taking photos, it is evident that people use the corridors between the buildings to socialize as this space is near their residential units; also, it is somehow shaded by the buildings; they even use them for their social occasions and celebrations like weddings, engagement, also kids use those spaces for playing with their neighbors, and as a result of the topography people use the steps as seating element.

Figure 6 Social activities outdoors between the buildings Source (By Author, 2022)

4.5. Economic pillar

4.5.1. Job opportunity

- Workplaces:

a) Availability: there are some commercial shops where they can work, but they are not enough for them, and their rent is high to seven thousand per month, as the shops are sold in auction by the government and the owners rent them to residents with high rental fees.

Figure 7 Commercial shops on the ground floor Source (By Author, 2022)

b) Quality: typical ground floor shops in residential units with average size.
c) Distribution: their distribution is random, but they are somehow clustered together in different spots.
d) Microbusiness (startups): the government prevents the families from having microbusinesses in their homes or any place not planned for the business. Families, especially women, start working on sewing machines in their homes as a startup business.

4.6. Urban & Environmental Pillar

Al-Asmarat district is mainly a residential-oriented project; it aims to provide human residential apartments for people with low income who used to live in slums, so the majority of the buildings in the project, it aims to afford humanly residential apartments for people with low income who used to live in slums, so the majority of the buildings in the projects are residential buildings with typical apartments, and the area of the apartment is almost 75-meter square.

The buildings in phases one and two consist of six floors without elevators, each with six apartments. However, in phase three, the buildings consist of ten floors with two elevators, and each floor consists of six apartments; the residents of phase three complain a lot about the maintenance issues of the elevators. There are several problems with the elevators; sometimes, they have to take the stairs to the tenth floor, which is not easy for most of them, but all the apartments are typical in the area, and room distribution is in all phases, each building group forms a residential cluster with different names; each has different elevation color, as shown in the coming figures.

Figure 8 Names of each building cluster

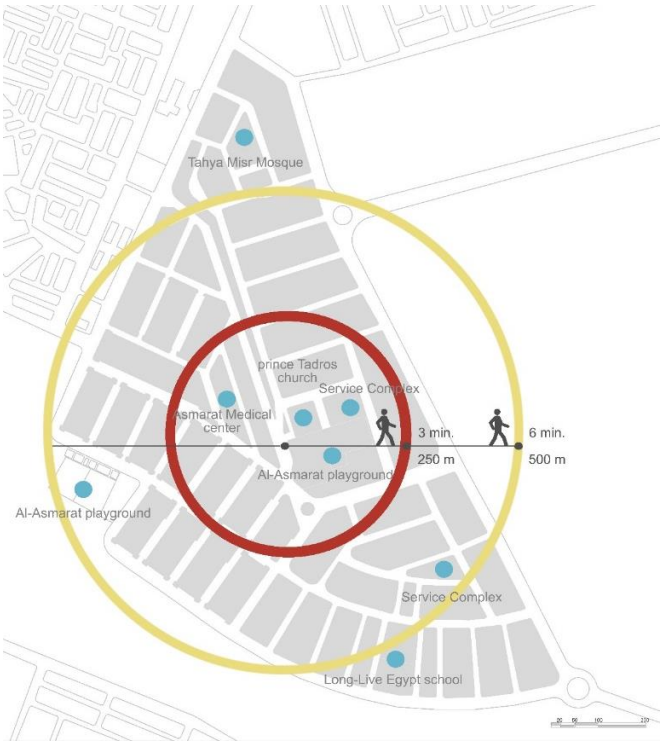

Figure 9 Walkability diagram & primary function Source (by Author, 2022)

Despite that, Al Asmarat district is a relatively walkable district which pedestrians can cover in six to ten minutes' walk; nevertheless, the lack of all those aspects makes the walking experience not pleasant at all and requires a lot of adaptations solutions from the pedestrians to enhance the existing situations, Also, there are no traffic lights or crossing signs; people are moving randomly in the streets which makes it not safe for pedestrians.

5. Conclusion

5.1. Case study's conclusion

In conclusion of applying the analytical tool to study Al Asmarat as a community development project, I conducted that the district has many strengths as well as weaknesses, which that may be because the government overlooked some aspects; furthermore, many aspects can be considered as opportunities to work on to develop the area more and more, and this also without neglecting the factors that threats the development process, so I used the SWOT analysis on the diagram to explain the founded conclusion.

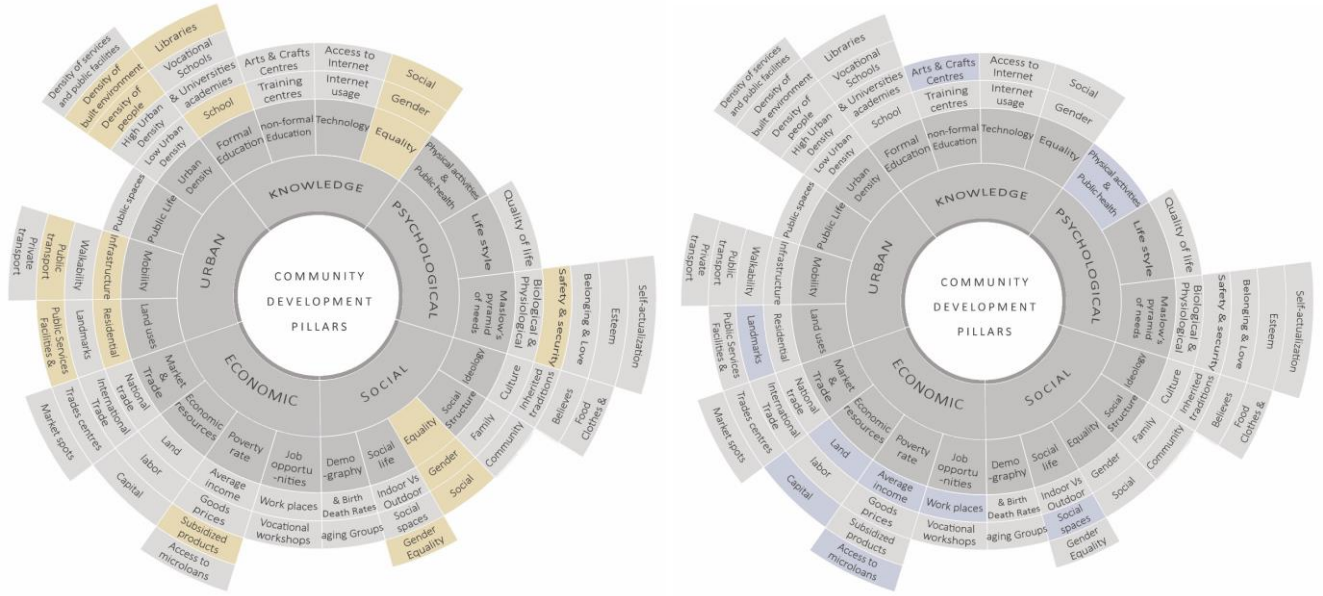

Figure 10 Strength Factors in Al-Asmarat Weaknesses Factors in Al-Asmarat
Source (by Author, 2022)

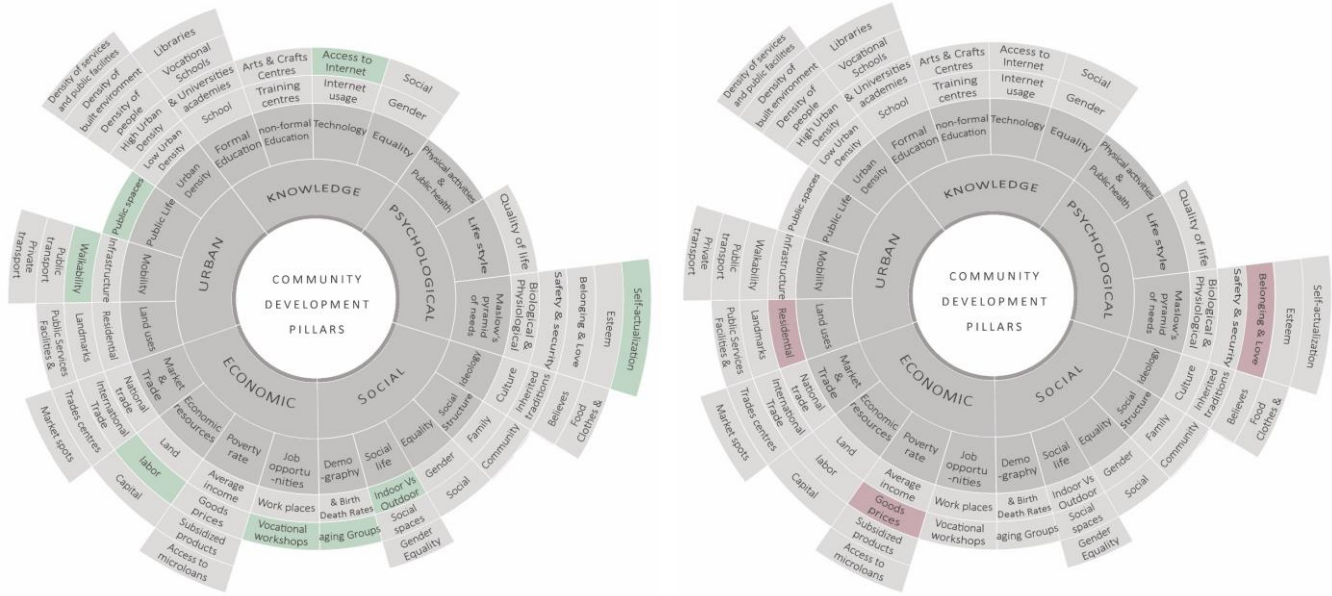

Figure 11 Opportunities Factors in Al-Asmarat Threats Factors in Al-Asmarat
Source (by Author, 2022)

5.2. General Conclusion

After the study of the different pillars of development and conducting the tool, and after applying the tool application on Al-Asmarat case study, I found that:

- The five pillars are interdependent; if you neglect one pillar, it will affect all the other pillars; for example, if the knowledge pillar is overlooked, this will narrow down the job opportunities and affect the economic state of the individual, which will lead to low self-steam and bad

psychological and social conditions, which will automatically reflect of the existing urban environment.

- The government overlooks some aspects as the psychological aspect of the national development projects, which leads to the lack of satisfaction of the users.
- The users should be part of the development process, either by studying their lifestyle and needs or by self-involvement in the development process; otherwise, they will change a lot after living by their means of adaptation, which will affect the actual image of the project.
- People resist any "change" because they fear the "unknown." Hence, the process of development and change requires cautious handling and needs highly skilled workers who know how change and development take place and have the skills to work with the people to induce them to change.
- No one model fits all, so the excessive standardization of the housing units' area and standard room distribution does not work for all families.

5.3. suggestion for further studies

- Community Participation and Governance
  - Focus: Examine the extent and effect of community participation in planning and post-relocation governance in Al-Asmarat.
  - Rationale: Community development thrives when beneficiaries are co-creators, not just recipients. Investigate bottom-up approaches versus top-down planning.
  - Question: How has participation (or lack thereof) influenced residents' sense of ownership, satisfaction, and social cohesion?
- Comparative Case Studies of Other Relocation Projects
  - Focus: on comparing Al-Asmarat with other similar national or international relocation projects, especially those also targeting informal settlements.
  - Rationale: This could help identify best practices and common challenges in community development for marginalized groups.
  - Examples: Maspero Triangle project (Egypt), Favela upgrading in Brazil, Slum rehabilitation in India.

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Conflict of Interests
The authors declares no conflict of interest.

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Public Urban Stairs as Social Infrastructure: The Case of Vendôme Stairs, Beirut

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A B S T R A C T

Urban stairs are integral to pedestrian infrastructure in some neighborhoods on the sloped side of Beirut. Typically designed for people to easily navigate their urban environment, public urban stairs are spatially vertical connectors to different neighborhoods and intricately linked to the social and cultural practices of the inhabitants. By being solely pedestrian and a car-free space, urban stairs play a critical role in providing socially inclusive spaces in between buildings. While they provide calm spaces in a dense fabric, residents of the surrounding potentially build up a strong Sense Of Place (SOP), a muti-dimensional concept that essentially embodies bonds between people and the physical environment. This paper explores Vendôme stairs, one of the many stairs in Mar Mikhael – Beirut, as a case study that matches the multidimensional SOP concept and thus contributes to the social infrastructure of the city. The Vendôme stairs play a vital role in navigating the city and were heavily affected during Beirut's port explosion in August 2020. In tandem between the physical and social aspects, the paper focuses on two interconnected layers of the case study, by collecting data, observing and mapping both spatial and behavioral patterns. The study aims at understanding and bringing evidence of the significant meaning and attachment of the residents to their urban space, through the various subdimensions of the SOP.

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1. INTRODUCTION

Vendôme stairs, one of the landmarks in Beirut, are part of the numerous staircases' network in the city, that have long been, and still are, primary pedestrian connectors as well as famous shared public urban spaces. Vendôme stairs link Mar Michael Street up to Geitawi Street within the Achrafieh neighborhood that sits on the highest hill of the capital. Considered part of Beirut's heritage, the stairs stand still as a witness to the turbulent history of the city and to the historic memories of its inhabitants. Beyond its historic and functional values, this paper explores the deeper connection between the Vendôme stairs

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and the community around it, a sense of place that have been forged and reinforced through time. The research's topic contributes to the literature that sheds light on the potential role of urban stairs, a space often overlooked, as a social infrastructure as important as other planned urban public spaces. The selected case study is examined through the lens of the SOP concept and framework.

Sense of Place (SOP) is a multi-dimensional concept rooted in disciplines that closely investigate human-space bonds, notably human geography, environmental psychology and urbanism, among others. The term itself is associated with well-known terms such as 'Genius Loci' (Norberg-Schulz, 1980), 'topophilia' (Tuan, 1974), 'insideness' (Relph, 1976), 'place attachment' (Low and Altman, 1992), all of which refer to strong connections between people and particular settings. Renown authors on SOP such as Tuan (1974) Relph (1976) and Seamon (1982) commonly suggest that the SOP concept relies equally on two main features: (1) the physical unique characteristics of a space and (2) the meanings, affections and happenings experienced by people in that space. In other words, a space only becomes a place when its favorable environmental features are coupled with positive meaningful experiences of people (Shamai, 1991; Cross, 2001; Nanzer, 2004; Seamon, 2021; Erfani, 2022; K'oyoo, 2025).

Studies that measure and assess SOP usually follow two main strategies: the first is considering SOP as one dimension with several indicators to assess, and the second is to sub-divide SOP to different dimensions and assess each dimension separately. The multi-dimensional strategy results in a deeper understanding of the SOP aspect of a particular setting as well as in a more nuanced SOP assessment. This case study adapts the multidimensional strategy of SOP's assessment, following the tripartite model suggested by Jorgensen & Stedman (2001). This model investigates SOP by looking into the affective (place attachment), cognitive (place identity) and behavioral (place dependence) dimensions. Place attachment, place identity and place dependence are three sub-dimensions to the more general SOP concept that are often measured and assessed in relevant literature (Williams et al., 1992; Deutsch and Goulias, 2009; Nielsen-Pincus et al., 2010; Boerebach, 2012; Dameria et al., 2020). These three SOP dimensions are the main filters by which this case study is explored in this paper; as they constitute the most relevant framework for the case of Vendome stairs in terms of context, history, evolution, surrounding community and contemporary use.

2. METHODOLOGY

This paper investigates the Vendôme stairs structured around the theoretical framework that defines the three dimensions of SOP: place attachment, place identity and place dependence. The analysis and reading of this case study focuses on both the physical and social indicators for each one of the three SOP dimensions (Figure 1). The methodology follows a mixed-method approach where quantitative data is mostly gathered for the physical aspect of the Vendôme stairs, relying on personal mapping and observations. As for the qualitative method, it depends on both in-depth interviews with owners of adjacent properties and brief conversations that authors conducted with users of the stairs. All data are then arranged according to the adapted SOP model. Therefore, the gathering and analysis of information are based on both, primary and secondary sources: empirical studies such as mapping, observations and interviews and existing studies such as previous publications and newspapers' articles.

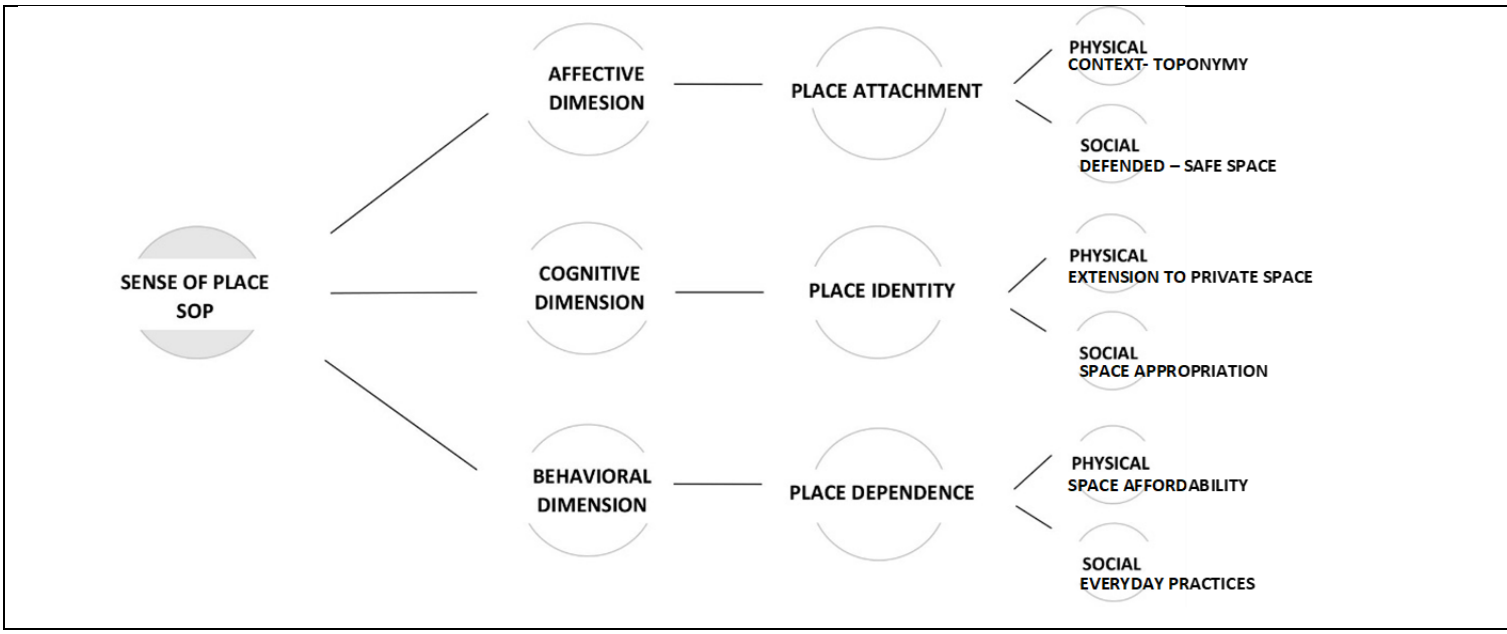

Figure 1. SOP Diagram by authors

3. PLACE ATTACHMENT

Place attachment is a concept that involves the emotional feelings one builds towards a particular space (Proshansky, 1978; Jorgensen and Stedman, 2001; Hidalgo and Hernandez, 2001; Brown & al., 2015; Seamon, 2021; Hawthorne et al., 2022), an "emotional involvement with places" (Hummon,1992, p. 256). This concept focuses on how strongly people feel towards a certain physical setting, thus, by definition, it deals with the **affective dimension** that contributes to the SOP or to the lack of it (Fried, 2000; Manzo, 2005). Authors on place attachment suggest that bonds can be forged between people and settings (Williams, 1992) as well as between people and people, in specific settings (Kyle and Graefe, 2005). Consequently, both the physical and the social contexts of a space are considered to be closely related to feelings of attachment. Moreover, the close connection between people and their environment whether it is because of the physical or the social context, is essentially dependent on time. The long-term experience enhances familiarity that increases feelings of security and comfort (Giuliani, 2003; Nielsen-Pincus et al., 2010).

Time is an essential component that strengthens the place attachment towards a space. In the case of the Vendôme stairs, the background of toponymy reveals a historical intertwined relation between families, community and the stairs. While unfolding social and urban historic narratives, toponymy in this context is a concept interconnected with the sense of place by revealing the way people engage, behave and connect with this space through time. The Vendôme stairs has had several toponymies or placenames since their genesis. They date back to the Ottoman era, and probably they were not initially designed as stairs, but their traces appear in the early maps of the 20th century. In 1909, with the introduction of electricity, five tramway lines were inaugurated in Beirut (El Wali, 1993, p.187), one of which connected the city center to Nahr and Daoura through the Rue Gouraud and Rue an-Nahr[1], the street located at the bottom end of the stairs. The traces of the stairs can be seen in the map from 1922 (Figure 2) as "*Sentier de la Gare*", a French designation indicating its role as an alleyway leading to the train station, 'Gare' meaning station. The stairs also appear as '*Montée Gebailé*" in the 1936 cadastral map of (Figure 3), 'Montée' meaning an upward slope in French and reflecting the hilly topographic nature of the area, and 'Gebailé' referring to the notorious and influential family figure, *Sheikh Younes*

1 The tramway warehouse was situated along Rue An-Nahr, close to the current location of EDL (Electricité Du Liban), in proximity to the stairs.

Nicolas Gebaily. The stairs are still designated as part of the '*Younes Gebaily'* street on the current cadastral maps. In addition, the stairs are widely known by various other names: Until almost a decade ago, the stairs were commonly referred to as *Vendôme Stairs*, named after the Cinéma Vendôme, formerly Olympia cinema which was built in 1952 on plot 633 (HousingMonitor, 2019). Unfortunately, Cinéma Vendôme was demolished in 2011 to make way for a tower, disregarding civic protests to preserve, despite its status as one of the three buildings on the same lot no. 633 listed as heritage architecture (The Executive magazine, 2011). Currently, the stairs are commonly referred to as *Geara stairs*, named after Mr. Marcel Geara who owns a private house along them. Informal sources suggest that he donated the land to the municipality, but this claim remains unsubstantiated. *Geara stairs* is the official name, according to municipal decision number 340 dated 13/3/2014, as indicated on the signage (Figure 4). The evolution of the stairs is closely entangled with that of the urban landscape and the urbanization factors. its toponymy provides insights into the historic evolution of the urban context reflecting narratives of the families and communities associated with it.

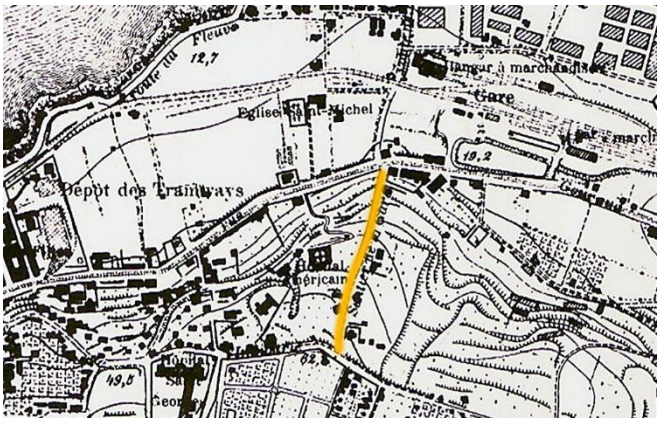

Figure 2. Sentier de la Gare, partial map. Bureau Topographique de l'Armée Française du Levant (1922), modified by authors

Figure 3. Montée Gebailé, partial map. Bureau Topographique des Troupes Françaises du Levant (T.F.L.) (1936), modified by authors

Another strong indicator of place attachment is the popular reaction to its threat of demolition in 2013. People gathered on the steps of the stairs as part of a collective mass mobilization, once rumor spread about plans to demolish it for new constructions in the neighborhood. As a matter of fact, the protests

protected it from demolition as citizens considered it an urban heritage and a cherished space integral to their daily life (Beirut Today, 2019). Moreover, On the 4th of August 2020, the port's explosion, numerous injured individuals gathered on the Vendôme stairs, which transformed into a safe zone for initial first aid before transportation to hospitals. The residents narrated how this place became a temporary refuge for the surrounding community to provide aid, care and support for each other.

Figure 4. Stairs Signage by authors

4. PLACE IDENTITY

Place identity has long been recognized in psychology as one of the main components of personal identity (Erickson, 1956). Introduced in environmental psychology, place identity is defined as an extension of the self (Proshansky, 1978; Berk, 2000), a self-perception associated with a milieu to the extent that the self is directly affected by it: for example, in a study by Wirtz and Harrell (1987) on the impact of change to the environment on people, home violation is directly associated with body violation. Consequently, place identity is essentially the **cognitive dimension** of SOP, by which people define who they are (Schultz and Tabanico, 2007; Lewicka, 2008; Bernardo et al., 2023). It acts as a "component of personal identity, a process by which, through interaction with places, people describe themselves in terms of belonging to a specific place." (Hernandez et al., 2007, p.1). Furthermore, this concept also includes the social construct related to identity which consists of the values, attitudes and nature of interactions associated with a space (Feldman, 1990). Thus, it enhances the sense of belonging of a group of people that commonly identify itself to that specific space (Nielson-Pincus et al., 2010).

In the aftermath of the tragic August 2020 port explosion[2], not only was the entire neighborhood significantly affected, but so were the stairs. Subsequently, the stairs underwent extensive rehabilitations efforts by NGOs in collaboration with UN bodies. Catalytic Action [3], a local NGO, in collaboration with UN Habitat Lebanon undertook the design and rehabilitation of the Vendôme stairs, a project that was completed in 2022, based on a socially inclusive participatory approach. Given the close identification of the local community with the stairs, co-designing with them was crucial to address their needs and restore a significant part of the physically and mentally traumatized neighborhood. The new design

2 On August 4th 2020, a massive explosion rocked the port of Beirut and caused massive destruction to several neighborhoods in the capital. The explosion, caused by hazardously stored ammonium nitrate, is rated as one of the most powerful non-nuclear explosions.

3 The codesigning process is documented on the website of Catalytic Action: BEIRUT'S PUBLIC STAIRS Beirut, Lebanon 2022 - Catalytic Action

consists of various seating areas spread along the stairs, with shading structures creating resting areas and facilitating social interaction. The inclusive design aims at addressing different ages of residents. Handrails are added for the elderly and playful multi sensorial furniture like speaking pipes and slides are well integrated to create play areas for the children. The resulting ensemble of urban furniture, canopies and details contribute to creating a socially inclusive environment. This initiative also facilitates the gradual re-opening of cafes and bars along the stairs. The buildings along the stairs are mostly residential ones and remained unchanged in the past few decades, except for Aya tower. The latter is the outcome of a building regulation which permitted the merging of multiple plots, after the civil war, aiming for a higher floor to area ratio (FAR), thus a higher exploitation factor [4]. These regulatory changes facilitated the construction of taller buildings and towers. In a similar vein, HAR properties, developers of Aya tower, purchased and merged plots number 633 and 1159 along the stairs. Despite all civic protests, they managed to destroy the three heritage listed buildings on lot no. 633, of which Cinéma Vendôme and built a multi-storey high tower (HousingMonitor, 2019). The ground floor of Aya tower consists of a single level pocket-like square, connected to the lively Mar Mikhayel Street. However, it is notably disconnected from the stairs by a wall, except for a secondary access to one of the retails upper levels (Figure 5). This design results in a clear boundary between the two spaces.

As for the ground floor/s of the various buildings located along the stairs, they consist of pedestrian entrances, narrow alleyways, private gardens, cafes, bars and restaurants. This diversity creates a direct connection between the buildings and the stairs, blurring the public-private boundaries and facilitating social interaction and transition (Figure 6). The various platforms act as social thresholds, with several physical elements spilling out from private residential spaces and cafes. The steps and landings of the stairs are occupied by private belongings such as small plants in pots, tree branches extending from private yards, motorcycle parking spots, hanging racks with clean laundry, small barbecue area, tables and chairs, curtains, storage space, wall graffiti and religious shrines (Figure 7). These spill outs indicate the extension of private spaces onto the stairs, transforming it into an in-between shared space, appropriated by the surrounding residents. These practices clearly reveal a sense of ownership over parts of the stairs by the nearby residents, an extension of their most private places that they occupy as they see fit, establishing a strong sense of mutual belonging between them and these stairs. In that regard, Hamza, a male café attendant in his late 20s at Strada café, pointed out that aunt Mimi, a neighbour in the adjacent residential building, enjoys the café's music, and sometimes misses it out when it is not playing. He also pointed out that the outdoor space on the platform is rented from the municipality at a higher cost compared to the café's actual rent. This physical marking of territory is further intensified by a sensory experience of smells and sounds emanating from the neighbouring houses; sitting on those steps, one can enjoy the smell of cooking and hear snippets of television, discussions, and music coming from nearby homes. This multitude of personalized spaces on the stairs makes it a hybrid shared space that is neither entirely private nor completely public; an urban element that blurs boundaries between these normally distinct private-public spaces in urban contexts. As such, the stairs are a clear extension of the self, where residents identify themselves to various sections of this vertical urban environment.

4 The law that governs the merging of adjacent plots of land is Law No. 646/2005, issued in the year 2005, also known as the "Law on the Regulation of Building Heights and Terraces".

Figure 5. Aya Tower and its Disconnecting Wall, by authors

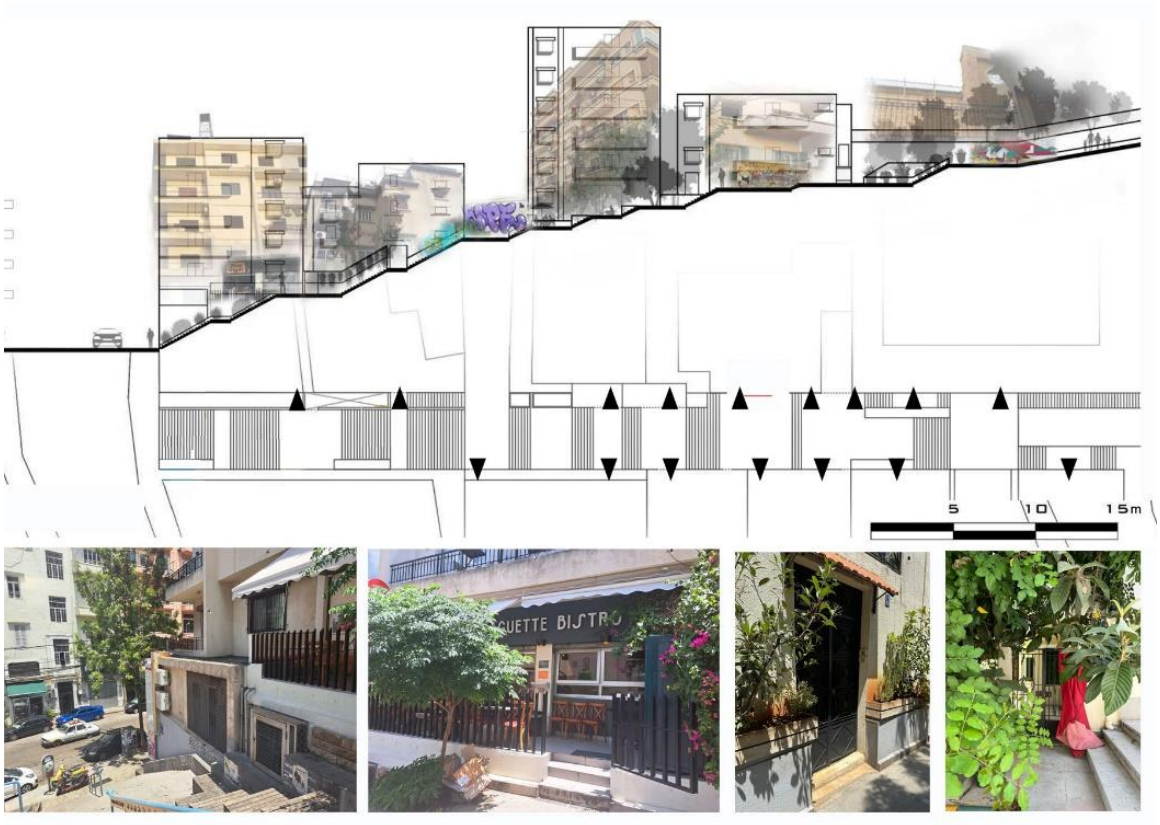

Figure 6. Stairs Accessibility, visuals by students in Architecture Design VI course, fall 2020, modified by authors

Figure 7. Space Appropriation on the Vendôme Stairs, by authors

5. PLACE DEPENDENCE

Place dependence refers to the **behavioural dimension** of SOP. It stems from the affordability of a space to provide the best setting for certain uses and activities. It indicates the suitability of space for users to accomplish their goals and objectives (Altman and Low, 1992; Hay, 1998; Jorgensen and Stedman, 2001; Nanzer, 2004; Lewicka, 2008). Also, it is "considered as the perceived behavioral advantage of a spatial setting relative to other settings" (Jorgensen and Stedman, 2001, p.238), adding to its definition the notion of comparability to other spaces. This SOP dimension suggests a bond between settings and individuals that reinforces feelings of trust and comfort to successfully achieve one's daily activities (Kyle and Chick, 2007; Rollero and De Piccoli, 2010). It is purely a functional connection to space based on continuous experience, where people believe they can best practice their activities in this space.

This reading on place dependence explores the stairs beyond their physical characteristic, by revealing the various daily activities and social behaviors intertwined with their physical nature. Currently, the stairs connect the gradient topography, spanning an elevation difference of nearly 29 meters, linking *Rue*

Khazinein at its upper end to *Rue An-Nahr* at its lower end, famously and commonly known as Mar Mikhayel Street. Along the stairs' ascent, a dead-end road intersects it and links to one of its platforms. This feature highlights the stairs' importance as a vital pedestrian element, transversally across the hill, but also serving as a continuation to the Geitawi neighborhood. The stairs are steep and long, yet they have few platforms with various uses. On a hot and humid July morning in 2024, we informally approached individuals going up or down the stairs, asking them about their experience with the stairs in their current rehabilitated configuration after the explosion. We randomly addressed one lady ascending and another descending the stairs. Georgette, a woman in hers 60s, has been living for 20 years in the neighbourhood along Saydet el Bzez, another nearby stair. She regularly uses the Vendôme stairs, as part of her daily practices, going up and down. After the 2019 economic crisis in Lebanon, she sold her car and since then relies on the stairs which lead to the public bus stop on the main boulevard. According to her, the renovated version of the stairs provides benches and shaded seating area, which are more comfortable than sitting directly on the steps. Unlike Georgette who navigates the stairs both ways, up and down, Anssara Khairallah, an 80 years-old lady, admitted that she only descends the stairs due to their steepness, despite living at the upper end. While pulling her shopping trolley, she explains how she incorporates the stairs into her daily activities, primarily for accessing the public bus stop.

Since its inception, the stairs evolved informally through everyday use. According to local narratives, lemon trees were previously planted along the Vendôme stairs, which originally served as a pathway for donkeys to transport goods to the neighbourhood on either side of it. Gradually, they became integrated into the urban fabric as the main pathway for pedestrians heading to the train station and those using the tramway. During the civil war (1975-1990), this discreet vertical passage served as a clandestine route for transporting weapons while also protecting individuals from snipers. The stairs are used as a pathway and a destination, a place for all citizens, all ages, different activities by day and night, temporary cultural, artistic and social activities. In 2011, the artistic festival titled in Arabic "Nehna wel Amar wel Jiran," (meaning "the moon, the neighbours and us") was initiated by the performance art company 'Collectif Kahraba'. It aimed to strengthen community bonds and highlight the stairs as all-inclusive communal space. Residents actively hosted the festival, participating in food preparation and engaging in other activities. Additionally, in 2015, a live-painting performance took place on the fences that separated it from the new construction site of Aya Tower (Beirut Today, 2019). On several occasions, Vendôme stairs served as a space for protests. Likewise, the stairs served as a gathering place for protesters during the popular uprising in 2019. Away from the scrutiny of security forces, people could strategize and coordinate their plans before marching to downtown. The daily activities, everyday practices, patterns of behaviour, permanent uses and temporary events illustrate the social engagement and the connection between community and the stairs as a physical urban element.

6. CONCLUSION

Beyond its role as a navigation element in the city, Vendôme stairs proved over the years to be not only a shared urban space but also a cherished place to the close inhabitants and a go-to destination for the neighborhood's visitors. Both its physical characteristics and social happenings demonstrate a strong sense of place marked by place attachment, place identity and place dependence indicators. The results of the study show a strong emotional attachment to that place reflected through its historical evolution, its role as a place of refuge and comfort and its importance to its protective community especially during times of threat. In terms of place identity attributes, the appropriation of the space as an extension of neighboring private living spaces is evident through the observations, as well as through the residents' practices of managing, maintaining and taking care of that space. Moreover, a much diverse array of functions and uses is afforded by that space. Perceived as an in-between space, the Vendôme stairs not only connect streets together but also bond its surrounding community that depends on it, and offer them a safe, practical, pleasant and calm place in the midst of a bustling urban environment. The stairs in this case are much more than spaces of flow, as they become historical, cultural and social places in the city. This paper, through its case study, highlights the importance of such urban infrastructures that are often overlooked as mundane urban elements, therefore not commonly investigated in the SOP literature. As the case study reveals, the Vendôme

stairs are much more than simple urban connectors in the city; they foster a strong sense of place among residents, contribute to a safer, and a higher-quality of urban environment, and strengthen the human-landscape relationship between people and their surrounding landscape.

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Ethics statements
No potentially identifiable human images or data is presented in this study.

Conflict of Interests
The author declares no conflict of interest.

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