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IMPRESSUM

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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 take action 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.

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- Heritage & Vernacular Studies
- Environment and Sustainability
- Transportation Systems
- Coasts and Fortifications
- 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.

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The author submits a manuscript;
The Editor assigns Reviewers to the manuscript;
The Reviewers review the manuscript;
The Editor drafts a decision to be sent to the Author.

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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 2 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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Pushing the Boundaries of Architectural and Engineering Education: A Case Study Analysis of the Experience, Outcomes, and Challenges of an Interdisciplinary and Collaborative Design Studio

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ABSTRACT

This study investigates the impact of an interdisciplinary and collaborative approach to architecture and engineering education through a case study analysis based on a Solar Decathlon studio conducted in Turkey. The studio, which competed in the Solar Decathlon Design Challenge 2024, engaged architecture and engineering students, academics, and professionals in collaboration with design and industry partners to repurpose an abandoned school site. The study uses a hermeneutic methodology to explore the lived experiences of team participants and assess the outcomes, benefits, and challenges of the interdisciplinary and collaborative studio experience in developing a professional horizon and design knowledge and skills to address contemporary issues. Through semi-structured interviews, surveys, and thematic analysis, the study sheds light on the symbiotic relationship between academia, industry, civil society, and state departments in architectural and engineering education. This research contributes to understanding the potential of interdisciplinary design education in addressing the 21st-century problems in the built environment.

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1. Introduction

Architectural and engineering education stands at a critical moment, struggling to evolve in response to a rapidly changing world. Traditionally rooted in the study of compositional theory and formal design principles, architectural education is embedded in a convention that highlights aesthetic outcomes. However, in the 21st century, architects face a shifting landscape characterized by increased complexity, digital advancements, climate crises, and changing societal needs. While responding to the contemporary issues, architecture must also transition from traditional leading roles to facilitating roles within multidisciplinary teams and collaborate across various fields to shape the built environment

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(Stone & Sanderson, 2022). Architectural education must evolve accordingly to prepare students for this dynamic future, emphasizing the acquisition of knowledge and its contextualization within contemporary challenges and opportunities.

Meanwhile, engineering education is focused on safety and serviceability in response to loading conditions, with limited project management integration for economically viable designs. However, as environmental and societal concerns escalate, there is a consensus that collaboration between architects and engineers is vital to address 21st-century problems, such as the housing crisis, climate change, environmental pollution, resource depletion, spatial injustice, poverty, and public health. Education must evolve to meet these demands by providing students with multifaceted knowledge, design skills, and critical perspectives. Consequently, engaging in real-world problems, scenarios, and dynamics is vital in practicing becoming an architect and engineer, starting from formal education.

By drawing from the literature that assesses the education of architects and engineers and employing real-world experiences, this paper untangles the dynamics of a studio model grounded in a real-world problem, interdisciplinarity, and collaboration, which aims at tackling the complex "wicked problems" of the built environment in the 21st century, containing environmental, economic, and socio-cultural issues. While the seminal works of architectural education indicate the need for counteracting fragmentation and distance within the built environment practice, the case study presented in this paper allows us to identify the potency and challenges in facilitating real-world design problems in an interdisciplinary and collaborative model in architecture and engineering education. The case study is based on a design studio conducted in 2023-2024 academic year by the authors, along with other advisors and partners, toward participating in a Solar Decathlon Design Challenge—a competition that aims to address the most pressing issues of the 21st century, through interdisciplinary teams and academia-industry partnerships.

Our research employs a hermeneutic methodology to explore the experiences of team participants and to assess the outcomes, benefits, and challenges of the interdisciplinary and collaborative studio model in developing a professional horizon, design knowledge and skills to address contemporary issues. This paper aims to address the following research objectives through semi-structured interviews, surveys, and thematic analysis:

a) To assess the development of complex thinking and design skills and awareness of contemporary issues of the built environment through a realistic, interdisciplinary, and collaborative studio model by tracking the indicators of complex design understanding;
b) To identify and describe the learning outcomes based on this model; and
c) To identify and describe the challenges and limitations based on implementing this model.

Through this study, the authors seek to contribute to the ongoing debates on integrating knowledge and bridging education and practice in architecture and engineering.

2. Contemporary issues in architectural education and civil engineering education

2.1. Splits and ruptures in architectural education

The education of architects and engineers is critical in addressing the crisis within the built environment, requiring critical self-reflection for its progress after a history of splits, fragmentation, and distancing.

Bernard Tschumi's review on architectural education illuminates the changing dynamics of the architectural profession and their reflection on education. Following the deep interconnection between the history of architecture and its educational methods, Tschumi (1995, p. 24) delineates significant shifts in architectural education throughout history, marked by distinct thresholds or dissociations. These dissociations represent critical moments in the evolution of architectural education.

The first dissociation has roots in Leon Battista Alberti's separation of the intellectual task of architecture from the craftsmanship of construction (Moravánszky, 2017, pp. 41-42), which marks an essential pivotal

point in the history of architecture. Alberti's redefinition of the architect as a thinker rather than a maker also established "a crucial reciprocity … between theory and practice" (Leach, 1995, p. 26) since the Renaissance, but the establishment of the School of Architecture in the late 17th century facilitated the separation of theory and practice within architecture to assert academic authority over practical skills (Tschumi, 1995, p. 24). The second dissociation in the late 19th century is the replacement of the logic of materials with the logic of paper rendering (Tschumi, 1995, p. 24). Peggy Deamer's (2020) critique of the traditional Beaux-Arts design, which offers valuable insights into the shortcomings of current pedagogical practices, also highlights this turn to paper renderings as a pivotal moment in the history of architectural education, which continues to influence the current practices. The last dissociation took place in the 20th century, with the further split between 'design' and 'job' architects (Tschumi, 1995, p. 25) and the development of a "theoretical practice" (Tschumi, 1995, pp. 24-25).

The extreme fragmentation within the profession is also reflected in education. At the same time, the current pedagogical practices heavily derive from the academic stance, they heavily focus on "the study of compositional theory and the traditional principles of formal design" (Salama, 2016, p. 60). Deamer's (2020) critique of traditional Beaux-Arts design education highlights the shortcomings of current pedagogical practices, particularly the overemphasis on formal education at the expense of engaging with contemporary challenges. Deamer (2020) advocates for a new pedagogy integrating theory, technology, and the environment and proposes reforms in architectural academia toward a more flexible and relevant curriculum, collaborative research, and re-evaluating professional practice courses.

Deamer (2020) also emphasizes the importance of architecture schools as think tanks to address contemporary issues and prepare students to confront them effectively. This stance resonates with Tschumi's (1995, p. 25) proposal to redefine the role of architects in the construction of technology rather than the technology of construction. It also resonates with Neil Leach's proposal for widening the horizon of architectural education beyond its traditional limits and engaging new theoretical tools by fostering cross-disciplinary engagement as "a way of addressing the problems of contemporary architecture" (1995, pp. 27-28). Thus, architectural education must integrate theory, technology, society, and environmental considerations with realistic design problems while fostering collaborations among and beyond disciplines.

Based on the discussion above, there is a need to redefine the role of architects in the construction of technology and equip future professionals with a horizon to confront the complex challenges of the built environment in the 21st century. In essence, the education of architects must evolve to reflect the complex dynamics of the contemporary world.

2.2. New horizons in engineering education

The engineering profession's creative, hence dynamic nature requires that education should continually evolve and incorporate new technologies and practices (Hall, 2021; ASEE, 1955), and it must engage with environmental stewardship, innovation and integration capacity, risk and uncertainty management, and public stewardship (Hall, 2021). Bae et al. (2022) further emphasize the need for knowledge and skills development for employability to meet industry expectations. The development of competencies on emerging technologies, integration of systems thinking into education, incorporation of real-world problem-solving, project-based education, and experiential learning are seen essential while the development of personal skills, teamwork, responsibility, lifelong learning skills incorporating humanistic and social sciences, and communication skills were emphasized by practicing engineers (Hall, 2021).

Engineering discipline aims to design and guide production through a creative application of scientific principles rather than developing knowledge based on observed facts and tested truths, and thus, bringing different personality traits together in a teamwork setting will facilitate both in-depth learning

and lateral broadening of the knowledge base in a collective setting (Liang & Yeh, 2014). According to Liang and Yeh (2014), teamwork and agreeableness positively affect "transforming imagination," while an introverted personality is good for "conceiving imagination." Thus, both aspects are necessary for engineering practice. Liggett and Etterna (2001) further propose that technology offers an opportunity to replace the time occupied in the past for hand calculations with a depth of knowledge, along with a broader spectrum of knowledge on several other disciplines, to aid the development of the students as professional engineers to guide the society towards a sustainable economy, without the expense of depth of knowledge.

Based on the discussion above, an integrated educational curriculum that takes advantage of technological tools for the guidance of students for in-depth learning within the discipline and provides awareness and understanding of a broader range of knowledge of other disciplines must be facilitated by using different teaching methods to develop a different range of personality traits in each course. In synthesizing these insights, this study aims to revisit engineering education with a model that integrates diverse skills, scenario-based thinking, and interdisciplinary collaboration toward addressing the 21st-century built environment.

2.3. Crossing disciplinary boundaries in architectural and civil engineering education

In response to the challenges posed by contemporary social and environmental problems, there is a surge of interest in integrating knowledge across disciplinary boundaries. There are various integration approaches with different levels of integration, including multidisciplinarity, interdisciplinarity, and transdisciplinarity: multidisciplinarity indicates several scientific disciplines working on a common problem, each discipline contributing its perspective without crossing boundaries; interdisciplinarity requires scientists from various disciplines to cross boundaries and create new knowledge collaboratively to address real-world problems; and transdisciplinarity involves integrating non-scientists in addressing real-world problems (Stock & Burton, 2011). Along these lines, Borucka and Macikowski (2017) discuss the challenges and complexities inherent in contemporary architectural practice and education and emphasize the need for specialization alongside interdisciplinary education to prepare students for the multifaceted challenges of the built environment. Rifaat (2019) proposes actions to improve architectural education, including forming multidisciplinary teams, introducing real-world projects, and engaging industry stakeholders. Andrews et al. (2020) advocate for a transdisciplinary approach to address climate change impacts, bringing together students and faculty from multiple disciplines.

Navarro et al. (2014) and Oliveira et al. (2022) present methodologies and findings regarding multidisciplinary educational initiatives and indicate the benefits of multidisciplinary teamwork and skill development. The findings by Navarro et al. (2014) suggest an increased understanding of the construction process, sustainable built environment, and solar energy systems with improved communication skills and abilities to work in multidisciplinary teams under realistic conditions and a better understanding of professional and ethical responsibility. Chang et al. (2022) and Heinendirk and Cadez (2013) investigate the impact of interdisciplinary pedagogical approaches on students' creativity, teamwork, and self-development, further suggesting the importance of crossing disciplinary boundaries in the education of civil engineering and architecture students. A study by Jin et al. (2018) also highlights the positive outcomes of interdisciplinary coursework, including improved collaboration and design quality, in addition to shortcomings, including deficiencies in the software skills of some students and drawbacks in linking BIM to building energy simulation software. Ali (2019) explores the benefits and challenges of interdisciplinary collaboration in the Architecture, Engineering, and Construction disciplines, similarly highlighting the importance of collaboration skills and software tools. Badawi and Abdullah (2021) evaluate interdisciplinary design courses and suggest improvements to enhance collaboration among architecture and engineering students after their study observed the unwillingness of architectural student groups to collaborate with the other disciplines, while some teams

recognized the benefit of cross-disciplinary collaboration. Their findings suggest the need to increase the physical time spent working together to overcome introversion. Thus, strategies to improve collaboration skills and use collaborative tools are essential for fostering successful interdisciplinary design courses.

Overall, the literature highlights the significance of beyond disciplinary collaboration in architectural and engineering education to address real-world challenges effectively (Figure 1).

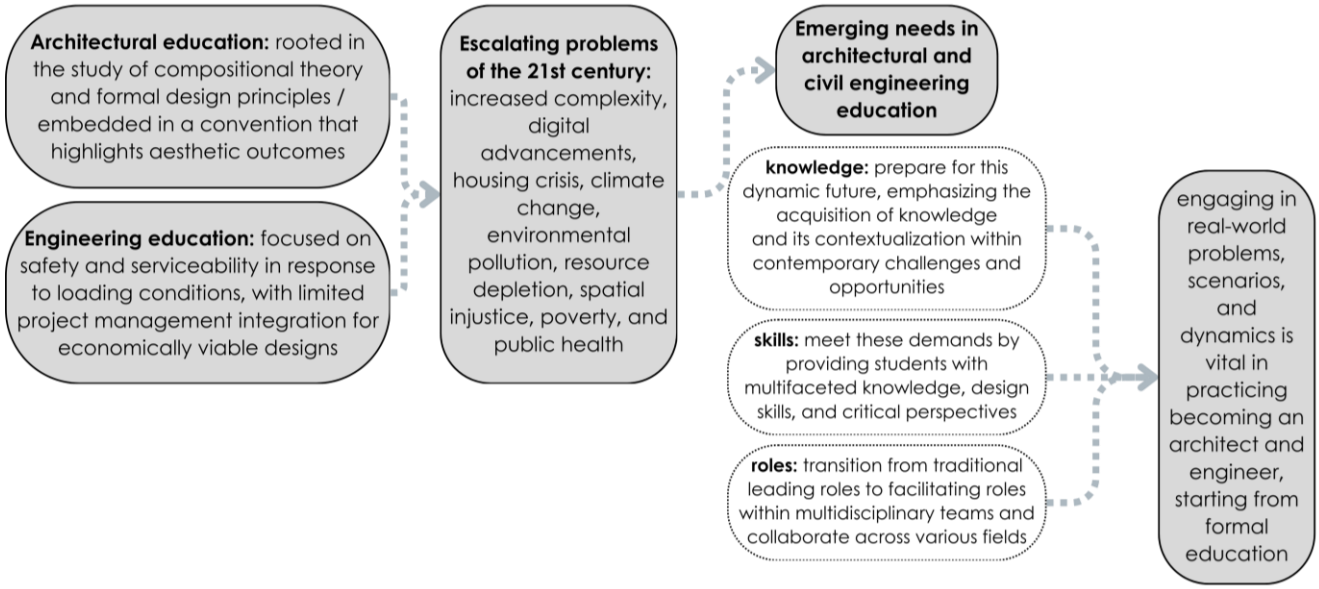

Figure 1. Theoretical background (Source: Developed by Authors, 2024).

3. The case of solar decathlon studio

In 2023 Fall, an experimental design studio was facilitated at the Architecture Department of Yeditepe University to undertake the Solar Decathlon Design Challenge 2024 as an interdisciplinary team with a collaborative studio model and realistic project. The Solar Decathlon is a collegiate competition organized by the U.S. Department of Energy to prepare "the next generation of building professionals to design and build high-performance, low-carbon buildings powered by renewables" (U.S. Department of Energy). While the competition aims to equip students for "the clean energy workforce" and "educate students and the public about the latest technologies and materials in zero energy design and technologies, smart home solutions, and high-performance buildings" (U.S. Department of Energy), it fosters collaboration and cooperation among academia, disciplines, design partners, and industry.

3.1. Team structure

Facilitated by two instructors and a teaching assistant from the Architecture Department, the studio officially included twenty second-year architecture students. The team further consisted of a civil engineering student, advisors from engineering and architecture, design partners (clients) who assigned the studio a real-life design problem, industry partners, and a specialist mentor assigned by the competition organizers (Table 1).

Table 1. Team structure (Source: Developed by Authors, 2024).

Student Lead	1	Architecture Department / Graduate Student / Teaching Assistant
Students	20	Architecture Department / Sophomores (two double-majoring in C.E.)
	1	Civil Engineering Department / Senior
Faculty Advisors	3	Architecture Department
	1	Civil Engineering Department / Cost and LCA Specialist
	1	Civil Engineering Department / Structural Design Specialist
	1	Civil Engineering Department / Water Systems Design Specialist
	1	Industrial Engineering Department / Solar Energy Supply Specialist
Acting Advisors	1	Civil Engineer / Sustainability Specialist
	1	Electrical Engineer
	1	Mechanical Engineer
	1	Architect / Visualization Expert
Mentor	1	Sustainability Specialist
Design Partners	1	State Department
	1	NGO
	1	University
Industry Partners	1	Lightweight Steel Construction Firm
	1	Opening Systems and Mechanisms Firm
	1	Glass and Glazing Firm

3.2. Course aims, content, and process

This experimental studio was conducted in the first architectural design studio. In the first architectural design studio at Yeditepe University, students conventionally design a house or housing by considering natural, spatial, social, and cultural contexts and the relationships between interior and exterior spaces, circulation systems, structural systems, and materials. They investigate the brief and site and prepare an architectural scenario and program for the intended users. They develop design through scaled site plan, silhouettes, floor plans, sections, elevations, system details, point details, 3D drawings, and physical models. Within the scope of the Solar Decathlon Design Challenge, students worked on a net-zero house design. In contrast to the regular competitive studio model, the studio aimed for one final project by integrating building systems beyond its conventional scope. The studio met once a week for a full day with the participation of the studio instructors and the students officially enrolled in the studio while the rest of the team mainly contributed through seminars and had input during the reviews. The syllabus remained flexible except for the set milestones, such as review days and competition submissions. The team worked beyond the academic calendar until its participation in the semi-final competition event (Table 2).

Table 2. Solar Decathlon studio course flow, achieved milestones, engagement with complex design thinking, and crossing boundaries of the disciplines with a collaborative model (Source: Developed by Authors, 2024).

Week #	Course Flow	Topics
1	Introduction	Introduction to the Solar Decathlon Design Challenge; Team building activities
2	Discussion Day and Workshop	Theoretical readings on house, dwelling, and housing informed by the fields of architectural theory, philosophy, and culture
3	Case studies	Introduction of the design problem (real-world complex problem) by the design partners or clients; Presentations on house design from the past solar decathlon winners are conducted by pairs of students
4	Theoretical lectures	Lectures on sustainable building, carbon emissions, earthquake ordinances, water sources, solar energy, quantity survey, zoning ordinances, contextual and environmental analysis, and site documentation by all team advisors; Visit to Bodrum (site visit) on the weekend

5	Site analysis, scenario and program	Analysis studies assigned to pairs of students
6	Conceptual design *First review with stakeholders*	Design proposals by four groups of students and evaluation of the proposals; Feedback by advisors and partners and consideration of how various systems inform the proposals
7	Conceptual design	Design proposals by two groups of students and evaluation of the proposals; Visit to the industry partner (lightweight steel construction) in that week and integration of structural system
8	Conceptual design	Convergence to one design proposal on the site plan after the evaluation of the progress
9	Design development, estimations, and simulations *Submission of the project summary to the Solar Decathlon Competition*	Students are assigned different tasks in pairs to develop spatial systems, water systems, energy systems, cost estimation, simulations, etc. after the evaluation of the progress - integration of systems; Visit to the industry partners (opening and glazing systems) in that week
10	*Second review with stakeholders*	Integration of systems
11	Design development, estimations, and simulations	Student pairs and tasks were reshuffled after the evaluation of the progress
12	Design development, estimations, and simulations	A structural model is built with the guidance of civil engineering student and topic understood well by architecture students
13	Presentation studies	Exchange of works for the completion of the presentation as a precise and inter-referential output after the evaluation of the progress
14	*Final review with stakeholders*	Integration of systems
15	Design revision and visualization workshops	Integration of the project systems, including resolved gutter system and shading devices after daylight simulation
16	*Submission and participation in the semi-final competition event*	Integration of systems

3.3. Realistic design challenge and brief

The design partners assigned the design problem to the team: designing affordable, movable, and deconstructible teacher homes on the derelict school sites in Bodrum. The region has witnessed a significant increase in property values and rental prices, impacting the economic feasibility of accommodations for middle-income individuals. Public school teachers assigned to the Bodrum region struggle with finding affordable rental homes, often resulting in transfer requests. This further impacts the viability of primary education. Furthermore, the decline in the permanent population in some villages in Bodrum and the consolidation of schools have left some village schools inactive, with their buildings in ruins. Responding to these challenges, the Bodrum District National Education Directorate collaborated with the Architecture for All Association and İstinye University to develop projects for the abandoned school sites. The studio received the brief and, after visiting the site and talking with local authorities, developed it further to consider the culture and history of the place, passive design strategies, generation of clean energy and reduction of energy demand, water cycle and conservation, material and site circularity, disaster resilience, health, local and renewable materials, logistics, and carbon emissions.

3.4. Complex design problem and integration of systems

The team responded to the competition requirements for net zero building, the client brief and site conditions. Initially, students conducted various historical and site analyses and collected climate data to evaluate opportunities and risks. Considering the site's life cycle, material circularity, and other factors, such as earthquake and fire resistance, the team opted for a steel structural system placed on

stone plinths, a reminder of the site's historical past.[1] An industry partner specializing in lightweight steel buildings joined the team and provided initial lectures and ongoing consultancy, assisting in resolving material connections and building physics requirements.

The students undertook tasks within and beyond architectural design, including the study of the connection between form, climate, envelope, energy, mechanical systems and materials' insulation values and carbon footprints. Energy modelling software was utilized with guidance from advisors and mentors, facilitating iterative investigations into shell and flooring systems and material alternatives. The civil engineering student assessed structural system options, and several students conducted calculations and analyses to determine material requirements, embodied carbon, cost, and the integration of water systems. Demand calculations, rainwater harvesting, and plumbing system designs were developed to mitigate water scarcity and achieve water circularity, with considerations for structural loads. Furthermore, several students learned to utilize local unit price books and software for cost calculations, providing feedback on material selection to optimize cost-effectiveness. Through collaborative efforts and guidance from mentors, the team navigated various challenges, informing the design process and improving the project's overall sustainability, integration, and feasibility.

3.5. Integration of Architectural and Engineering Perspectives and Collaboration with Stakeholders

The lack of engineering students from various fields pushed architecture students to explore various systems of building with guidance from advisors and gain literacy on systems integration. Starting with the site visit, architecture students investigated the environmental and experiential conditions of the place, and they conducted research and communicated with locals to understand the constraints of the site, its history, local culture, and economy, as well as the connections between the site and neighboring settlements. After collecting data, liaising with the relevant advisors, and dwelling on more resources, architecture students converted the data into usable information, crossing the boundary of their own discipline. Reflection of this information on the design has proven satisfactory for the preliminary design stage.

At the design development stage, different groups of architecture students working on solar energy, water systems, plumbing, energy analysis, envelope insulation, and cost estimates carried out more detailed analyses with guidance from advisors and partners. The implications of acquired knowledge were shared with the team during weekly studio hours to integrate the necessary principles of the systems into the project. On the other hand, the civil engineering student worked only on the structural system to suit the architectural forms that architecture students predominantly defined. Therefore, the civil engineering student remained like a service provider to respond with solutions to the demands of the architects.

The group's collaboration was facilitated during studio hours and through the online classroom and a shared online folder, where the team archived the work weekly. Hence, the whole team facilitated a timely understanding of the components. Reviews were the driving force in integrating and aligning different project components with the team and investigating the areas that needed revision or further development. Design partners, as the clients, provided feedback on all studio reviews. While most advisors were physically present at these reviews and some regular course days, online meetings made participation and feedback from most stakeholders possible.

[1] The stone plinth was envisioned to be built from local stone and left as a permanent part of the site after the potential removal of the houses.

4. Methodology

Hermeneutic methodology guides this research, which seeks to describe and interpret the experience, outcomes, and challenges of interdisciplinary collaborative models based on realistic projects. Hermeneutics is the theory and methodology of interpretation (Gadamer, 2006). Hermeneutics' interpretative framework is a dynamic engagement rather than a search for a singular meaning, and the interpretation originates within a researcher's horizon—a temporal and cultural context that defines understanding (Gadamer, 1988). In hermeneutic research, the horizon has a dual role: a limitation defined by our existing perspectives and an opening to transcend those limits through engagement with new interpretations. The researcher continually expands this horizon by studying fragments to derive meaning for the whole and studying the whole to derive meaning for the fragments (Gadamer, 1988), which unfolds in a dialogue with the text. Another implication of the hermeneutic approach, as also employed in this research, is the continual expansion of knowledge based on a dialogue between people.

4.1. Research design

This research entails a process of collection and reflection on experiential data to gain insight into the outcomes and challenges of an interdisciplinary and collaborative studio model (Figure 2).

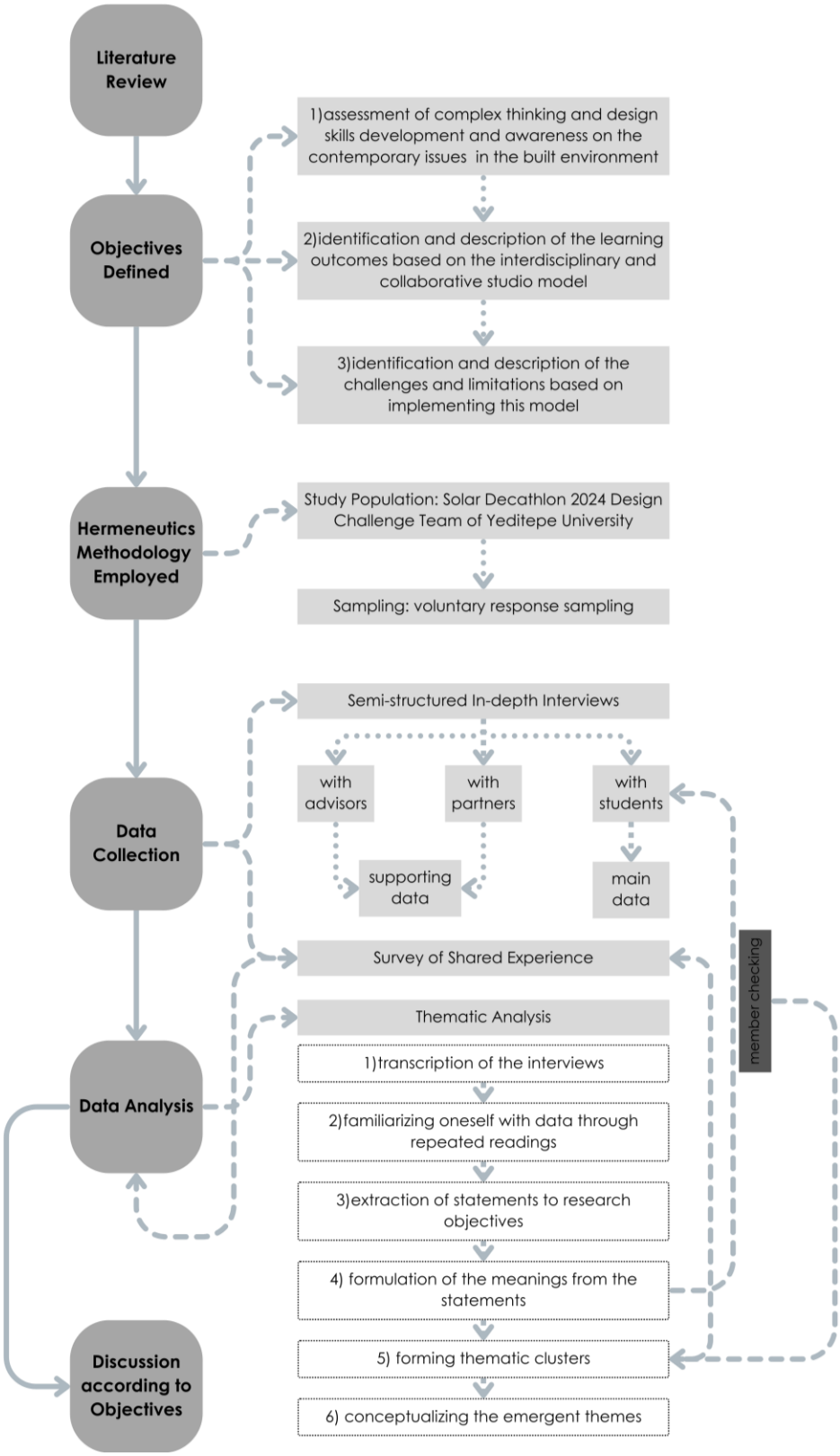

Figure 2. Research design (Source: Developed by Authors, 2024)

4.2. Data collection

The data was collected through semi-structured interviews with team members using a voice recorder and a follow-up survey based on the formulated meanings that emerged from the interviews. The interview questions were shared with the respondents in advance to allow them to reflect on their experiences adequately.

4.3. Sampling

The population of this research consists of the Solar Decathlon studio team members. The sample size is adaptive or emergent, and it uses the principle of saturation, in which the sample size is decided a posteriori since "determining qualitative sample size a priori is an inherently problematic approach" (Sim et al., 2018, p. 619). This research uses voluntary response sampling (Stratton, 2023, p.148).

4.4. Data analysis

The authors interpret the data in dialogue until they establish a shared and commonly agreed meaning. The data interpretation follows the steps of thematic analysis outlined by Braun and Clarke (2006):

1) The authors transcribe the interviews.
2) The authors familiarize themselves with data through repeated readings.
3) The authors extract statements from the transcripts and list them under the relevant research objectives.
4) The authors formulate meanings from the statements.
5) Thematic clusters are formed based on the formulated meanings.
6) The authors conceptualize emergent themes.

Once the themes emerge, the authors revisit the relationship between the themes and whole transcripts to record any new insights. The authors conduct the process together to converge the findings. The findings are presented in tables and narrative format. The follow-up survey sheds light on the percentage of respondents sharing the experience presented in the formulated meanings.

4.5. Reliability and validity

In qualitative research, reliability and validity are defined as "trustworthiness, rigor and quality" (Golafshani, 2003, p. 604). In hermeneutic research, validity is not a linear and predetermined condition. However, it is rather established within the process of research as an "audit trail" (Freeman, 2011, p. 544), which Freeman describes as "a view of research representation as a form of correspondence to reality" (2011, p. 544). The researcher thus focuses on "the public disclosure of processes" (Anfara Jr et al., 2002, p. 29). Trustworthiness in this research was ensured through the thick description (Geertz, 1973), transparency, and member-checking techniques. Member-checking involves respondents acting as co-analysts and co-interpreters, helping in understanding both the realities and the researchers' interpretations of those realities (Livari, 2018, p. 111).

5. Findings

The authors interviewed 16 respondents: eight students, five advisors, and three partners. After transcribing the interviews, two authors concurrently conducted thematic analysis in dialogue. They created formulated meanings by going through each team membership role in three consecutive phases, creating thematic clusters, and finally reflecting on all clusters to list the emergent themes. The emerging formulated meanings were shared with the respondents to verify the authors' interpretations.

The findings are presented in tables 3 through 11, focusing on one team membership role and a particular research objective.

Table 3. Formulated meanings, thematic clusters, and emergent themes from student experiences within the scope of the first research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Thematic Clusters	Formulated Meanings
environmental frameworks	1a	design with climate data	understanding that decisions on building orientation relative to the sun and wind, window openings, and system placements have influenced the design
	1b	design with environmental impact	understanding the environmental impact of building siting
			awareness on the carbon footprint of selected materials and systems
	1c	design with the consideration of life cycle analysis of resources	awareness on materials selection based on recycling potential, environmental impacts, and construction advantages
	1d	design with energy systems and performance	understanding the relationship between envelope design, passive ventilation, and building's energy consumption
socio-cultural frameworks	2a	design with the consideration of historical and cultural heritage	awareness on historical context and its effect on design decisions
socio-economic frameworks	3a	design with affordability	understanding affordability principles and incorporation of cost calculations to inform design decisions
	3b	design with life cycle use	awareness on incorporation of flexible and adaptable design approaches considering user profile change
economic performance frameworks	4a	design with the cost of engineering systems	understanding the role of architectural layout decisions in cost reduction of mechanical, electrical, and plumbing systems
constraints of demands	5a	design with local regulations	awareness on project development in accordance with regulations, specifications, and zoning plans
			awareness on the impact of building ordinances and regulations on building design
	5b	design with client demands	awareness of carefully and thoroughly evaluating client needs to develop the design
	5c	design with user demands	awareness on spatial organization for user needs
	5d	design with energy criteria	awareness of design criteria related to net-zero buildings
constraints of supply	6a	design with logistics	awareness on design options evaluation for logistics
	6b	design with local and renewable resources	understanding limits of local conditions for circularity
	6c	design with the spatial requirements of engineering systems	awareness on distribution systems' effect on building design and its spatial layout
			understanding the impact of structural system on spatial and facade design
	6d	design with limited resources	definition of success in design as a design developed under constraints and restrictions
	6e	design with variability of resources	[extracted from other roles]

Table 4. Formulated meanings and emergent themes from advisor experiences within the scope of the first research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Formulated Meanings (Advisors)
environmental frameworks	1a	understanding the value of ecological and climatic data and their impact on design / designing sustainably considering climate data
	1b	awareness on importance of integrating climate, ecological data and passive strategies for a sustainable project
	1c	awareness on the design for water circularity and distributions of blue-gray-black water
	1d	Understanding the demands for net-zero and its interaction of passive systems, facade design, and generation of solar energy / awareness of the design for water circularity and distributions of blue-gray-black water / awareness of the design of water circularity and distributions of blue-gray-black water
socio-economic frameworks	3b	negotiation between client demands and varying user profiles
constraints of demands	5b	negotiation between client demands and varying user profiles
	5c	
constraints of supply	6b	beginning and developing design by utilizing local resources
	6c	awareness of the importance of connection details on building performance / reflecting electrical systems requirements by consulting with professionals / incorporating implications and constraints of structural system selection with openings, systems, and connection details / ability to reflect supplier information for requirements of the treatment systems
	6d	ability to reflect rainfall data to calculate the roof catchment area for rainwater harvesting
	6e	indication of a detailed perspective about the realistic constraints of the seasonal and temperature-related variability of data

Table 5. Formulated meanings and emergent themes from partner experiences pertaining to the first research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Formulated Meanings (Partners)
environmental frameworks	1b	understanding how system choices affect each other and the environment in a real project
	1c	understanding the benefits and disadvantages of the lightweight steel system in terms of sustainability
	1d	design detailing for energy conservation
socio-cultural frameworks	2a	understanding the impact of settlement, environment and history data on design/building
constraints of supply	6a	awareness on modularity parameter and off-site building selection, which must be reflected in the design, transportation of building elements, and structural calculations

Table 6. Formulated meanings, thematic clusters, and emergent themes from student experiences within the scope of the second research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Thematic Clusters	Formulated Meanings
content of knowledge acquisition	1a	knowledge on building detailing and systems integration	gained building assembly and envelope knowledge and developed technical drawing skills based on a project with a specific structural system
			learned to design by reflecting systems' details
	1b	knowledge on cumulative design phases	learned all project development phases from the pre-design phase to the construction drawings
	1c	knowledge on the preparation and methodology of design process	experienced the shift from individual theoretical readings toward smaller and then larger groups to be immersed in the process
	1d	understanding space requirements of systems	ability to translate technical constraints into spatial design
method of knowledge acquisition	2a	learning through models and/or mock-ups	understanding systems function and integration via mock-ups/details of industry
			understanding building's structural system with a physical model produced by peers

	2b	interdisciplinary peer learning	understanding building's structural system facilitated by a student from another discipline
	2c	awareness on the value of critique, panel discussion and multiple perspectives	gaining new perspectives through a wider range of jury critiques
	2d	data collection methods	[extracted from other roles]
integration of knowledge	3a	developing a holistic and integrated design perspective	ability to design with a holistic and integrated approach, as opposed to discipline-bound design studios with individually-led projects
	3b		learned about holistic thinking and system integration in design at an earlier stage in their education
	3c	learning to reformulate the design brief	learned to extract and respond to user needs in an architectural project
expansion of knowledge	4a	beyond curriculum learning	acquired knowledge on a structural system that is not typically included in the curriculum
	4b		acquired higher-level knowledge through research and articles
	4c	beyond curriculum learning on environmental sustainability	developed a capacity to learn and understand building physics and environmental design subjects and tools
	4d		learned the concept of energy performance through interdisciplinary seminars and analysis tools
ability to design with limits and constraints	5a	awareness on the constraints imposed by systems	understood how engineering systems affected the architectural design decisions through consulting with engineers
	5b	understanding on the impact of contextual, physical and local constraints on design decisions	understood decision-making in accordance with contextual conditions, logistical considerations, and performance requirements
	5c	ability to work within the limits and constraints of systems	learned to work within the limits of engineering, contextual and environmental systems
technical skills	6a	development of presentation skills	learned the importance and method of conveying their project idea and developed expression skills
	6b	learning new software and tools for analysis	developed a capacity to learn and understand building physics and environmental design subjects and tools
	6c	gaining technical drawing skills	gained assembly and envelope knowledge and detailing skills with a specific structural system
personal and organizational skills	7a	development of coordination and communication skills	acted as a bridge between different stakeholders and developed coordination and communication skills
	7b	development of conflict management and consensus-building skills	learned to facilitate diverse project solutions through compromise and consensus-building in teamwork
	7c	gaining communication skills with different stakeholders	learned to communicate project-based needs to supplier companies and communicate with team members
	7d	gaining outreach skills	sought additional consultancy beyond advisors and disciplines offered by the studio
	7e	gaining change management or iterative design skills	learned change management as the design changed with the feedback from all systems and stakeholders
	7f	gaining self-motivation skills	learned to stay motivated within the chaos of a large team
	7g	gaining resilience	learned to stay patient with team members
professional equippedness	8a	preparing for professional practice in advance	gaining unique experience toward professional career

Table 7. Formulated meanings and emergent themes from advisor experiences within the scope of the second research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Formulated Meanings (Advisors)
content of knowledge acquisition	1a	consideration of all details, not common to a typical architecture studio / learning to incorporate advice from other disciplines into design
method of knowledge acquisition	2a	designing with advice from other disciplines
	2b	fostering a professional project approach in an interdisciplinary environment rather than treating it solely as a course / improved project expression technique owing to learning from others, recognizing and addressing own shortcomings
	2c	learning to design with advice from other disciplines / acquisition of interdisciplinary vision and development of different perspectives through seminars and non-architecture advisors
	2d	learning data sources, open sources, and collection methods, such as solar radiation, rainfall data, and regional data
integration of knowledge	3a	developing a more holistic approach / bringing holistic presentations including sketches, examples, and analysis to the lessons / materialization of technical dimensions and calculations of the project in students' eyes, owing to the study's project-based nature since it serves a particular purpose
expansion of knowledge	4a	familiarization with systems other than reinforced concrete and discovering their potential in design
	4b	acquisition of values and experience in real-world problems, including sustainability, as future professionals
designing with limits and constraints	5b	understanding the influence of interdisciplinary collaboration on project concept
technical skills	6b	learning to perform sunlight and solar path analysis and use digital tools accordingly / experimenting with different software tools for building energy analysis by learning relevant parameters
personal and organizational skills	7a	gaining skills in creating mutual work time, managing the design process despite enforcements to aim for a specific target, being mutually dependent, and accepting differences of opinion
	7b	developing the experience of designing with consensus-building rather than majority decision or individual decision-making
	7c	ability to communicate well with the parties they contacted for decisions regarding system layouts
	7d	realization of insufficiency of knowledge from one's field for a successful project and seeking support from other disciplines
	7e	recognition of the collaborative nature of decision-making in architecture, understanding the influence of engineering data, embracing interdisciplinary learning and project's continuous evolution based on shared knowledge, effective self-assessment of findings, identifying areas for improvement, and gaining insights into own capabilities
professional equippedness	8a	importance of experiencing and learning the information that will be beneficial to their profession at as early as second-grade level

Table 8. Formulated meanings and emergent themes from partner experiences within the scope of the second research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Formulated Meanings (Partners)
content of knowledge acquisition	1c	an enriching experience, encouraging the students to engage in multifaceted research and requiring both collaborative and individual work
method of knowledge acquisition	2c	emergence of a collective project produced with students and experienced academics and professionals
integration of knowledge	3b	learning not to settle for the client's brief only but also to collect and analyzing own data, developing and detailing the brief based on field observation
expansion of knowledge	4a	developing a vision for new systems like modular building systems, gaining awareness of off-site building production techniques, cultivating insights into new approaches for construction methodologies
personal and organizational skills	7a	experiencing working together, dividing work, and taking responsibility for 3rd-semester students / developing individual knowledge and skills within a collaborative and collective setting persistently during the semester
	7g	long-term intensive work conducted in this studio with great benefit to the students
professional equippedness	8a	gaining insight into the architecture profession after graduation / remembering and benefitting from this process while practicing the profession of architecture / gaining a complex design awareness in the design process for future application

Table 9. Formulated meanings, thematic clusters, and emergent themes from student experiences within the scope of the third research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Thematic Clusters	Formulated Meanings
complexity	1a	burden of handling a realistic project as a student	limiting nature of design, contextual and other constraints making the studio too serious
project coordination	2a	difficulty of coordinating a large team	lack of work coordination due to the involvement of a large number of people
	2b	coordination related delays in collaborative design	large team resulting in delays in subsequent phases
	2c	partial presence of some stakeholders negatively impacted the process	lack of all advisors' and partners' full presence during all course hours resulting in integrating other-field-specific issues
schedule management	3a	progressive delays impacting peers	cumulative work resulting in delays in receiving tasks from peers to continue with one's tasks
	3b	time and scope conflict with the project's collaborative and realistic nature	conflict between formal semester duration and time required for a realistic project with a collaborative model
	3c	need for a detailed advance-planning	lack of planning in the sharing of tasks
	3d	lack of advance definition of deliverables	lack of clarity of tasks to be completed
	3e	coping with stress because of delays in predecessor work	becoming interdependent resulting in stress as the tasks were received from the teammates shortly before their deadlines
	3f	idle time impacting productivity of team members	unproductive stand-by times while waiting to receive work from peers
conflict management	4a	intragroup conflicts	social conflicts and controversies among student team members
	4b	intra-group adaptation requirements	time required to get adjusted to team members and resolve conflicts
			time required to resolve communication problems
interdisciplinary representation	5a	lack of student representation from all relevant disciplines	lack of students from other disciplines resulting in struggle to understand the subjects of other disciplines
	5b	limited engineering impact on the project outcome due to unbalanced student representation	limited number of engineering students resulting in deficiency in innovation despite the development of a functioning project

foundational knowledge	6a	lack of area-specific background	lack of subject-specific knowledge required in design process
	6b	lack of design knowledge	lack of general knowledge required in design process
	6c	lack of individual design experience	lack of foundational and individual design experience
	6d	lack of foundational knowledge and skills due to engaging lower division students	necessity of placing a studio informed by sustainability in upper division after taking a conventional design studio, building physics, BIM, etc.
	6f	task-specific knowledge	lack of developing detailed knowledge possessed by classmates due to the fragmentation of tasks
tool experience	7a	prior acquaintance with analysis tools is needed	lack of prior knowledge of tools for energy analysis
	7b	prior acquaintance with coordination tools is needed	lack of knowledge of useful tools for collaborative design
fragmentation	8a	losing holistic view of the project	lack of understanding on the whole and all aspects of the project due to the fragmentation of knowledge
diffusion	9a	feeling less accountable for the outcomes	lack of addressing individual responsibility
	9b	collective product is affected by each individual's performance and cannot be guaranteed	interdependence for speed and quality of work
individual skill development	10a	hindrance of individual creativity and accountability	limitation of self-creativity and self-responsibility due to the collective nature of decisions
	10b	the collaborative studio model led to shortcomings in self-organizational skills	lack of advantages in problem-solving and managing uncertainties due to individual work
			struggle with scope management of an individually-driven design project in the following semester
	10c	weight on analytical process hindered visual communication skill development	shortcomings in visual communication due to data-driven design

Table 10. Formulated meanings and emergent themes from advisor experiences within the scope of the third research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Formulated Meanings (Advisors)
project coordination	2c	suggested benefit of full-time contributions from various disciplines in the studio process / proposed increased instructional value with continuous involvement of all advisors / deficiencies in integrating studies conducted with the industry partner into the project
schedule management	3b	challenges on collaboration due to varying course schedules and personal life demands / difficulty of aligning specific client needs with competition requirements, potentially leading to unmet expectations / rushed calculations resulting from students' workload in other courses
	3c	delaying calculations of the water systems that should start from the beginning of the work to the end of the project
conflict management	4a	difficulty of managing differences of opinions and not being offensive on students' side
	4b	managing to adapt in the end, despite the difficulty of managing differences of opinions and not being offensive on students' side
interdisciplinary representation	5a	possible achievement of a more functional project if an engineering student team was constantly involved in the production process in the design team / lack of mechanical and electrical engineering students resulting in deficiencies in a clear expression of the solutions produced for passive strategies
foundational knowledge	6a	challenges for the students due to a lack of theoretical background in energy and building physics
	6d	hampered project efficiency due to limited program/tool knowledge and planning foundation among second-grade students / weaknesses in expression techniques due to the lower division of students
tool experience	7a	challenges in using software in a limited time frame since it was complicated or not user-friendly
fragmentation	8a	inability to thoroughly master every subject for everyone, although everyone worked in every field

Table 11. Formulated meanings and emergent themes from partner experiences within the scope of the third research objective (Source: Developed by Authors, 2024).

Emergent Themes	Cluster Codes	Formulated Meanings (Partners)
project coordination	2c	developing an uneconomical architectural project due to pushing the limits of off-site and modular construction systems / enhanced interactive industry collaboration to mitigate communication breakdowns / need to ensure that everybody is committed to the project schedule to achieve their increased contribution throughout / proposed closer process monitoring and meetings beyond official reviews
schedule management	3b	inability to solve the design in compliance with the project brief provided by the client / challenge of combining a competition project with a real problem
interdisciplinary representation	5a	suggested facilitation of peer learning by involving students from every discipline, achieving joint research in their field, and achieving explanation of the subjects to each other in the student's language / possible benefit of understanding what the other discipline does by involving students from different disciplines in the same team
	5b	suggested facilitation of students from various fields with a teacher from their discipline

A follow-up survey enlisting formulated meanings emerging from the interviews was shared with all students. Eight interviewees and an additional student responded to this survey. The follow-up survey results completed by nine student informants are presented in bar charts corresponding to three research objectives (Figure 3, Figure 4, Figure 5).

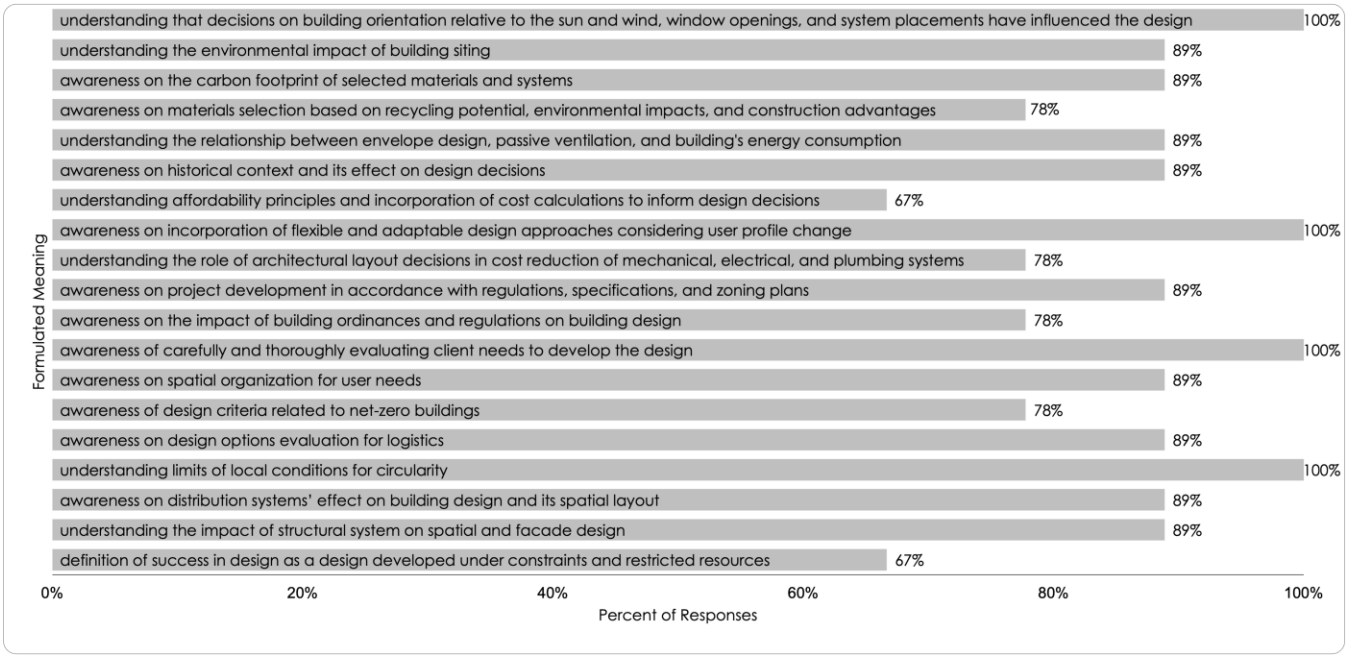

Figure 3. Percentage of students concurring with the first research objective's formulated meanings derived from peer responses (Source: Developed by Authors, 2024).

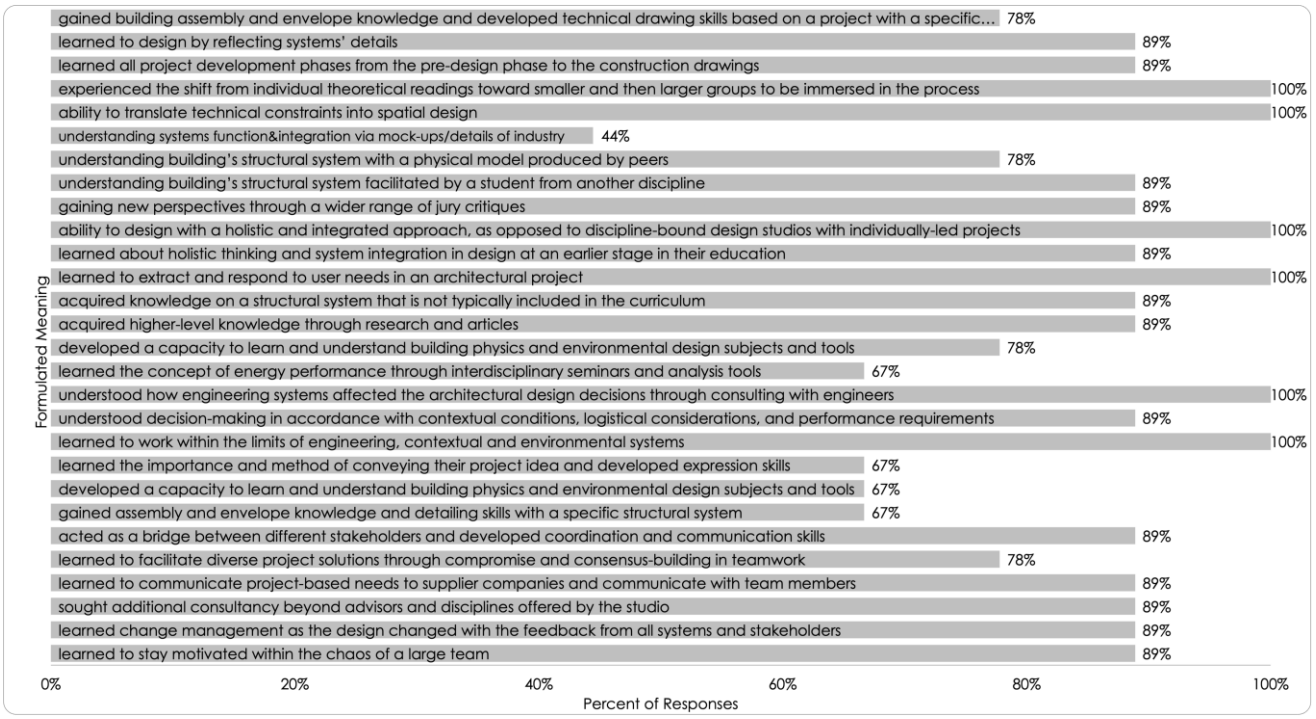

Figure 4. Percentage of students concurring with the second research objective's formulated meanings derived from peer responses (Source: Developed by Authors, 2024).

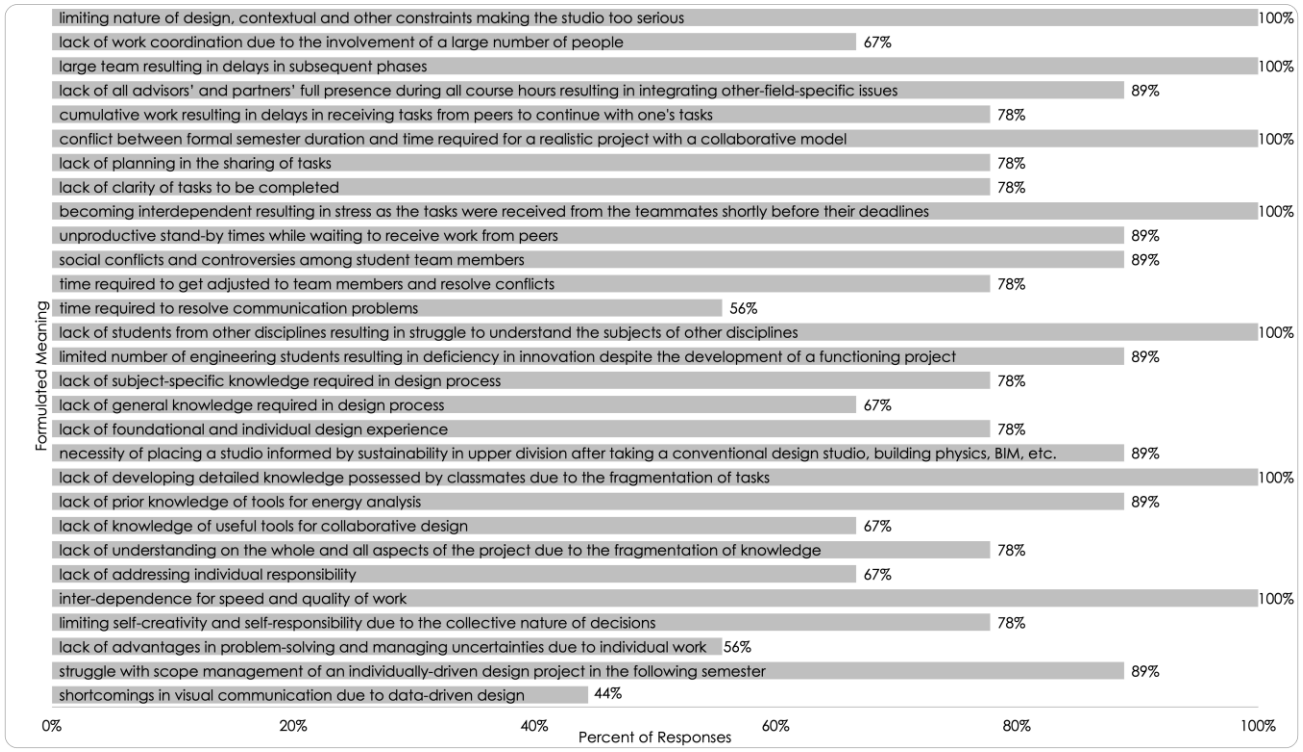

Figure 5. Percentage of students concurring with the third research objective's formulated meanings derived from peer responses (Source: Developed by Authors, 2024).

6. Discussion

Within the scope of the first research objective, an understanding of various interrelated frameworks of design and an awareness of complex design thinking come through statements that fall under the emergent themes of environmental, socio-cultural, socio-economic, and economic performance frameworks and constraints of demands and supply. All respondents reported having developed an understanding and awareness of passive systems, client factors, design adaptability, and building circularity, which are prominent subjects in contemporary scholarship on the built environment and central to sustainable development while most respondents have developed an understanding of siting-environment, design-carbon footprint, envelope-energy, form-energy, structure-form, facade-structure, design-resource, design-logistics, and several other relationships through collaborating with the other disciplines in a realistic project.

Several students articulated their unique experience in contrast to conventional studios and their grasping of design complexity and maneuvers to resolve the design:

> So, when we're designing architecture, we generally talk about it conceptually. But the action of turning it into reality goes through engineering. When this happens, of course, some of our decisions need to change. Maybe larger openings, maybe the materials on the facade changed, they weren't suitable, they didn't fit the calculations, or the static parts.

Based on their experience, one respondent underlined the grasping of complexity rather than design thinking reduced to form-making:

> I've learned that designing is a very complex thing. Because, you know, when we were doing a design in the first grade, it was always limited to what was in my head. But now, for example, I'm learning that cost is important. While dealing with engineering tasks, I realized how important the coefficient of a material used on a wall is. Or how important it is to calculate, for instance, the carbon emissions of a cooling system we use. The importance of this knowledge and skills has increased in my mind.

Parallelly, one of the team advisors, who has continued to teach the same group of students in the next studio, observed the reflection of complex thinking in the new studio:

> Most students think, 'What will be the structural system of this building? What will be the details of the structural system? How much span will be crossed? What will be the connection details?' When expressing their designs, they [other students in previous years] used to bring those volumetric things. They would bring one small cube for the initial concept. Currently, the work they bring includes structural details. They don't bring a closed volume, but they bring certain openings with structural carriers. They've started to think a bit more in detail, and their questions are in that direction. They started asking questions about the structure, about the engineering of the building, regarding their own structures. … They started coming to every class with their sketches, examples, analyses, everything. They [other students in previous years] used to just bring a sketch. They look at it more holistically now.

The research reveals an improved understanding of various design frameworks and complexities, including environmental and socio-economic factors, leading to an awareness of sustainable design principles among respondents. Students reported transitioning from conceptual to detail-oriented design thinking, influenced by interdisciplinary collaboration and real-world project experiences, demonstrating a holistic approach and a deeper grasp of design complexity.

Within the scope of the second research objective, the respondents reported learning outcomes on the 'content of knowledge acquisition,' 'method of knowledge acquisition,' 'integration of knowledge,' 'expansion of knowledge,' 'ability to design with limits and constraints,' 'technical skills,' 'personal and organizational skills,' and 'professional equippedness.' The findings underscore the profound impact of

sustainable design thinking, collaborative teaching models, and interdisciplinary learning on students' architectural education. Students gained practical knowledge and technical skills by working on projects with specific structural systems, developing the ability to design with attention to detail throughout all project phases. They transitioned from individual theoretical readings to group immersion and learned to translate technical constraints into spatial designs and understand system function and integration through industry-provided mock-ups and drawings and interdisciplinary peer learning. One student noted their experience on that:

> Consera [industry partner] had sent us an AutoCAD file. We could look at a two-dimensional drawing plan at the same time. As we roamed around and looked at it, it became three-dimensional as well. And when Ali Osman, who was in our team, modelled it once, I said, 'Oh, this is how it really is, it connects like that.' That was one of the moments when it all came together, both when I looked at that AutoCAD file and when Ali Osman made that model.

They also gained new perspectives from diverse jury critiques. Furthermore, they developed a holistic design approach, responding to user needs and acquiring knowledge not typically covered in the curriculum, including higher-level concepts in building physics and environmental design. Architecture students learned to consult with engineers, make decisions based on contextual and logistical considerations, and work within engineering and environmental constraints while the engineering student learned the impact of various factors on building loads and learned to solve a new system by consulting with partners. Additionally, they improved their communication and coordination skills, acting as bridges between stakeholders and effectively conveying project needs to supplier companies. They also learned change management, motivation, and resilience within large teams, providing them professional career experiences.

Within the scope of the third research objective, 'complexity,' 'project coordination,' 'schedule management,' 'conflict management,' 'interdisciplinary representation,' 'foundational knowledge,' 'tool experience,' 'fragmentation,' 'diffusion,' and 'individual skill development' are the emergent themes. The research findings highlight various challenges faced in the collaborative studio setting, including the limiting nature of design due to contextual constraints, lack of work coordination in large teams leading to delays, and difficulties in considering interdisciplinary issues due to the absence of all advisors and partners during regular course hours. Additionally, issues such as cumulative work delays, conflicts between semester duration and project completion time, lack of efficient task planning and clarity, and social conflicts among team members were observed. Lack of subject-specific and general knowledge and foundational and individual design experience were noted, along with challenges in adjusting to team dynamics, resolving communication problems, and managing dependencies among team members. As a consequence of this studio approach, the collective decision-making process was found to limit self-creativity and self-responsibility, and the data-driven approach hindered the development of visual communication skills compared to individually-driven projects due to allocating more time to analysis skills than representation skills. Overall, the study suggests that collaborative studios informed by sustainability should be preceded by individual design studios and take place in the upper division after the relevant coursework to address these challenges effectively.

7. Conclusion

In conclusion, this study highlights the imperative for architectural and engineering education to adapt to the complexities of the 21st-century built environment. The sustainable design objective acted as a tool to respond to the need for complex design thinking facilitated by interdisciplinary collaboration. This study reveals an improved understanding of design frameworks and sustainable principles among students, facilitated by real-world project experiences enabled by the engagement of various stakeholders. The findings emphasize the importance of transitioning from conceptual to detail-oriented and integrated design thinking and developing holistic approaches to address contemporary

challenges. Moreover, the study highlights the need for education to equip students with multifaceted knowledge, technical skills, and critical perspectives while addressing coordination, communication, and interdisciplinary integration challenges. Through this study, the authors shared a specific studio model that can be improved continuously for future implementation and adapted by other schools of the built environment.

Ultimately, the research contributes to ongoing discussions on integrating knowledge and bridging education and practice in architecture and engineering, advocating for interdisciplinary and collaborative models that prepare students for the dynamic and interconnected realities of professional practice and the world in general.

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An Overview of the Effects of Passive Solar Strategies on Thermal Comfort

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ABSTRACT

The paper presents the impact of passive solar strategies on residential buildings concerning the thermal comfort factor. This study focuses on passive solar design elements like orientation, shading, and thermal mass to offer improved energy efficiency and occupant comfort. With a global natural gas crisis looming, interest in alternative heating and cooling is surging. With the growing concern of reducing the energy use by buildings while maintaining proper thermal comfort, both in cold and hot climates, the interest shifts to passive solar strategies. In this view, 547 publications have been analysed to reveal knowledge gaps and trends in the research. The bibliographic and thematic analysis techniques identified some approaches to passive solar design but no dominant method. Further, the study found under-researched areas within themes that appeared established. The authors have finally concluded with calls for further research and collaboration across institutions and nations to address these gaps and develop effective passive solar strategies. These findings contribute to sustainable architecture by pointing out the pros of applying passive solar strategies to reduce heating and cooling loads. In this respect, this was an original approach since it brought both quantitative and qualitative data together to measure thermal comfort. This is further underpinned by raising the need for energy-efficient building designs as measures toward mitigating climate change impacts.

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1. Introduction

Since most people spend 90% of their time indoors and rely on mechanical air conditioning and heating, buildings are now the world's biggest energy consumers (Cao, Dai and Liu 2016). Over 40% of all energy used worldwide and over 30% of all CO2 emissions are generated by buildings, which consume a considerable portion of this energy (Yang, Yan and Lam 2014). Architecture must incorporate sustainable design methods due to increased energy usage and environmental concerns, a promising method to improve indoor thermal comfort (Gou, et al. 2018). A special focus is placed on ventilation approaches that use air and other renewable energy sources as ambient energy, as well as how they interact with heating and cooling systems (Omer 2008). Reducing dependency on mechanical heating and cooling systems has emerged among these strategies: passive solar design. By

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reducing power consumption, passive design is a strategy that can lower the demand for energy in buildings.

The capacity of passive solar strategies to offer long-term and affordable solutions for indoor thermal comfort has driven them to gain increasing popularity. This is accomplished by maximising heat loss through the use of the building's design, orientation, and materials. Its efficiency can be greatly influenced by climatic factors and architectural concerns, but it can increase indoor thermal comfort and lower energy usage in buildings. Designers of buildings can maximise the use of passive solar strategies to obtain the best thermal comfort and efficiency in a variety of climatic conditions by carefully evaluating a range of elements and using computer modelling tools. For instance, a study (Tawil, et al. 2018) carried out in Libya showed how passive heating and high thermal mass with passive cooling might provide indoor thermal comfort throughout the nation, avoiding the need for active solar or conventional heating and equipment. Grid energy management can also benefit from passive solar strategies like collector-storage wall systems using phase-change materials. Traditional architecture also offers inspiration for passive solar strategies, especially in tropical climates where traditional houses utilise natural lighting and ventilation to achieve indoor thermal comfort. Additionally, the effectiveness of passive solar strategy has been proven in numerous locations throughout the globe. Passive solar strategies provide a more natural and peaceful indoor thermal environment and save electricity.

The study's main aim is to determine the passive solar strategies for influencing residential building thermal comfort. The variables of passive solar design, like orientation analysis, shading, and thermal mass, are considered to explain their effect on indoor thermal conditions. The objective is, therefore, how effective the strategies would be in enhancing thermal comfort while reducing energy consumption for heating and cooling.

The present study is conducted with the notion of alleviating the growing energy use in residential buildings. Since climate change has turned into an acute global challenge, there is a serious urgent need for sustainable building practices that improve the thermal comfort class while reducing energy use. This research work will assess how effective passive solar design strategies are in improving thermal comfort and energy performance in a building. The research questions, therefore, are geared toward establishing major passive solar design elements that provide a most important contribution to thermal comfort and energy efficiency. This study, therefore, provides significant insights—actionable for architects, builders, and policymakers. Some unique points of this research are as follows:

1. Latest and Wide Time Range: The study was founded on a period of the last 40 years; hence, from 1982 up to 2022, it is very broad and very recent but lacking in information from 2023.

2. Worldwide Overview: It contributes to the determination and evaluation of passive solar strategies and their efficiency in various parts of the globe. All of these categories are discussed in detail.

3. Systematic Classification: Systematic classification of factors and methods that were in use very frequently in passive solar strategies has been done. This classification is based on similarities and differences. It covers key elements and advantages. Current development status of the field was explored, whereby a table showing data gathered with features such as publication year, source, authors, type of publication, number of methods combined and used and the primary purpose either cooling or heating.

4. Identification of Potential Studies: Several potential studies on passive solar cooling and heating solutions were identified in the review, pointing out avenues of future research.

5. Bibiliometric and Bibliographic Analysis: With its focus on bibliometric and bibliographic analysis, this paper locates the major contributors and co-citation, direct citation networks, and bibliographic coupling networks for assessing and analysing research activities that have been working effectively.

6. Thematic Review: The identification, and in-depth examination, of themes emerging from the literature was done with MaxQDA. This tended to bring greater clarity regarding the trends and themes dominant in the field.

1.1. Brief history of passive solar strategies and purpose

Recent years have seen a rise in the popularity of passive solar techniques as a practical means of achieving thermal comfort within buildings while consuming less energy. Utilising the sun's free heat and light to reduce the need for heating and cooling systems lowers energy costs and encourages more environmentally friendly building techniques. The climate in which they are employed can, however, affect how effective passive solar techniques are. Passive solar techniques in hot climates must be carefully planned to prevent overheating, whereas in cold climates they must be planned to optimise sun gain while avoiding heat loss (Stutz, et al. 2017). Passive solar methods are becoming more and more popular as a realistic way to achieve indoor thermal comfort while lowering energy usage in buildings. The effectiveness of the principles of passive solar design in terms of indoor thermal comfort has been examined in numerous studies (Huang, et al. 2007) (Hou, et al. 2021; 2020) (Zhao, et al. 2020) and has been applied to a variety of climates around the world. These studies demonstrate that passive solar techniques can considerably increase thermal comfort indoors, even in harsh climates. For instance, in a hot and humid area, passive solar techniques like shade, natural ventilation, and thermal mass can cut inside temperatures by up to 8°C compared to conventional structures. This strategy makes use of the sun's natural heat and light to cut down on the demand for heating and cooling systems, leading to lower energy costs and a more environmentally friendly structure. The climate in which passive solar techniques are used, however, can affect how effective they are. To prevent overheating in hot areas, passive solar methods must be carefully planned, whereas in cold climates, they must be planned to optimise solar gain while reducing heat loss (Stutz, et al. 2017).

Numerous studies have looked at the usefulness of passive solar design concepts in terms of indoor thermal comfort (Gou, et al. 2018) (Huang, et al. 2007) (Kapsis, Dermardiros and Athienitis 2015). Passive solar design principles have been used in numerous parts of the world with a variety of climatic conditions. These studies show that even in the most severe regions, passive solar techniques can greatly increase indoor thermal comfort. For instance, passive solar techniques like shading, natural ventilation, and thermal mass can lower indoor temperatures by up to 8°C as compared to traditional buildings in hot and humid conditions (Randjelovic, et al. 2021). To access solar radiation, though, some requirements must be met. For instance, the sun's position is influenced by the principles of building facades (solar altitude and azimuth), the slope and orientation of the site, any obstruction present on the site, and the potential for shadowing caused by obstructions outside the building (Lotfabadi 2015).

Passive solar techniques can also help in cold climates to cut energy use and increase thermal comfort. For instance, a Canadian study indicated that a passive solar house maintains a more constant interior temperature while using 60% less energy to heat than a conventionally constructed house (Kapsis, Dermardiros and Athienitis 2015). Standard passive solar solutions for cold places include increasing solar gain through south-facing windows, storing heat through thermal mass, and reducing heat loss through insulation and airtightness (Marszal, et al. 2011). The effectiveness of passive solar methods can be affected by a variety of elements, including building orientation, shading, glazing characteristics, and ventilation, even if they have demonstrated potential in terms of improving thermal comfort indoors and reducing energy use (Ahmed, Kumar and Mottet 2021). For instance, a study carried out in Spain discovered that the effectiveness of passive solar solutions was greatly influenced by the orientation of the structure, with south-looking buildings performing noticeably better than those facing other directions (Sun, et al. 2020). Like how shading from nearby structures or vegetation can lessen the efficiency of passive solar techniques and raise the requirement for artificial heating and cooling, (Randjelovic, et al. 2021) shading from nearby structures and vegetation can also limit solar gain.

Building designers must carefully consider several aspects to enhance the efficiency of passive solar solutions, including the building's orientation, glazing characteristics, shading, thermal mass, and ventilation. The performance of various design options may be modelled using computer modelling tools, and passive solar techniques can be deployed more effectively in a variety of climatic situations. (Marszal, et al. 2011).

1.2. Passive Solar Strategies

According to the research, the idea of passive solar design can easily be incorporated into a house at the planning stage (Morrissey, Moore and Horne 2011). This was reflected in a good number of the publications analysed in the study, as captured in Figure 2. Several of the articles explored the tendency for future growth or further research. Passive solar building designs are gaining popularity to save energy and reduce the environmental effects of construction. According to Stevanović's (Stevanović 2013) examination of simulation-based optimisation research, sunspaces are among the passive solar design options that can successfully reduce a building's energy demand. The implementation of energy-efficient and affordable passive solar heating systems was examined using a variety of approaches and resources. A range of passive solar approaches have been explored in the study to maximize natural sunlight and manage solar gain through shadow. Improved building orientation, for example, and the addition of internal greenhouses or sunspaces have both been shown to be beneficial passive solar solutions for decreasing energy demand for heating while increasing solar heat. Passive solar design solutions, such as sunspaces, have proven to considerably cut building energy usage (Stevanović 2013). Furthermore, research on the influence of sunspaces on buildings has been underway for years, demonstrating their potential to lower the demand for heating energy and the use of fossil fuels.

The numerous passive solar techniques covered in the review may be classified into the following groups:

1.3. Passive Solar Cooling

1.3.1. Thermal Mass

It is best to shade all of the windows during the summer months with overhangs or other coverings like shading, shutters, and framework. A south-facing window with a sunshade that covers half of the window's height can screen summer sunrays while letting in winter sunrays when the sun is lower on the horizon at sunrise and sunset (Kuczyński, et al. 2021). Since the sun's angle is lower in the morning and afternoon, overhangs on windows facing east and west are less effective. Employing plants to provide shade or reducing the number of windows that face east and west can be effective for cooling. Generally speaking, one can use landscaping to block summertime heat gain (Zhang, He and Yang 2010).

1.3.2. Ventilation

Natural ventilation is effective in keeping indoor temperatures close to outdoor temperatures, making it a cooling method when indoor temperatures are equal to or higher than outdoor temperatures (Gross 2021). The most suitable natural ventilation strategy will depend on the current climate. In areas where the daytime wind blows, and daytime ventilation is advantageous, it is advisable to open windows on the sides under and opposite the building to ensure cross ventilation. During the design phase, windows should be installed on walls opposite the prevailing wind. Wing walls can improve ventilation by connecting windows to walls perpendicular to the prevailing wind. Strong vertical panels placed at right angles to the wall between the two windows can increase the natural wind speed by taking advantage of the pressure difference created by the wing walls.

1.3.3. Convective Cooling

Convective cooling is an ancient method used to bring cool nighttime air from the outside and expel hot interior air. High vents on the leeward side help escape hot air near the ceiling, while low vents on the windward side allow cool air to flow in (Ketwong, Deethayat and Kiatsiriroat. 2021) In regions without consistent breezes, thermal chimneys can nonetheless accomplish convective cooling by creating a region of warm or hot air and include a high outer exhaust opening. Warm air is expelled from the building via the upper vent, while colder air is brought in through the lower vent. An illustration of this concept may be seen in a sunroom that is connected to the south side of a building and has vents at the top. In this setup, air is pulled from the main living area and then discharged via the upper vents. (Saraei and Moujaes 2021).

1.3.4. Shading

During the summer, it is best to darken all windows with curtains or other coverings such as blinds, shutters or nets. South-facing windows with half-height window shades block summer sunlight and allow winter sunlight to penetrate low on the horizon at sunrise and sunset. Due to the low angle of sunlight during morning and afternoon, projections on windows facing east and west are ineffective. Utilising vegetation for shading or decreasing the quantity of windows facing east and west to enhance cooling efficiency (Yao and Zheng 2017). In general, landscaping can be used to combat the summer heat.

1.4. Passive Solar Heating

1.4.1. Indirect Gain

The thermal body, positioned between the sun and the living area, captures solar radiation and transfers it to the living space. Indirect gain systems use around 30-45% of the solar energy that is absorbed by the glass adjacent to the thermal mass. A popular example is the Trombe wall, which incorporates a 15–18 cm --thick brick wall beneath a single or double layer of south-facing glass. The black outside surface collects solar heat, stores it in bits, and then distributes it into the living room. The heat is transported to the room when the internal temperature goes below the wall temperature (Pucar and Despic 2005). Operational vents at the top and bottom of the heat storage wall allow heat to bubble between the wall and glass and closing these vents at night guarantees radiant heat continues to warm the living space.

1.4.2. Direct Gain

The living space itself acts as a solar collector, absorbing and releasing heat. The south-facing glass allows solar energy to enter the home, interacting with the dark brick floors and walls. This material absorbs and stores solar heat during the day and transmits it indoors at night. The thermal mass also absorbs energy, which helps regulate the heat intensity during the day. Water tanks in living spaces can store heat, but their integration requires careful structural support. Direct-gain systems efficiently use 60–75% of solar energy through windows (Esen 2000). To optimise this system, it is very important to insulate the thermal mass from the outside temperature to prevent the spread of the received solar heat. Heat losses occur mainly when heating elements come into direct contact with the ground or when the outside air cools.

Optimising a building's orientation for optimal solar heat gain during the winter and less during the summer is crucial. This involves aligning the structure along the east-west axis, using southern exposure for windows, and placing shade components to minimise heat gains. Additionally, adding sunspaces or internal greenhouses can help capture and retain solar energy, reducing heating energy demand.

These areas serve as a barrier between the inside of the building and the outside, storing and slowly releasing heat back into the structure. (Stevanović 2013) The research discovered that sunspaces were beneficial in lowering energy usage in buildings. Thermal mass materials like concrete or masonry help control indoor temperatures by absorbing and dissipating heat, eliminating the need for additional heating or cooling technology. Proper insulation and air sealing are crucial for maintaining acceptable interior temperatures and reducing energy losses. Shade mechanisms like blinds, louvres, and overhangs can also help decrease solar heat gains and glare, thereby significantly reducing energy use.

Numerous studies on passive solar design solutions have been undertaken, as represented in the review. Here are a couple of such examples:

- Researched and analysed simulation-based optimisation studies that sought to assess the efficiency of passive solar methods such as sunspaces in lowering energy consumption in buildings. This study aimed to discover significant metrics and variables that determine the performance of various techniques (Stevanović 2013).
- The European research project OFFICE (Optimisation of Facades for Integrated Concepts of Energy and Environment) (2008–2011) (He, et al. 2021) investigated several techniques and technologies for implementing passive solar heating systems that are both economical and energy-efficient in buildings. The goal of the study was to look at how modern materials, components, and technologies may improve energy performance.
- Thermal Balance for Efficient Heating and Cooling" looks at numerous passive solar design solutions, such as properly designed windows, walls, and other components, as well as the usage of thermal storage walls and vented Trombe walls (Athienitis, et al. 2015).
- Released "The Solar House: Passive Heating and Cooling," a book that explores the basics of passive solar architecture and gives in-depth research and case studies on successful passive solar projects (Chiras 2002).
- Undertook research to look at how occupant comfort and well-being were affected by passive solar design measures. It examines how thermal comfort, natural lighting, and ventilation affect a building's overall performance. These studies, along with others, show how progress and research are continuous (Arif, et al. 2016).

2. Methodology

The Framework for Literature/Thematic Review

The following processes constitute the framework utilised for reviewing the literature, as illustrated in Figure1.

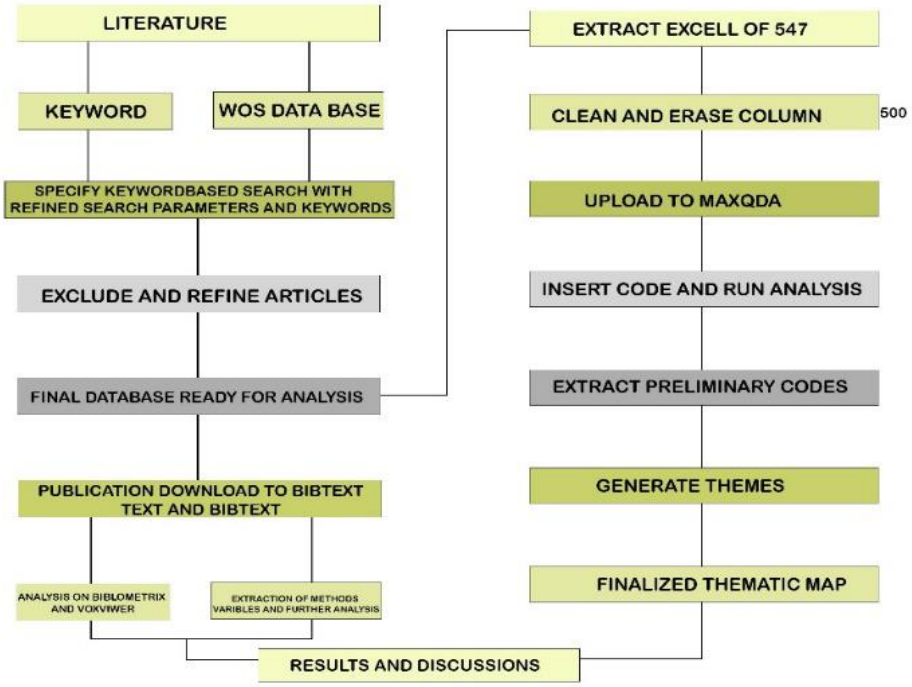

Figure 1. Methodology Framework (Source: Author)

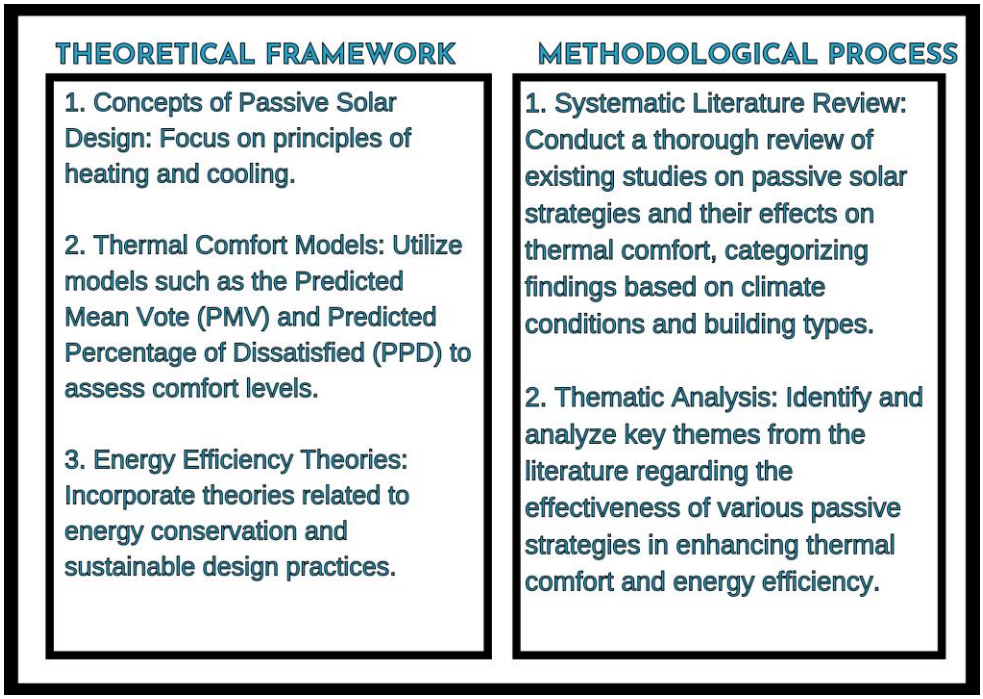

Figure 2. Theoretical Framework and Methodological Process (Source: Author)

A broad keyword search using the Web of Science database was performed to identify the most pertinent sources, conduct a more focused keyword search using bullions to refine the expected results and ensure a more precise search criterion. A more precise keyword will help identify the most relevant resources; conduct a more focused, refined search. The final list of sources was assembled using the following criteria: The practice of using passive solar techniques to cool, heat, or provide thermal comfort in specified climates or various/different temperature zones. A set of standards was developed to distinguish between the use of passive solar for heating and cooling. Analysing sources in-depth and extracting data that is pertinent to thermal comfort, passive solar techniques, and the qualities mentioned in the data collection section. Descriptive analysis was performed on all the data. To discover bibliometric networks, a bibliometric and biographic study of sources mentioned in the Web of Science was conducted. A more detailed cleaning of the data on Excel was done, bringing the total number of papers ready for thematic review to 500, ready for import on MaxQDA. Codes within MaxQDA were created to represent key themes and patterns identified in the literature. Descriptive analysis was performed on all collected data, providing an overview of the characteristics, trends, and patterns identified within the literature. Discussions (findings, interpretation, implications for future research, ideas for further research, etc.). Integrating insights from bibliometric analysis with RStudio and VOS Viewer and the thematic review within MaxQDA enriched the overall depth of the discussions.

The resulting measures or metrics in bibliometrics are often counts of the observed frequency of events of a given type, which, when expressed as ratios of the total number of recorded events, may be regarded as probabilities of occurrences (Borgman and Furner 2002). This strategy is used to evaluate the most cited sources, analyze research innovations, and identify journals with the most published work in a specific field of study. For this study, bibliometric analysis helped the assessment of literature by identifying collaboration in research, citation analysis, and how far research in this field has progressed, among other things see Figure 2. Co-authorship, direct citation, keyword occurrence network, and bibliographic coupling are examples of parameters. The software bibliometrix (version 4.2.2) and VOS viewer (version 1.6.19) were used to evaluate the bibliometric investigation. The analytical results contributed to the data collected, which was then included in the findings.

2.1. Alternatives Thematic Review

A thorough examination of the literature within a particular topic or conceptual framework is what a thematic review entails. Finding and examining patterns of meaning in text data is the process of thematic analysis, a qualitative research technique (Boyatzis 1998, Braun and Clarke 2006, Guest, MacQueen and Namey 2011). Numerous techniques, including theme mapping, memo writing, and coding, can be used to accomplish this (Braun and Clarke 2006). One piece of software that can help with thematic analysis is called MaxQDA. According to (Braun and Clarke 2006), it offers a range of tools for organising and evaluating text material, such as note writing, theme mapping, and coding. Identifying and analysing themes in a text dataset is part of the process of doing a thematic review with MaxQDA Figure 3. The following steps are usually involved in the process:

Data import: The text data must first be imported into MaxQDA. There are several ways to accomplish this, including importing a CSV file, copying and pasting the data into a text box, or using a data-gathering tool that exports to MaxQDA. However, in this particular scenario, an Excel file was imported.

Coding: Coding the text data is the next stage. Coding is the process of giving labels to text passages that illustrate various topics. Numerous coding techniques, including inductive, deductive, and hybrid coding, are available for usage (Braun and Clarke 2006).

Memo writing: Making notes about the coded data is the process of composing a memo. Memos are useful for jotting down ideas, observations, and analyses of the data.

The technique of graphically expressing the coded data is known as "thematic mapping." Numerous techniques, including the creation of these networks, thematic maps, and thematic trees, can be used to accomplish this (Braun and Clarke 2006).

Interpretation: Understanding the topic's findings is the last stage. This entails formulating judgements based on the data and establishing links with the larger body of literature.

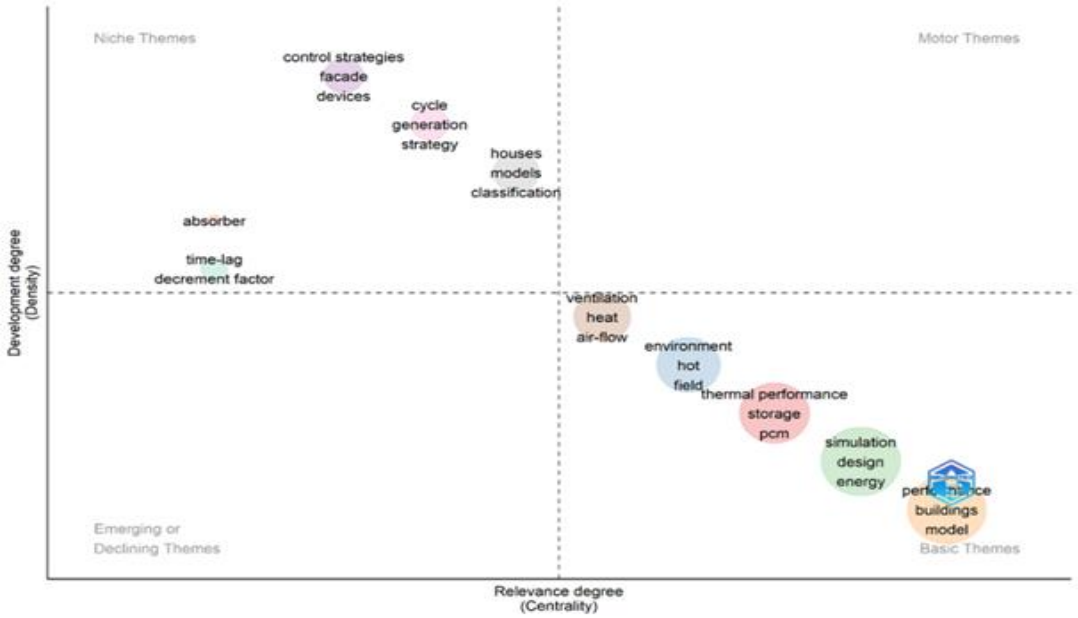

Figure 3. Thematic Map (Source: Author)

2.2. Data collection

The primary publishing source was determined to be the Web of Science (WoS) database. From general to specific, the data was gathered in that sequence. All languages and documents from the Web of Science's history (up to 2022) were included in the search. A broad keyword search produced a lengthy list of 10692 articles. We reached 10547 items after 2023 was removed. 8040 articles were offered in total to refine it. The final filtering resulted in a specific list of 1426 publications from the Web of Science. The articles underwent a more thorough cleaning process to remove irrelevant ones and ensure that only articles closely related to the fields were left. This decreased the overall number of papers used for the analysis to 555. However, the final list consisted of 547 documents, which were used to run the bibliometric analysis. Furthermore, the data in Excel format was further streamed to a total of 500 articles, which were used for the thematic analysis. To gather the most recent findings, a survey of the scholarly literature from 1982 onward was conducted. In the final list, more than 65% of the publications were published after 2015. The timeline of publication, as captured in Figure 4, depicts the total number of publications considered in the study from the graph, there has been an increasing trend up until 2015 and 2017, a noticeable decline in 2018, and an even lower decline in 2022. Several factors might have contributed to the decline of the research into passive solar strategies and their implementation from 2018 to 2022. Economic priority changes may have reduced the investment in sustainable building research during periods of financial instability and shifted funds to more immediate concerns. Changes in technology for alternative solutions, like advanced photovoltaics, battery storage, or active solar systems, could have eclipsed passive solar strategies, focusing attention and funding on their perceived efficiency. It has probably seen a decline because of changes in government policies and building codes, as well as a shift in the market to faster and more inexpensive construction methods. In addition, funding research into other pressing issues or new technologies might have been realigned. Global events, such as the COVID-19 pandemic, could have relocated research efforts into health-related areas from studies on passive solar strategies. The field perhaps reached a saturation point beyond

which major discoveries were made and published; research activity then began to naturally decrease as the field matured. All these factors call for attention so that interest and investment in passive solar strategies can be re-awakened, stressing their place as key players in sustainable building practices for energy efficiency by offering real-life experiences in their applicability and practical advantages.

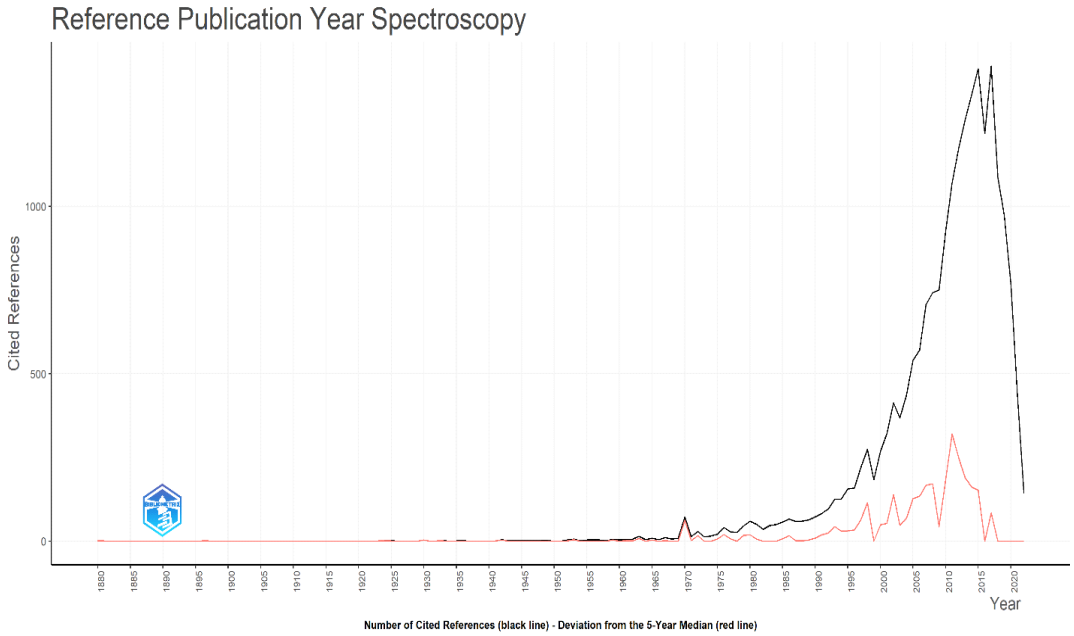

Figure 4. Timeline Publication (Source: Author)

3. Results

3.1. Bibliometrics Analysis

A well-liked and precise method for analysing and understanding a vast amount of scientific data is bibliometric analysis. It enables us to highlight the boundaries of an area and explore the complex details of its evolutionary history. In recent years, bibliometric analysis has grown in popularity in the scholarly community (Donthu, et al. 2021). According to (Godin 2006), bibliometrics was originally addressed in the 1950s, showing that the approach is not new. The growth of scientific research is particularly related to the proliferation of bibliometrics-based publications, which has increased over time, with an average of 1021 articles during the last ten years. However, due to the complexity and impracticality of applying typical review techniques to large bibliographic databases.

It is noteworthy that the growth of scientific databases like Web of Science, PubMed, and Scopus has made it quite simple to obtain substantial amounts of bibliometric data, spurring an increase in bibliometric analysis interest among academics in recent years. Scientific databases as well as bibliometrics tools like R Studio, VOS Viewer and Leximancer are improving accessibility and broadening the field's appeal. The quantitative evaluation of bibliographic data is known as bibliometrics, and it is a field of library and information studies. The best outcomes of a set of bibliographic items are typically summarized using bibliometrics. Numerous bibliometric studies on a variety of topics are accessible in the literature. Bibliometric methodology is the practice of applying quantitative approaches to bibliometric data, such as units of publishing and citation (e.g., bibliometric analysis, and citation analysis).

Whereby the use of bibliometrics may be used for everything from assessing publications to examining cooperation trends to investigating the intellectual hierarchy of a study topic. In this instance, journals

may also reflect the research field. Journal reviews have been provided using the bibliometric technique. Now is the time to compare bibliometric analysis to other often employed review alternatives, like systematic literature reviews and meta-analyses (Ramos-Rodríguez and Ruíz-Navarro 2004). Meta-analysis and bibliometric analysis both rely on quantitative methods as opposed to systematic literature reviews that typically employ qualitative techniques and may be distorted by interpretation prejudice from academics with diverse backgrounds (Donthu, et al. 2021). Therefore, they can prevent or mitigate this prejudice.

In this study, bibliometric analysis was performed on the 547 WOS -referenced articles. To list the most important associations or authorities in the field of study, Figure 5 was created, showing the affiliations that the researchers are listed under. The organisation with the most publications is denoted by the affiliation with the longest stroke, and the circles next to it show the organisation's greatest impact (number of papers published). In addition, a list of the top 10 affiliations in the research region with the most publications was presented; the aforementioned ten affiliations are indicated on the map by signatures. The majority of the 547 publications (36 of them) were written by authors from Tianjin University in China, followed by Xi'an University of Architecture and Technology (34 publications) and Chongqing University of China (29) in that order. There is also a strong relationship between the various titles associated with the study area and the author affiliations and author countries this is well represented in Figure 4.

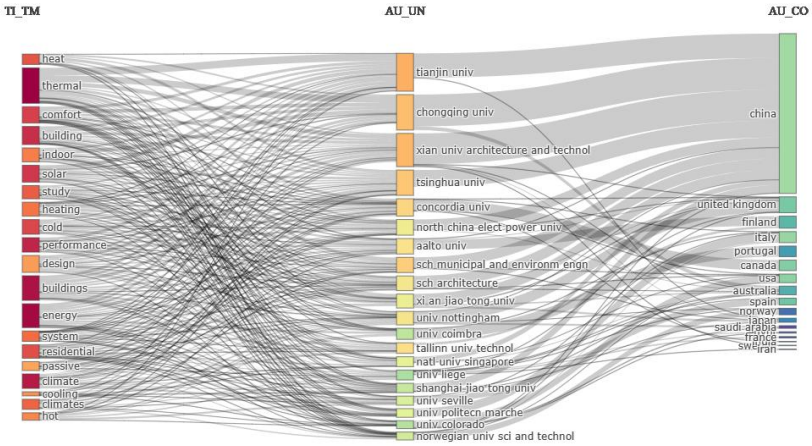

Figure 5. Three-field plot (Source: Author)

There were 15364 total citations for the publications that were considered in this study. The rest of the 547 articles have an average of roughly 28 citations on each one. Journals are also examined in terms of production over time. Determined in Figure 4 are a trend line and the years of production that were above the trend. With over 170 articles published in the Energy and Buildings journal in 2021, this shows a rise in interest in specific journals.

The data was acquired during the literature research, which served as a framework for additional quantitative analysis. The consolidated table (Table 1) has the 25 most cited articles. Providing details on the important characteristics of the research location, as well as the passive solar strategy used. The essence and differences of each approach utilized in the research field will be discussed in the last section. In addition, information on approach combinations, as well as a discussion of the merits and downsides of each methodology, will be presented.

Table 1. Showing the most cited publications in the review (Source: Author)

S/No	Name	Year	Title	Journal	No of Citations	References
1	Givoni. B	1992	Comfort, Climate analysis and building design guidelines	Energy and Buildings	266	(Givoni,1992)
2	Yu. W	2015	Application of Multi-Objective genetic algorithm to optimize energy efficiency and thermal comfort in building design	Energy and Buildings	249	(Yu,etal.2015)
3	Liu.Z	2017	Feasibility and performance study of the hybrid ground-source heat pump system for one office building in Chinese heating-dominated areas	Renewable Energy	166	(Liu, Xu and Zhai, et al. 2017)
4	Leckner.M	2011	Life cycle cost and energy analysis of a Net Zero energy house with solar combi system	Solar Energy	159	(Leckner and Zmeureanu 2011)
5	Jokisalo. J	2009	Building Leakage, infiltration and Energy Performance analyses for Finnish detached houses.	Building and Environment	146	(Jokisalo, et al. 2009)
6	Hobbi.A	2009	Optimal design of a forced circulation solar	Solar Energy	135	(Hobbi and Siddiqui 2009)

			water heating system for a residential unit in a cold climate using TRNSYS			
7	Rad. F.M	2013	Feasibility of combined solar thermal and ground source heat pump systems in cold climate, Canada	Energy and Buildings	133	(Rad, Fung and Leong 2013)
8	Emmi. G	2015	An analysis of solar-assisted ground source heat pumps in cold climates	Energy Conversion and Management	114	(Emmi, et al. 2015)
9	Maerefat.M	2010	Passive cooling of buildings by using integrated earth-to-air heat exchangers and solar chimneys	Renewal Energy	113	(Maerefat and Haghighi 2010)
10	Thalfeldt .M	2013	Façade design principles for nearly zero energy buildings in a cold climate	Energy and Buildings	112	(Thalfeldt, et al. 2013)
11	Pereira. L.D	2014	Assessment of indoor air quality and thermal comfort in Portuguese secondary classrooms: Methodology and results	Building and Environment	111	(Pereira, et al. 2014)
12	Papadopoulos.A.M	2002	Feasibility of Energy-saving renovation measures in	Energy and Buildings	111	(Papadopoulos, Theodosiou and Karatzas 2002)

			urban buildings.The impact of energy prices and the acceptable payback time criterion			
13	Gaurino.F	2017	PCM thermal storage design in buildings: Experimental studies and applications to solaria in cold climates	Applied Energy	109	(Guarino, et al. 2017)
14	Ozel.M	2013	Determination of optimum insulation thickness based on cooling transmission load for building walls in a hot climate	Energy Conversion and Management	107	(Ozel 2013)
15	Bakirirci. K	2011	Energy analysis of solar-ground source heat pump system with vertical closed-loop for heating applications	Energy	107	(Bakirci, et al. 2011)
16	Zhang. A	2017	Optimization of an ultra-high CPV Casse-grain Koehler unit 200x Concentration Ratio	Energy Building	105	(Ferrer-Rodriguez,etal.2019)
17	Okeil.A	2010	A holistic approach to energy-efficient building forms	Energy and Buildings	105	(Okeil 2010)
18	Ismail. K.A. R	2008	Comparison between PCM-filled glass	Energy and Buildings	103	(Ismail, Salinas and Henriquez 2008)

			windows and absorbing gas-filled windows			
19	Freewan A.A. Y	2014	Impact of external shading devices on thermal and daylighting performance of offices in hot climate regions	Solar Energy	102	(Freewan ,2014)
20	Stazi. F	2012	The behaviour of solar walls in residential buildings with different insulation levels:An Experimental and Numerical study	Energy and Buildings	99	(Stazi,Mastrucci and di Perna 2012)
21	Sokhansefat. T	2018	Thermo economic and environment analysis of solar flat plate and evacuated tube collectors in cold climatic conditions	Renewable Energy	98	(Sokhansefat, et al. 2018)
22	Fang. Z	2014	The effect of Building envelope insulation on cooling energy consumption in summer	Energy and Buildings	98	(Fang, et al. 2014)
23	Liu. Z	2015	Investigation on the feasibility and performance of ground source heat pump (GSHP) in three cities in cold climate zone, in	Renewable Energy	97	(Liu, Xu and Qian, et al. 2015)

			China			
24	Susorova .I	2013	The effect of geometry factors on fenestration energy performance and energy savings in office buildings	Energy and Buildings	96	(Susorova, et al. 2013)
25	Nguyen .A.T	2011	An investigation on climate responsive design strategies of vernacular housing Vietnam	Building and Environment	94	(Nguyen, et al. 2011)

Visualisation of the publications and journals published and reflected in Table 1 was further clarified with bibliographic analysis.

3.2. Bibliographic Analysis

An efficient way of examining a variety of bibliometric networks is visualisation (Van Eck and Waltman 2014). In the next part, the results of the bibliographic analysis will also be reported. The bibliography reviews all co-citation networks of the researchers and serves as a presentation of co-citation analysis throughout this review. Figure 6. The top 103 writers out of 9980 who exceeded the threshold level with the minimum number of citations of 15 were utilized for visualization, and the total number of its nodes has been reduced to make it easier to understand. In the illustration, each circle stands for a different author. The circumference of a circle indicates how many citations an author has accumulated. According to co-citations, authors and journals that are positioned close to one another in the visualisation have a stronger relationship than those that are farther apart. In bibliography reviews, the researcher's co-citation network serves as a representation of the co-citation analysis conducted in this review. The circumference of a circle indicates how many citations an author has gathered. According to co-citations, authors and journals that are positioned close to one another in the visualization have a stronger relationship than those that are farther apart. Below is the list of the most cited author groups. 1. Givoni, B, (Givoni 1992). 2. Yu.W (Yu, et al. 2015). Figure 7. An analysis of documents with at least 10 citations generated figure 6 of a direct citation network which got the highest link of 197 by 386 of the 547 documents. It is very vital in determining an article's number of citations and it helps in the identification of key publications.

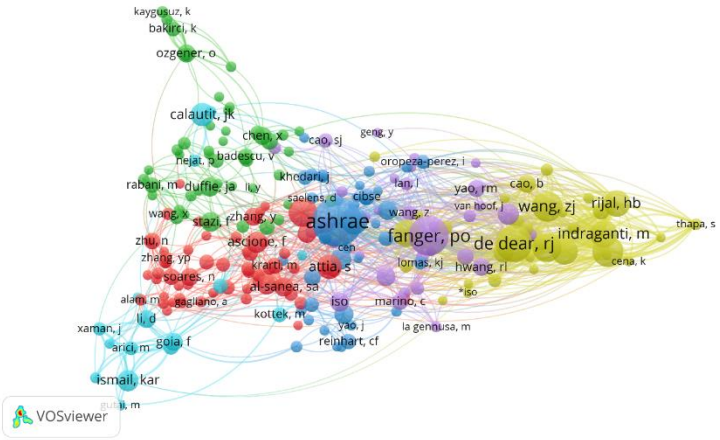

Figure 6. Direct citation network of articles (Source: Author)

The analysis of the keyword network of occurrences was conducted, to give a better insight into the words researchers use in the study field and to determine if there were new subtopics. Since keywords are related to the core content of the publications and analysis of keywords can identify critical results of studies related to passive solar strategies, figure 7 shows the overview of the keywords of a core data set of 2323 authors with a minimum number of 10 documents per author that meet the threshold.

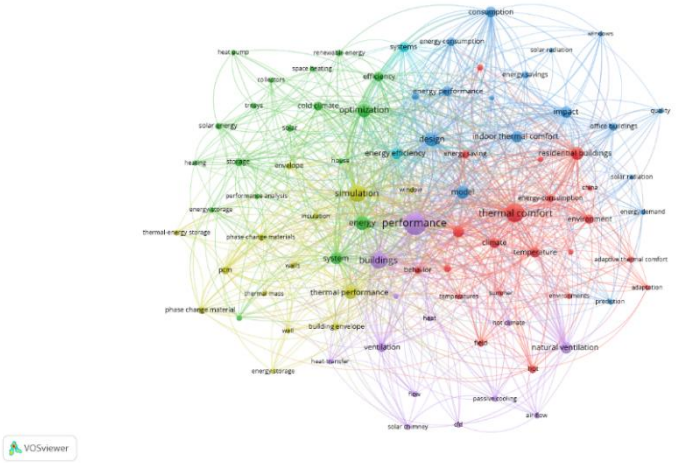

Figure 7. Co-occurrence network of keywords (Source: Author).

3.3. Thematic Analysis

To further identify patterns, trends, and recurring themes within the research area being studied and to synthesise and integrate knowledge generated from the WoS source, creating a coherent narrative that contributes to a deeper understanding of the subject. This is to further help identify gaps in existing literature, guide future investigations, and contribute to knowledge advancement in the study area. Thematic reviews inform research questions, guide methodological choices, and support evidence-based practice (Thomas and Harden 2008). They enhance literature review quality by offering a structured and systematic approach, ensuring comprehensive and well-organised reviews. They also

contribute to theory development by synthesising existing knowledge, proposing new perspectives, or modifying existing ones. They also facilitate effective communication and collaboration among researchers by providing a concise summary of existing knowledge. Overall, thematic reviews are essential for organising, synthesising, and evaluating existing knowledge, ultimately contributing to the advancement of research in a particular field.

3.4. Coding Structure

The initial code of 7, as captured in Figure 8, was applied, which yielded some considerable patterns tilting the data towards thermal comfort research. An additional 6 codes (building orientation, sunspaces, thermal mass materials, insulation and air sealing, shading, and optimisation) were added, making the total codes 13. However, the additional codes, all yielded zero appearance (see Fig.9 below), which means that none of the additional codes had an appearance of up to 3 in the 500 documents under analysis.

Figure 8. Cloud code (Source: Author)

As captured in Figure 9, with 230 occurrences, the term "simulation" is the most common one in the articles. This shows that in the subject of thermal comfort and passive solar strategies, simulation is an extensively employed methodology. With 207 documents, "cooling" is the second most common term. This suggests that to improve building energy efficiency and occupant comfort, researchers are actively investigating and debating cooling solutions. "Heating" and "thermal comfort" are mentioned somewhat less frequently, with 165 and 113 mentions, respectively. This implies that, although these subjects are significant, the present research focus may not be as focused on them. The terms "passive solar strategies" and "passive solar" occur just twelve and six times, respectively. This indicates that research on passive solar design principles is comparatively less common compared to other fields, highlighting a considerable gap in the literature.

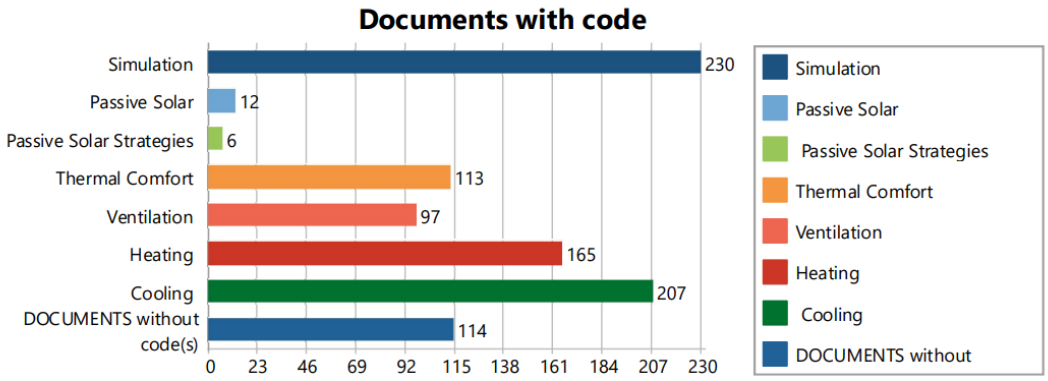

Figure 9. Showing documents with code appearance. (Source: Author)

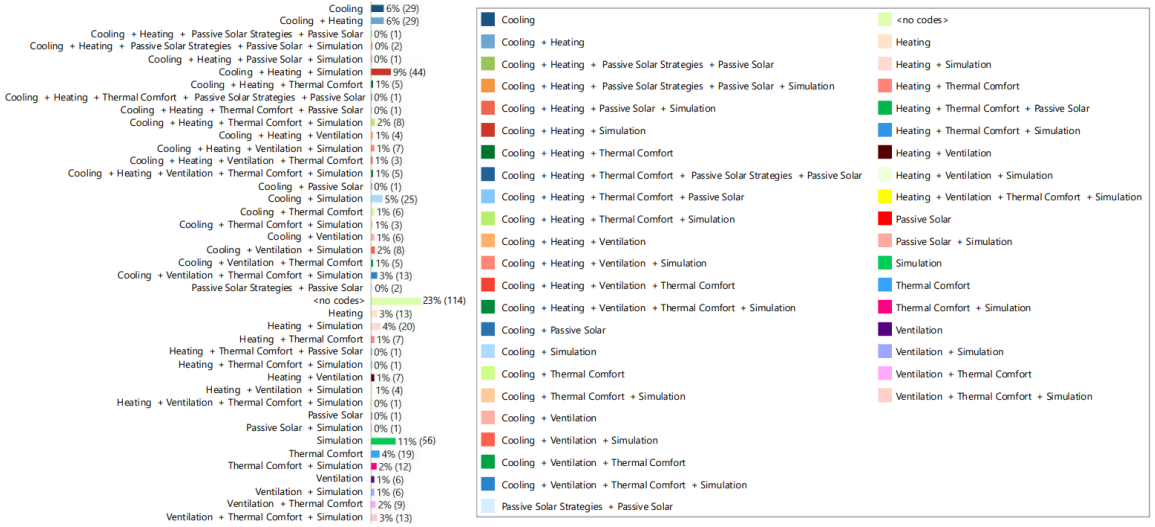

Figure 10. Showing documents with code appearance. (Source: Author)

In summary, taken as a whole, Figure 10. highlights the disparity in attention that various subtopics within the larger field of building energy efficiency receive. It implies that while thermal comfort, cooling, and simulations are extensively studied, passive solar solutions need further in-depth investigation.

4. Discussions

4.1. Results

Researchers work hard to publish articles and educate the public about the most recent scientific discoveries in various fields of interest as professors at universities. If there are more publications but no changes in the amount of energy used, what is wrong with this scenario? How can this be fixed? Since the United States and China consume more energy overall than any other nation, with China using the most electricity and the U.S. using the most oil, even though other elements affect a country's energy consumption-level of industrial development, geographic extent, style of living—the population has the greatest impact. The three most populous nations in the world are China, the United States, and third-placed India. Furthermore, the Joint Research Centre of the European Union estimates that total

worldwide CO2 emissions rose from 34.1 GT in 2010 to an all-time high of 37.9 GT in 2019. Emissions decreased to 35.962 GT in 2020 as a result of the COVID-19 epidemic and the ensuing travel and transportation limitations, but it is anticipated that they will rise again once 2021 totals are available. With carbon dioxide emissions in 2020 totalling 11680 Mt (11.680 GT), China will be the world's highest CO2 emitter. In 2020, this will account for slightly over 32% of global emissions. With 4.535 GT, or roughly 12.6% of the total global emissions, the United States produced the second-highest quantity of carbon emissions (Looney 2021). According to the above statistic, China has the biggest use of energy worldwide as well as the highest rate of publishing for passive solar technologies. Instead of the three universities, China also has the highest publishing rank. There is conflict as a result.

The results of this study provide a critical understanding of how passive solar strategies influence thermal comfort in residential buildings. The findings indicate that orientation, shading, and thermal mass play significant roles in regulating indoor temperatures and reducing reliance on mechanical heating and cooling systems. These results support the initial hypothesis that passive solar design can significantly enhance energy efficiency. The discussion also highlights the implications of these findings for sustainable building practices and policy-making. The functionality of the methodology was robust, employing both quantitative measurements and qualitative assessments to provide a holistic view of thermal comfort. Additionally, passive techniques like better window design that encourages natural ventilation and allows solar radiation to raise low temperatures in the winter can be used to maintain thermal comfort in residential structures. The thermal efficiency alternatives for buildings in various climatic settings have also been the subject of numerous studies. Passive solar design is a climate-sensitive strategy that emphasises the building's energy-saving component and incorporates design strategies to support thermal comfort in various climates. Despite the benefits of passive solar design techniques, based on the analysis, the field still has little research, showing that a lot needs to be done in that field of research.

4.2. Critical Review and Argument on the Results

The outcomes that emerge from the studies cited in the bibliography provided have different implications for the theoretical frameworks in which they engage, particularly those relating to renewable energy, energy efficiency, and the design of sustainable buildings. On the whole, results return a significant improvement in understanding the impact of variables on building energy performance and thermal comfort. For instance, in their study, Tudiwer and Korjenic 2017 demonstrated the huge impact of facade openings on interior temperature in buildings, resulting from the interaction of different climate zones. Thus, this outcome further substantiates the hypothesis that architectural design elements might turn into an essential share of passive solar heating and cooling strategies. Their approach to assessing different climatic zones adds strength to their findings, which suggest that localized architectural adjustments are needed to achieve optimal energy performance.

Wang et al. (2009) took into account the design process of zero-energy houses in the UK, and their results show that in the case of mixing energy-efficient technologies with renewable energy systems, zero-energy status can be achieved. Their case study approach did a very good job of demonstrating practical implementation and real-world challenges effectively, thus providing strong grounds for future research and policy development. Zhai and Previtali 2010 evaluated the energy performance of traditional vernacular architecture and concluded that traditional design elements offer superior thermal comfort and are often more energy-efficient than their modern counterparts. This forms part of the theoretical framework of learning from historical practices of buildings to come up with better modern sustainable design. Yang, Yan, and Lam 2014 were said to have given a holistic review of thermal comfort and its implication on building energy use. Their findings reflect a very important aspect of human comfort in the design of energy-efficient buildings, therefore corroborating the supposition that energy savings should not be at the expense of occupant comfort. Based on a detailed literature

review, subsequent analysis has shown that thermal comfort should be integrated into energy modelling frameworks.

4.3. Implications of the Results

These studies have a triple implication: first, they all reaffirm that building design elements, such as façade openings, thermal mass, and ventilation, are the real promoters of energy efficiency and comfort in a building. These results imply the need for architectural and engineering practices to seriously include climate-responsive design principles. Second, they underline the need for an integrated approach in sustainable building design—marrying technology with tradition. Studies in ancient vernacular architecture and zero energy house design indicate that fusions of traditional wisdom and modern innovations are more effective means to achieve sustainability solutions. Thirdly, the emphasis on occupant comfort and social acceptance indicates technological advancements in building design also having to meet human-centric factors. It thereby fits the theoretical framework of sustainable development, which emphasizes the fine balance among the three dimensions in such initiatives: environment, economic, and social.

4.4. Response to the Hypothesis

The hypothesis of the article is that passive solar design elements can tremendously enhance thermal comfort in residential buildings. With this hypothesis, the authors respond in the light of making a detailed analysis of the mentioned passive solar strategies. It discusses how building orientation, shading devices, and incorporation of thermal mass interact to affect the indoor thermal environment. Orientation: The aspect of optimum orientation, which maximizes the winter solar gains while minimizing overheating during summer, is taken up for investigation. This likely includes simulations or empirical data comparing different orientations and their influences on indoor temperatures. Shading: The authors test various shading techniques, such as overhangs, louvres, and vegetation, to try to pinpoint their effectiveness at blocking excess solar radiation during hot periods. They investigate how shading devices can allow comfortable indoor temperatures without necessarily allowing natural light. Thermal Mass: The study explores the contribution of thermal mass toward the stabilization of indoor temperature conditions through the absorption and release of heat. Comparisons between various differently configured buildings, in terms of their thermal masses and their daily temperature fluctuations, are hence imperative.

5. Conclusions

A review of passive solar thermal comfort techniques used in both hot and cold climates is presented in this article, with bibliometric and bibliographic methods used to visualize the data. An examination of research-related publications. This study was conducted in response to growing worries about improving thermal comfort and reducing energy consumption in buildings. Because of this, there is a growing interest in determining how passive solar design strategies affect the thermal comfort of indoor spaces. By examining publications, nations, authors, and keywords, this review aimed to better understand current trends and future directions in this field's research. The number of publications in the subject area increased rapidly and significantly between 2015 and 2017, then began to fall considerably in 2020. Authors Yu and Givoni B. were the authors with the most cited references, while Wang, Zhaojun, Yang, Liu, Kurnitski, and Jarek. The Energy and Buildings journal had the highest number of articles and has shown considerable steady growth over the years, followed by Building and Environment. Most documents are in China, followed by those from Italy, England, Japan, the United States, and Canada. Significant research efforts are required in the field of passive solar strategies to yield substantial improvements in thermal comfort. This, in turn, can contribute to the reduction of climate emissions and the attainment of long-term energy efficiency goals. The main focus of the research is on simulation, with a particular focus on topics related to heating, cooling, and thermal comfort methods, but despite

extensive research in these areas, observations show that energy consumption remains unchanged. There is a lack of comprehensive research detailing passive solar building solutions that are critical to addressing future climate change challenges.

This study tackles key challenges associated with energy consumption in residential buildings by showcasing the effectiveness of passive solar strategies. It adds to the body of literature on sustainable architecture by providing fact-based information on how these strategies enhance thermal comfort and reduce energy use. The results confirm the research questions and hypotheses, underlining the importance of incorporating passive solar design principles in building practice. Thereafter, the study acknowledges limitations to this study, such as climatic conditions and building designs which vary. Further research is required to fully understand and increase the generality of these findings.

Data availability statement
The original contributions presented are readily available on request.

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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The Digital Decathlon - A Journey in Building Information Modelling Education

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ABSTRACT

The "Digital Decathlon" Erasmus+ project addresses the critical need for digital and green transitions in the Architecture, Engineering and Construction (AEC) sector by proposing an innovative approach for higher education. The project aims to prepare the next generation of professionals through a BIM-based design competition, designed as a novelty learning/gaming pathway for university students. By engaging participants from diverse countries and related academic backgrounds, the project fosters collaborative workflows and interdisciplinary teamwork by adopting a digital and gamified approach, providing hands-on learning and design experience. This paper presents the conceptual framework, methodologies and materials defining the prototypical learning format, which integrates online learning resources and tools, collaboration and mentoring, subject to a quality assessment for improvement and replication. Overall, the Digital Decathlon contributes to the advancement of educational methods necessary to address current challenges and to create the digitalised and sustainable built environment of tomorrow.

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1. Introduction

In the present era of urgent green transition, it is even more recognised that a parallel digital transition is necessary to cope with the complexity of sustainability challenges, demanding an acceleration in the development of new skills and competences, thereby an advancement in educational and training offerings. To address this requirement, Digital Decathlon is a 28-month project co-founded by the EU Erasmus+ programme coming with the slogan "build digital- build better". Merging academics from five European university departments in the AEC field, the underlying premise of the project is that the global demand for energy-efficient and decarbonised buildings can only be met by leveraging the untapped potential of digital technologies, particularly considering the game-changer BIM (Building Information Modelling). The project sets out with the ambitious goals of innovating BIM education by

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fostering digital knowledge, skills and competencies, while promoting more collaborative, interdisciplinary and intercultural ways of working. Inspired by the ancient Greek game format, Digital Decathlon is structured as a proper competition in which participant students must complete 10 disciplines to win, interpreted as BIM use-cases.

The paper contextualizes the current state-of-art in BIM implementation at EU level, both in the profession and education fields; then, the topic of BIM education inside the ERASMUS+ program is explored to underline the collective effort in finding new ways of teaching/learning; in this perspective, design competitions and novelty gamification approaches are introduced. Following, the contribution provides an overview of the project's methodology, detailing the format and the structure, the learning objectives, the design task and the competition requirements. The results of the first competition are analysed and discussed in terms of lessons learned, contributing to the optimization of the forthcoming second competition and the further improvement of the innovative learning format (Figure 1).

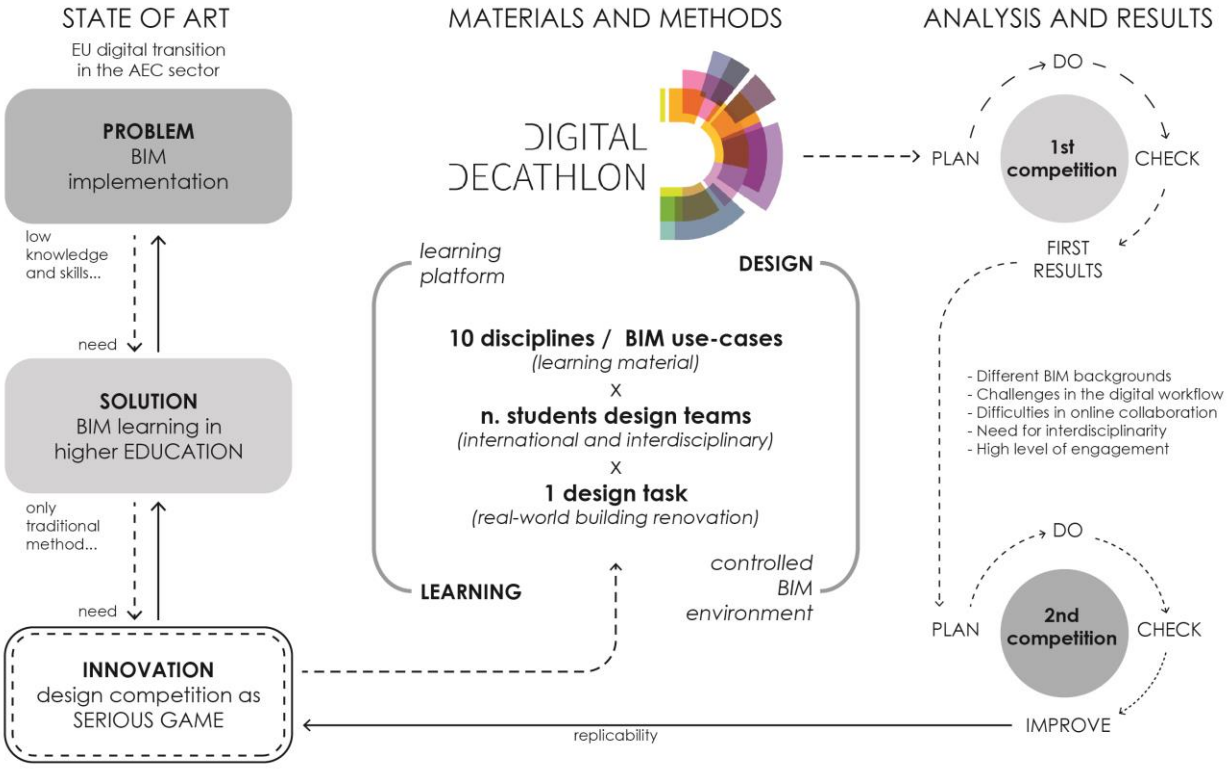

Figure 1. Structure of the study (developed by Author)

2. State of the art

Globally recognized as the most transformative and influential digital innovation in the AEC sector, BIM extends beyond traditional three-dimensional modelling by incorporating object-based semantic and relational databases, enabling a comprehensive collection, analysis, and sharing of data on technological components, properties, and performance, facilitating holistic lifecycle management and enhancing decision-making across the entire project lifecycle. Moreover, BIM is evolving in maturity, becoming a cornerstone within the ecosystem of Industry 4.0 technologies and beyond, including sensors, IoTs, augmented reality, robotics, drones, artificial intelligence applications and big data.

Although the development of BIM began several decades ago—dating back to the mid-1970s with the pioneering work of Charles Eastman (Eastman, 2011)—and despite its widespread global adoption, the formal integration into the EU regulatory framework only began with the European Directive 24/2014 on public procurement, which refers to "building information electronic modelling". According to Fiamma and Biagi (2023), this initial missed denomination has created a misunderstanding that still conditions clarity, speed and effectiveness in its adoption and diffusion, contributing to divergent implementation across EU member states. As national regulations increasingly mandate the use of BIM mandatory for public works projects, the sector remains largely unprepared, highlighting the urgent need for accelerated BIM education. If, on one hand, consistent up-skilling, training, and education are essential for fostering a common understanding, facilitating data exchange, and establishing standardized practices (Semaan et al., 2021), on the other hand, recognized barriers to BIM implementation include low levels of knowledge, resistance to cultural change, and a lack of awareness of its benefits (Charef et al., 2019). While technical training courses are proliferating to address the shortage of BIM skills, higher education institutions must reinforce their efforts on equipping future professionals with broader competencies, such as project management skills, to ensure comprehensive preparedness for the evolving demands of the AEC sector.

2.1. BIM education in Europe and the role of Erasmus+

From an AEC educational perspective, it is recognized that integrating ICTs such BIM enhances the acquisition of skills and spatial competences, serving not as mere graphical but as meaningful learning support, also boosting student motivation (Besné et al., 2021). However, an analysis of BIM courses across several European countries reveals that university offerings still largely rely on conventional teaching methods (Kępczyńska-Walczak, 2022 - BIMaHEAD project Erasmus+). The same study highlights the innovative potential of gamification approaches in this field. Moreover, considering the 20 years of experience in the US context, university BIM education should aim to increase, beyond knowledge, interdisciplinarity and collaboration among students (Morganti et al., 2022 – BENEDICT project Erasmus+).

The need to innovate AEC education in Europe towards digitalization and BIM can be found in the European Union's Erasmus+ flagship initiative for transnational cooperation and mobility in education, training, youth and sport. Launched in 1987 for higher education, the funding program enlarged in time, targets and numbers, reaching to this day more than 15 million people. Parallel to the growing interest in the AEC sector, the topic of BIM entered in more than seventy projects in the Erasmus+ financing period 2014-2020, with the majority of them falling under Key Action 2 - Cooperation for innovation and the exchange of good practices, and referring to higher education and vocational training. Key topics in these projects clearly describe the objectives and innovation needs in BIM education, with Erasmus+ addressing:

- Digital competencies in ICT-new technologies;
- New innovative curricula/educational methods;
- Open and distance learning;
- Environmental and climate change.

In the current funding program (2021-2027), seventeen projects are actually dealing with BIM education, mostly under KA2 (82%). Considering "cooperation partnerships in higher education" (KA220 HED), seven BIM-focusing Erasmus+ projects can be found, including Digital Decathlon, Bim4Energy, nZEBRA, BIM-LCA, GREENBIM, DIGILAB/BE and BIM4HEI. Looking at these projects, it is possible to observe not only the common need to still support the adoption of BIM in the higher education, but also the

reasons behind, that is the possibility to develop reliable and collaborative processes, and the capacity to perform simulations and analyses, such as energy performance and LCA calculations.

2.2. Innovative learning approaches: desgin competitions and serious games

Worldwide architectural competitions represent the best procedure when innovative projects have to be developed, particularly those requiring interdisciplinary expertise to address complex challenges such as environmental sustainability. While the tradition of competitions spans millennia, recent decades have seen a notable increase in competitions specifically targeting students. As testified by literature, this trend reflects their growing recognition as valuable didactic and educational tools, even more integrated into AEC academic curricula. Competitions offer a wide range of educational benefits, including "improving the ability to design, the ability to socialize through teamwork, and the ability to manage time" (Gunagama and Pratiwi, 2019, p. 6). Described as an "activating tool in architecture education" (Ilkovičová and Ilkovič, 2018), competitions provide students with practical and informal experiences that enhance their design skills.

Aligned with the mission of higher education institutions to prepare students for professional practice, competitions offer a unique opportunity to engage with real-world environments, apply theoretical knowledge to practical challenges, and simulate professional experiences. In this context, competitions can be viewed as a gamification tool for education, analogous to serious games. Designed not just for entertainment and exploiting digital technologies, serious games aim to educate by facilitating learning, training, health improvement, or raising awareness; they have already been adopted in architectural education (Goli et al., 2022). Design competitions in educational settings can be considered serious games based on the following shared characteristics:

- Educational Purpose: Aimed at developing knowledge and skills;
- Gamification Elements: Incorporating rules, guidelines, challenges, and rewards that engage and motivate students, encouraging active participation;
- Simulation of Professional Experience: Providing a controlled and realistic experience of professional life, combining creativity, technical proficiency, collaboration, time management, and project management. Competitions thus serve as essential tools for preparing students for the demands of the real-world work environment.

3. Materials and methods

To enhance learning and teaching methods in line with new digital requirements, the Digital Decathlon offers an innovative approach rooted in serious games. This method for BIM education was first piloted by the Digital Decathlon project leader, Jade University, in the BIM GAME project (Heins et al., 2021; Grunwald & Heins, 2022; Bhat et al., 2023).

The Digital Decathlon is structured as a design competition—a serious game for students in the interdisciplinary fields of architecture, civil engineering, and building services engineering. It immerses students in a BIM environment to collaboratively develop integrated design projects, challenging them to navigate 10 gaming disciplines or BIM use cases (Figure 2 and Table 1).

As a professional design competition, the Digital Decathlon includes key elements such as a real-world context, a design task, a timeline, briefs and guidelines, defined roles and regulations, minimal requirements, assessment criteria, a jury, and a reward system. To familiarize students with real BIM practice, Warsaw University prepared an Exchange Information Requirements (EIR) document, which clearly defines the scope of BIM technology application in the competition. In response, students are required to develop a BIM Execution Plan (BEP). Reflecting the EU's Renovation Wave priorities, the design task for the first competition centred on the requalification of an existing building.

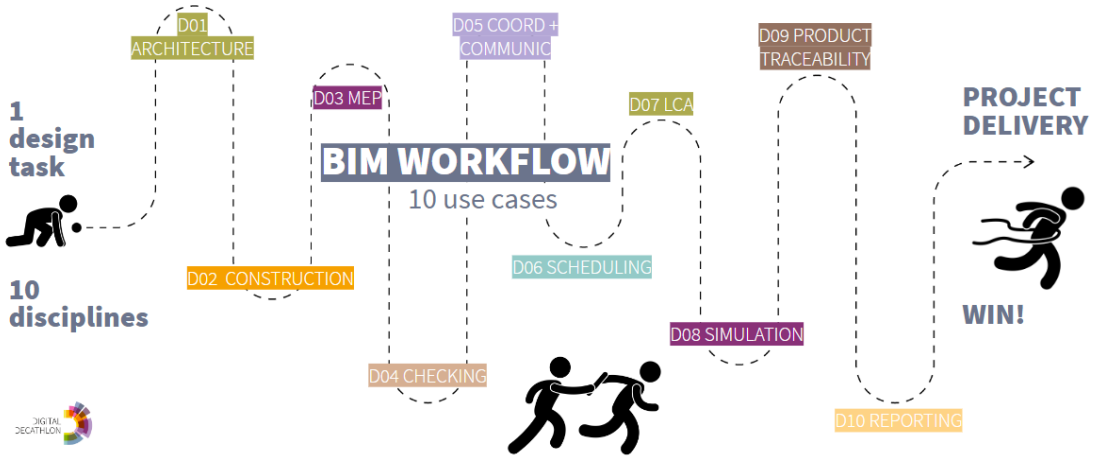

Figure 2. The Digital Decathlon competition across the 10 disciplines/BIM uses (developed by Author)

Table 1. DIGITAL DECATHLON disciplines/BIM uses and corresponding specific learning objectives

n.	Discipline	Specific Learning Objectives
1	ARCHITECTURE	Develop a design idea/spatial programme in a 3D model, with corresponding visualizations
2	CONSTRUCTION	Define and verify a wooden structure
3	MEP (Mechanical, Electrical and Plumbing)	Integrate MEP systems
4	MODEL CHECKING	Test the quality of models
5	DESIGN COORDINATION and COMMUNICATION	Coordinate models
6	CONSTRUCTION SCHEDULING	Visualize construction phase
7	LIFE CYCLE ASSESSMENT	Calculate LCA
8	SIMULATION	Perform energy and solar simulations
9	BUILDING PRODUCT TRACEABILITY	Organize building products' documentation
10	REPORTING	Communicate work in progress and results

For each discipline, dedicated digital learning materials were developed and delivered to students as engaging "click tutorials" on a specialized learning platform—Moodle (developed by Karelia University), which also provided online support tools. Additionally, to align initial BIM competencies, a pre-qualification online BIM basics course (developed by the University of Wuppertal) was offered and completed by all participating bachelor's students. In parallel, and simulating real-world conditions, a controlled Common Data Environment was established to allow students to experience BIM-based collaborative working.

To optimize the gaming format and ensure a high-quality learning experience, the project employs a methodology based on quality cycles (plan, do, check, and improve) with two planned competition/learning cycles. The first competition has already concluded, and the second is currently being prepared, leveraging the insights and results from the first cycle for continuous improvement.

4. Analysis and Results

The design task was introduced to students during the opening event held in Wuppertal, Germany, in October 2023. To provide students with an immersive experience of the project site and context, the launch of the first competition took place at the Wuppertal Solar Decathlon 2021-22 (solardecathlon.eu) (Figure 3), a renowned location featuring full-scale prototypes of future sustainable houses still functioning as Living Labs. At this venue, twenty-five students from five partner universities, organized into five interdisciplinary and international teams (Figure 4), gathered for the first time and began the concept design phase collaboratively.

Figure 3. Launch of the first competition in Wuppertal (by Christian Heins)

Working in interdisciplinary and international teams, students engaged in strategic co-planning of the BIM process. They selected two disciplines each, based on their academic background, competencies, and learning interests, and organized their online collaboration accordingly.

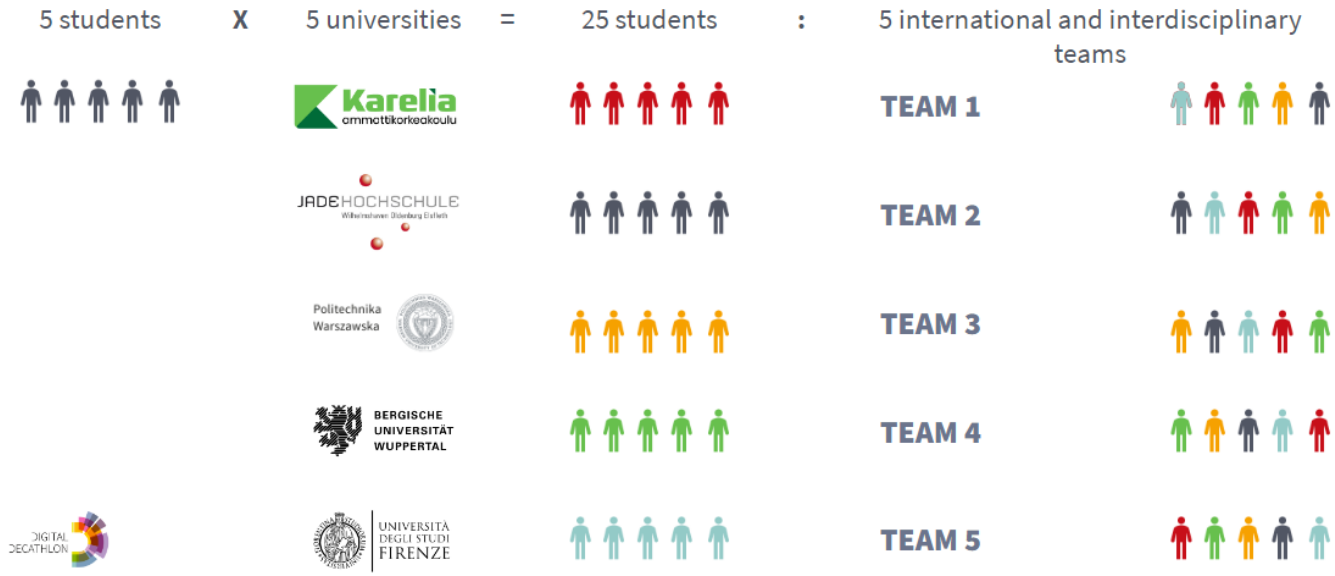

Figure 4. Composition of the student teams (developed by Author)

The design task required students to repurpose an abandoned former logistics center into a multi-purpose cultural centre, contributing to the ongoing regeneration of a former industrial area and transforming it into a vibrant neighbourhood with diverse social and cultural activities.

Students were provided with detailed instructions on the content and organization of learning materials for the ten disciplines and the competition itself. A BIM asset model of the building was also delivered. With all learning materials available online through Moodle and a clear ten-step design task, student teams worked autonomously and remotely to develop their project proposals. A mid-term review was conducted to assess progress.

The design proposals were developed in an interdisciplinary manner, leveraging the collaborative capabilities of the controlled BIM environment. Students enhanced the sustainability of their designs through simulations (e.g., energy consumption) and detailed analyses (e.g., LCA). Additionally, trainers offered on-demand coaching sessions via videoconference to address specific issues. After four months of remote teamwork, each student team submitted their BIM materials in the Common Data Environment (CDE), along with two representative A1 posters (Figure 5) and a multimedia presentation.

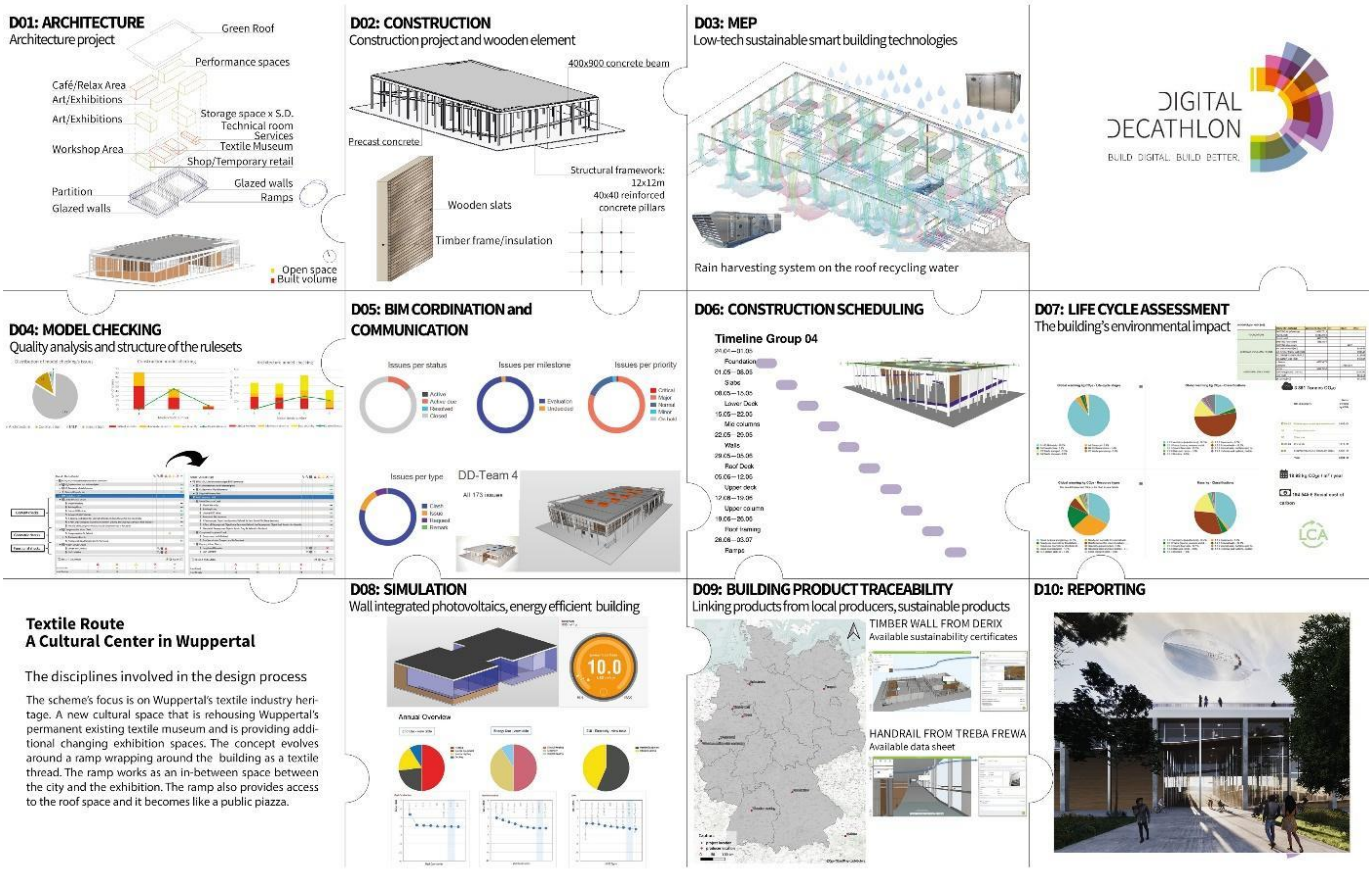

Figure 5. Winner project's poster (students: A. Antoniadou, A. Stuenkel, C. Girod, M. F. Perri, P. Wojnar)

The winners were announced at the final event held at the University of Florence in February 2024. During this event, student teams presented their approaches to the BIM process across the ten disciplines/BIM uses and demonstrated how these approaches supported their design solutions. The final jury consisted of the project team of trainers and external BIM experts. The evaluation was based on weighted assessment criteria (Table 1) aligned with the learning objectives, ensuring a coherent and fair assessment process.

In addition to evaluating the technical outcomes of the integrated design proposals, the first competition provided initial insights into the challenges and opportunities of innovating BIM education through a competition-based, gamified approach. Key findings include:

- Diverse BIM backgrounds: despite targeting students with similar academic backgrounds, varying levels of prior BIM experience were evident;
- Digital workflow challenges: the array of software, plug-ins, and data management systems in the BIM environment was a novelty for the mayority of students, necessitating dedicated technical support;
- Online collaboration difficulties: relying solely on remote working sessions led to a decline in team enthusiasm;

- Need for interdisciplinarity: students had limited experience collaborating with peers from different disciplines;
- High engagement: while students were eager to learn, the added human, social, and intercultural value of the experience was highly appreciated.

These insights highlight both the benefits and areas for improvement in using a competition-based and gamified approach to BIM education.

5. Discussion

Echoing the uneven implementation of BIM in the professional realm, the study revealed a varied level of BIM background among students, including challenges in managing the digital ecosystem. Additionally, students displayed limited experience in interdisciplinary design—a critical component for developing truly sustainable projects, which BIM can facilitate. This underscores the need for higher education systems to enhance and innovate learning methods to better prepare students for the digital demands of professional work. Furthermore, the exclusive use of online modalities presents challenges, highlighting the need for improved gamification features.

Despite these challenges, the Digital Decathlon observed a positive student attitude towards learning, reflecting a strong recognition of the importance of digitalization and the benefits of participating in an international competition with an intercultural social dimension.

Aligning with theories on experiential learning and serious games, the project's primary hypothesis was that engaging students in a structured, interdisciplinary competition simulating real-world professional challenges would foster critical BIM skills, collaborative competencies, and a deeper understanding of sustainable building practices.

The insights gained from the first competition's strengths and weaknesses have identified crucial areas for improvement to optimize the upcoming second competition. The project demonstrated that serious games and competition-based learning can effectively enhance digital skills and competencies, supporting the hypothesis that gamification can improve learning outcomes. The iterative learning cycles and feedback mechanisms embedded in the project provided students with valuable opportunities for reflection and continuous improvement, essential for deep learning.

6. Conclusion

This study investigated the potential of a gamified, competition-based approach to BIM education, using the Digital Decathlon project as a case study. The primary issue addressed was bridging the gap between traditional BIM education and the evolving demands of the construction industry, particularly the integration of digital competencies. The research tackled these challenges effectively by implementing a structured competition that engaged students in a realistic, collaborative BIM environment. Early results suggest that the innovative Digital Decathlon format successfully fosters critical BIM skills and enhances students' understanding of sustainable building practices, thus achieving the research objectives.

The study's key contribution is its innovative approach to BIM education, demonstrating that serious games and competition-based learning can significantly improve digital literacy and interdisciplinary collaboration among students. This approach is effective in preparing students for the complexities of contemporary construction projects and addressing sustainability challenges. Additionally, the study emphasizes the value of incorporating social and intercultural dimensions into technical education, extending beyond mere skill acquisition.

However, the study has limitations. The format is still in its initial prototypical phase with a limited number of participants. Variations in students' prior BIM experience suggest that further refinement is needed to

ensure consistent learning outcomes. Future phases of the project will explore strategies to standardize initial BIM skills, facilitating smoother and more successful development of integrated projects. Subsequent iterations of the Digital Decathlon should address these limitations to ensure that the model can be scaled and replicated globally.

Despite these challenges, the study highlights the importance of advancing educational models to better address deficiencies in students' digital backgrounds and improve the integration of digital tools in learning and design processes. Further research is needed to develop more comprehensive and standardized BIM education across higher education institutions, ensuring students are well-prepared for sustainable projects.

Although in its early stages, the Digital Decathlon is providing significant contributions in BIM education by enhancing not only technical skills but also human and social soft skills, valuing the importance of collaborative, international, intercultural, and interdisciplinary learning experience.

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The author declares no conflict of interest.

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Small Historical Centres and Their Connection with The Landscape: Fragility and Complexity in Italian Contexts

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ABSTRACT

This paper addresses the issues of fragility and complexity of small towns, particularly regarding the Italian case. Results define a possible conjunction between the landscape historical characteristics and the creation of circuits for the usability of smaller centres that can be connected to each other, based on their features. A prototype schedule, including GIS elaboration, is the novel proposal illustrated in the paper: it derives from the investigation carried out within the Working Group of the Italian Ministry of Culture, aimed at defining a Charter for Small Villages. The approach innovativeness consists in the comparison methodology between different landscape units that can also be extended to similar cases, defined on the basis of the involved factors matrix.

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1. Introduction

The investigation focuses on the study of smaller settlements and the potential interventions able to enhance the landscape in which they are located. The scientific literature addresses this topic from multiple perspectives. On one hand, there are numerous sectoral studies aimed at the conservation of historical centres, particularly from an architectural and restorative point of view (Pelà, 2018; Satterthwaite, 2021; McKnight et al., 2019). On the other hand, there are numerous sectoral studies focused on the preservation of the territory: in fact, these centres are often located in fragile areas, especially regarding the hydro-geological characteristics of the terrain on which they are built (Rodriquez et al., 2018; Ramírez Eudave & Ferreira, 2021). This research attempts to integrate the themes of fragility and complexity, the two main characteristics that distinguish these centres. The issue of

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fragility is increasingly recognised in historical centres, whereas the complexity - involving active perception and participation in decision-making processes - is less explored and is the focus of this work. These aspects take on comparable connotations, especially in European countries (Megyesi & Boldizsár, 2016; UCLG, 2017; Klusáková & Vic Ozouf-Marignier, 2017; Matoga & Pawłowska, 2018; CTME, 2020; European Commission, 2023).

Fragility arises from physical aspects related to risks (exacerbated by climate change) and anthropogenic use (linked to the presence of inhabitants and the changes they have made to the territory). In Italy, a significant portion of the territory is defined as fragile, due to its orographic configuration and geological-structural asset. However, it is important to highlight that, in relation to a widespread process of urbanisation and infrastructural development, the ecological-environmental system's functionality levels are currently severely compromised (Smith TM & Smith RL, 2017; Di Venosa & Morrica, 2018; Acierno, 2019).

Complexity, in its theoretical components - that influence disciplinary debate - and its physical components - that emerge from professional practice - encompasses both natural and urban systems (Vercelloni, 1992; Farina, 2004; Arcduecittà, 2013). It manifests in material and immaterial relationships tied to multiscalarity and to the need to reconcile urban growth with environmental protection. This involves connections between elements closely linked to the landscape, such as urban planning, hidden natural systems, anthropised environments, green networks, and human networks (Connolly, 2004; Shane, 2004; Mostafavi & Doherty, 2010; Turner, 2016). Therefore, it is necessary to consider all concurrent environmental, geographical, biological, and territorial factors to develop management solutions that account for all possible interactions and avoid creating further imbalances (Allen, 1999; Tsenkova, 2016; Allen et al., 2017; Gill et al., 2007; Kelbaugh, 2019).

Fragility and complexity are thus interrelated aspects that manifest in real space, consisting of natural, agricultural, and urban contexts, defining both their potentialities and significant vulnerabilities. The general considerations, briefly listed, are of particular relevance in the Italian context. The general theme, for which the researchers' lines have been outlined, is specifically analysed in this paper concerning the Italian case. It is believed that the specific treatment may be interesting as Italy has always addressed the issue of landscape planning with a specific plan dedicated to it, including the aesthetic sense of landscape beauty and subsequently the importance of perception (Cialdea, 2019).

The approach of the "Landscape Plan" in Italy originates from the 1940s, aiming to enhance the aesthetic aspect with a strong focus on the "panorama" (the first law introducing these concepts is Law No. 1497 of 1939 "On the Protection of Natural Beauties"), and provides for the establishment of landscape constraints on assets for which a list must be drawn up, and for which interventions are subject to the authorisation by the Ministry of Cultural Heritage (Repubblica Italiana, 1939). Things changed in the mid-1980s when Law 431/85 (known as the Galasso Law) introduced new concepts for the protection of areas of particular environmental interest. At that time, more attention was devoted to safeguarding the "environmental system": thus, the concept of landscape constraint also changed from being the legislative tool that ensures the protection of the landscape aesthetic and visual aspect (as sanctioned by Law 1497) to becoming the tool aimed at ensuring the protection of the environment as an "ecosystem". Furthermore, the Galasso Law has the great merit of having, for the first time, required the Regions to carry out an organic and systematic protection of their territory: The Regions are appointed to identify the areas to be protected and to draft Territorial Landscape Environmental Plans for vast areas (Repubblica Italiana, 1985).

The definitive shift in the approach to the landscape topic occurred in 2004 with the promulgation of the new Code of Cultural Heritage and Landscape, which came into force in May of the same year. It adopts the concept of landscape heritage in place of the environmental one, emphasising the multiple components of the landscape ranging from the morphology of the places to its architectures and to its history, while not neglecting its environmental component. It states, "*landscape means a homogeneous*

part of the territory whose features derive from nature, human history, or their mutual interrelations. The protection and enhancement of the landscape safeguard the values it expresses as perceptible identity manifestations" (Repubblica Italiana, 2004).

The general approach of the new Code focuses on the provision of enhancing the territory, fulfilling the reformed Title V of the Italian Constitution, which distinguished the activities of protection from those of enhancement. The Regions and Local Authorities are thus called upon to organise activities aimed at constituting an "integrated system" of enhancing the "heritage". It is also noteworthy that in the meantime, the European Landscape Convention (Council of Europe, 2000) had been signed, and as Urbani Minister stated enacting the Code of Cultural Heritage and Landscape: "Regarding the landscape, a true Copernican revolution has been carried out, which will allow overcoming the administrative impasse due to the continuous conflict between regional and local planning instances. Thus, a planning and management of the landscape is reached in accordance to territorial conditions, but still able of safeguarding the extraordinary cultural characteristics of Italian landscapes as the identity heritage of the entire national community". Therefore, the two themes - the landscape interpretation and the definition of landscape quality objectives (as provided by the Code) - merge with the evident interesting potential of a new plan aiming to carry out a threefold action of conservation, requalification, and development (Cialdea, 2018, 2023).

Additionally, the theme of small centres is currently a focus of the Italian Ministry of Culture, which has established a National Committee for the Landscape, of which the first Author of this contribution is the Vice-president since 2018. Specifically, within the Committee, a Working Group named "Gruppo Borghi" has been established, aimed at drafting the National Plan for Small Centres. In fact, the national panorama sees a great preponderance of medium-small towns and small towns. As the "National Strategy for Adaptation to Climate Change" (MATTM, 2015a, 2015b) highlights, there are fewer than 50 large centres, i.e. with more than 100,000 inhabitants: in which a quarter of the total national population lives; medium-large sized centres, i.e. with a number of inhabitants between 40,000 and 100,000, are just over 150 and accounting for almost 15% of the national total; the medium-small sized centres (from 10,000 to 40,000 inhabitants) number just over a thousand in which approximately 30% of the national population resides. But most urban centres are small (with fewer than 10,000 inhabitants). In fact, despite hosting a total population similar to that of medium-small sized centres, they reach the number of seven thousand. In these cases, the almost total absence of the urban-metropolitan dimension means that the relationship between the settlement system and the landscape is closer.

This document is organized into five parts. The first chapter reviews the state of play. The second presents the analysis methodology based on landscape indicators applied to small historical centres. The third and fourth chapters describe results and discussions and finally there are the conclusions.

2. Material and Methods

The research undertakes an inductive analysis of the theoretical disciplinary debate and operational experiences related to landscape design within contemporary landscape planning and the landscape design emerging from bottom-up systems. It proceeds with an applied project experience of Community Landscape from the perspective of the technical-scientific community.

The geographical context considered encompasses the Italian territory, particularly focusing on areas within landscapes deemed minor, where smaller historical centres are located. These territories can be defined as marginal or typically non-urban, with a more rural character. These areas are united by a common convergence of ecological-environmental dynamics and historical-cultural attributes, although they are engaged in landscape projects that utilise heterogeneous approaches, implying a variety of territorial scales and a diversification in the types of cultural and landscape assets involved.

The core analysis examines whether it is possible to integrate two factors: identity and belonging. Identity is approached through an objective vision linked to planning analysis, while belonging is examined from a subjective perspective, considering the ongoing bottom-up initiatives for landscape enhancement. Figure 1 describes the methodology approach, developed to highlight the peculiarities that distinguish the different approaches to landscape design, adopted respectively by top-down and bottom-up systems, in order to extract principles and objectives within the new debate.

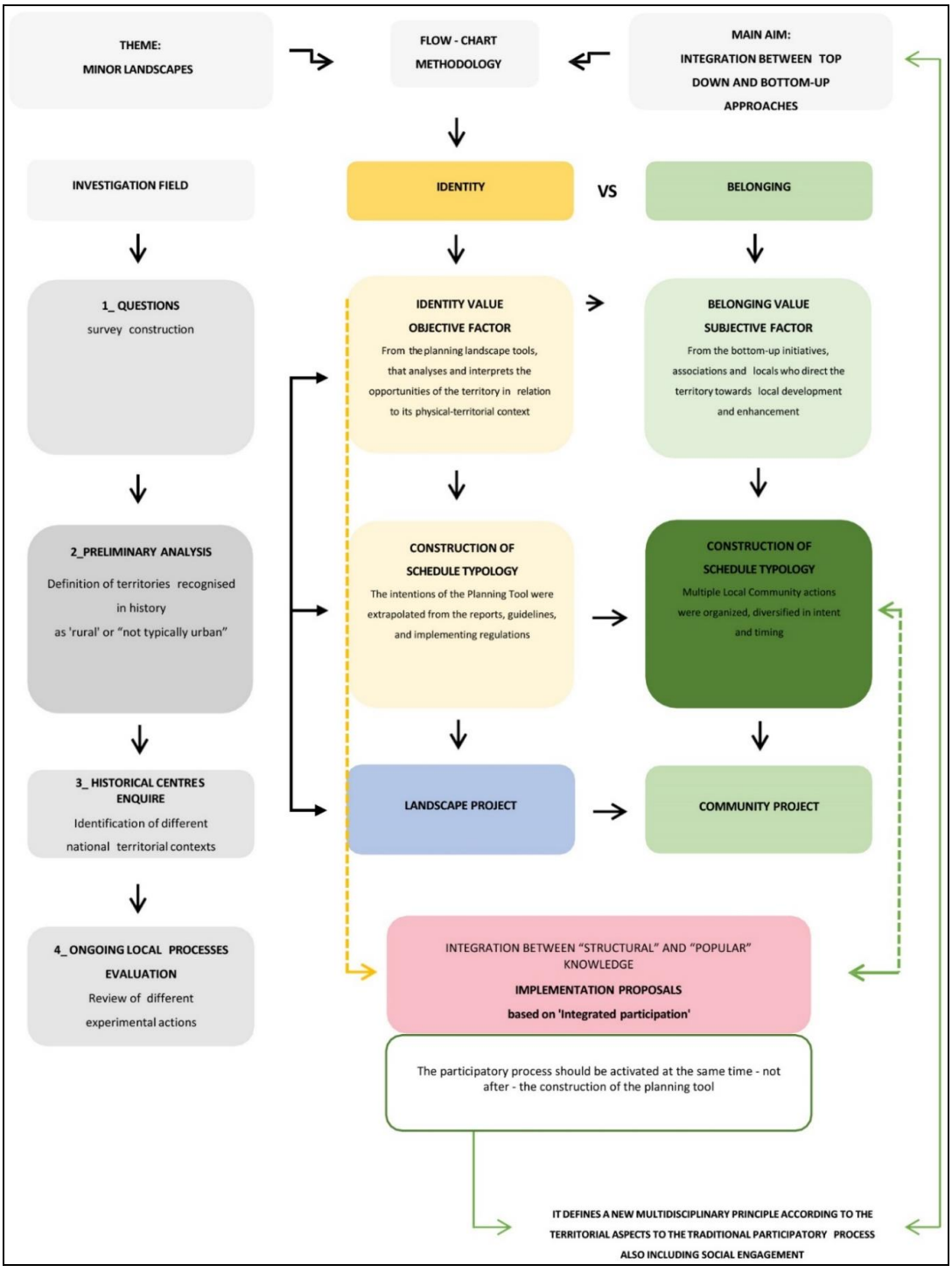

Figure 1. Flow-chart (Author's Elaboration 2024)

A landscape typology schedule was created to synthesise the various processes and to dscrive both landscape and community projects.

The final phase arises from the desire to experiment with a practical case of possible integration between "structural" and "popular" processes resulting from multidisciplinary knowledge. It proposes a model of new integrated participation for the enhancement of landscape design defined by the Middle-Lab, as the technical-scientific community. This aims to highlight principles related to the role of the Middle-Lab between top-down and bottom-up approaches in an innovative discussion context.

2.1. Identity: Theoretical approach and Data collection method

The study of landscape identity within the Italian urban planning context is governed by the already cited Landscape Plan, which is responsible for ensuring a preliminary and detailed survey of the territory for effective protection. It highlights the diversity and richness of the landscape, encompassing geographical structure, architectural elements, and historical heritage, while maintaining a constant focus on environmental aspects. The law defines the landscape as a segment of territory characterised by both the natural environment and the historical interaction of humans. The protection and promotion of the landscape aim to preserve its values as tangible expressions of identity. Regions and Local Authorities are required to organise activities to create an "integrated system" for the enhancement of their own heritage. Meanwhile, the Code considers the above-mentioned European Landscape Convention, for which the landscape is a portion of territory perceived by populations, whose character is the result of the interaction between natural and human factors. Authors around the world extensively study aspects of identity (Lynch, 1964; Norberg-Schulz, 1979; Assunto, 2006; Stobbelaar & Pedroli, 2011; Loupa Ramos et al., 2016; Butler & Sarlöv-Herlin, 2019).

In Italy, legislation has evolved, shifting the focus from mere protection to enhancement and sustainable development, defining the landscape project. Contemporary territorial planning operates in an uncertain context, preserving essential elements and orienting towards sustainable development, responding to environmental dynamics and the needs of various stakeholders. The preliminary phase of information acquisition and analysis integrates technical knowledge and the empirical insights of citizens and stakeholders, central to the definition of public policies. This approach necessitates broad consensus, highlighting the importance of dialogue and mediation to resolve disputes between divergent interests, which are not yet fully integrated to ensure adequate active participation.

Therefore, several elements identified in the numerous cases examined have been captured, and the main parameters useful for comparison with other methods have been established: land use parameters, areas under restriction, settlement systems feature, natural elements peculiarities and interventions strategies.

2.2. Belonging: Theoretical approach and Data collection method

The concept of belonging is associated with an emotional attachment and deep-rooted connection to a territory, perceived as a cohesive and significant whole. This emotional bond links individuals and communities to a place, clarifying, for instance, the sentimental value of villages—places of lived histories, perceived as familiar and meaningful, where people and places are interconnected, and traditions bear witness to the passage of time and the transmission of knowledge. Belonging frames, the community as a crucial environment for developing innovative interpretations of territorial issues and challenges, considering the active bottom-up initiatives at the national level. The community acts as a catalyst for identifying and enhancing unexplored resources and potential, enriching the social fabric and amplifying the collective capacity to respond to local challenges, thus supporting an effective territorial development strategy (Arnerio, 2000; Uwajeh & Ezennia, 2018; Granata, 2021).

In smaller historical centres, practical communities are emerging, activating new territorial paradigms through sociality, culture, and educational tools based on European educational guidelines, such as situated learning. This form of learning is effective for all participants, occurring through the exchange of experiences and circular experimentation—a process that places innovative local initiatives at the

centre of the territorial system. The territory is viewed as a resource for the community, which, through education and training, commits to managing and enhancing it, reusing resources and creating true Community Academies. These are places of exchange and cultural planning, based on a horizontal process (van Empel, 2008; Jankauskaitė-Jurevičienė & Mlinkauskienė, 2021; Aldegheishem, 2023; Deep, 2023). Communities have regained importance as reference points and generative matrices of the very notion of landscape. This resurgence is the result of a cultural shift linked to the concept of belonging to places and the desire to emerge from subordination to metropolitan territories. It places the concept of community-based projects as actions and responses to marginalisation through bottom-up initiatives.

3. Results

Results demonstrate relevant differences between the three distinct processes, related to different outcomes of enhancement projects, developed within the framework of landscape planning tools.

3.1. Landscape-Projects

The present analysis focuses on the added value of linear infrastructures capable of connecting diverse elements, highlighting how the visual and structural influence of various components contributes to defining and enriching the context of the examined territories. These include architectural elements, rural archaeology, historical-cultural itineraries, minor pathways and roads, historical settlement structures, and natural or inhabited features.

The first case specifically synthesises one of the projects derived from the Territorial Address Plan with landscape relevance of the Tuscany Region (Regione Toscana, 2015), titled "Leopoldine in Val di Chiana". The second case comes from the Regional Landscape Plan of the Friuli-Venezia Giulia Region (Regione Friuli-Venezia Giulia, 2018), titled "Il Cammino delle Pievi in Carnia". It includes the Network of Cultural Heritage, following the regulations of Part II of the Code of Cultural Heritage and Landscape and the UNESCO guidelines. One of the main guidelines aims to enhance and protect the scenic road leading to the Pieve. Table 1 summarises the main characteristics of the two selected areas in this discussion, according to the principles defined in the Data Collection Method.

Table 1. Landscape-Projects (Author's Elaboration 2024)

Localisation	Infrastructure	Landscape Unit	Cultural Heritage Value	Previous Usability	Final Realisation
Stradone di Montecchio	Hisotrical Buildings along the Stradone (Tuscany, Italy)	Agricultural area of the Tuscan territories with buildings known as 'Leopoldine',owned by the Medici family of Florence later reclaimed by Grand Duke Pietro Leopoldo I di Lorena.	Leopold-era villas, farms, farmhouses and land systems, agricultural plots and roadways of historic origin, hydraulic drainage works for water control.	Agricultural area with strong value Abandoned buildings	Recovery of the area and restoration of the Leopoldine, buildings founded between the 16th and 17th centuries. Preservation and valorisation of the reclaimed land with the recovery of the historical and cultural elements and the introduction of a new usability linked to slow mobility.
Il Cammino delle Pievi in Carnia	Hisotrical Buildings in the Carnia Mountain Chain (Friuli-Venezia Giulia, Italy)	A mountainous area in the upper Val But, Val Pontaiba and Val Chiarsò in Carnia that passes through historic Carnic Pievi and two Sanctuaries.	Carnic churches, Alpine Club nature trails, historic mountain villages and nuclei, religious archaeological architecture, spiritual sites.	Small villages locatetd in carsic areas and valley floors Watercourses and streams Mountain areas between the Pre-Alps and the Carnic Alps	The path of the Pievi in Carnia represents a strong memory of the ancient Alpine peoples who guarded the lives of Christians. They were erected between the 5th and 14th centuries. In the Landscape Plan it is inserted in Sacred Paths for enhancing the landscape value.

The Stradone di Montecchio (Figure 2) is located in the 15th District, the Piana di Arezzo and Valdichiana, as defined by the Landscape Plan of the Tuscany Region. This area is characterised by the creation of an infrastructural corridor named "Leopoldine in Val di Chiana", focusing on the buildings along the historic road infrastructure. The area boasts a heritage that combines architecture and nature, with historic nuclei serving as the pillars of the settlement fabric. Evidence of the interaction between humans and the environment includes kilns and structures related to the land reclamation carried out between 1703 and 1736 by the Leopoldine Dynasty, such as the Leopoldine and the Grand Ducal Farms, which are notable for their architectural features and agricultural character. These structures form aggregated units along significant routes, including the Stradone di Montecchio and the Abbadia axis. The project proposes the development of a cycling and pedestrian pathway aimed at enhancing the reclamation scheme, which is currently compromised due to the abandonment of many Leopoldine farmhouses. It proposes the restoration of historical and landscape heritage. Within the project proposal, particular attention is given to the creation of rest areas along the Reclamation Path, designed as places for gathering and information for travellers.

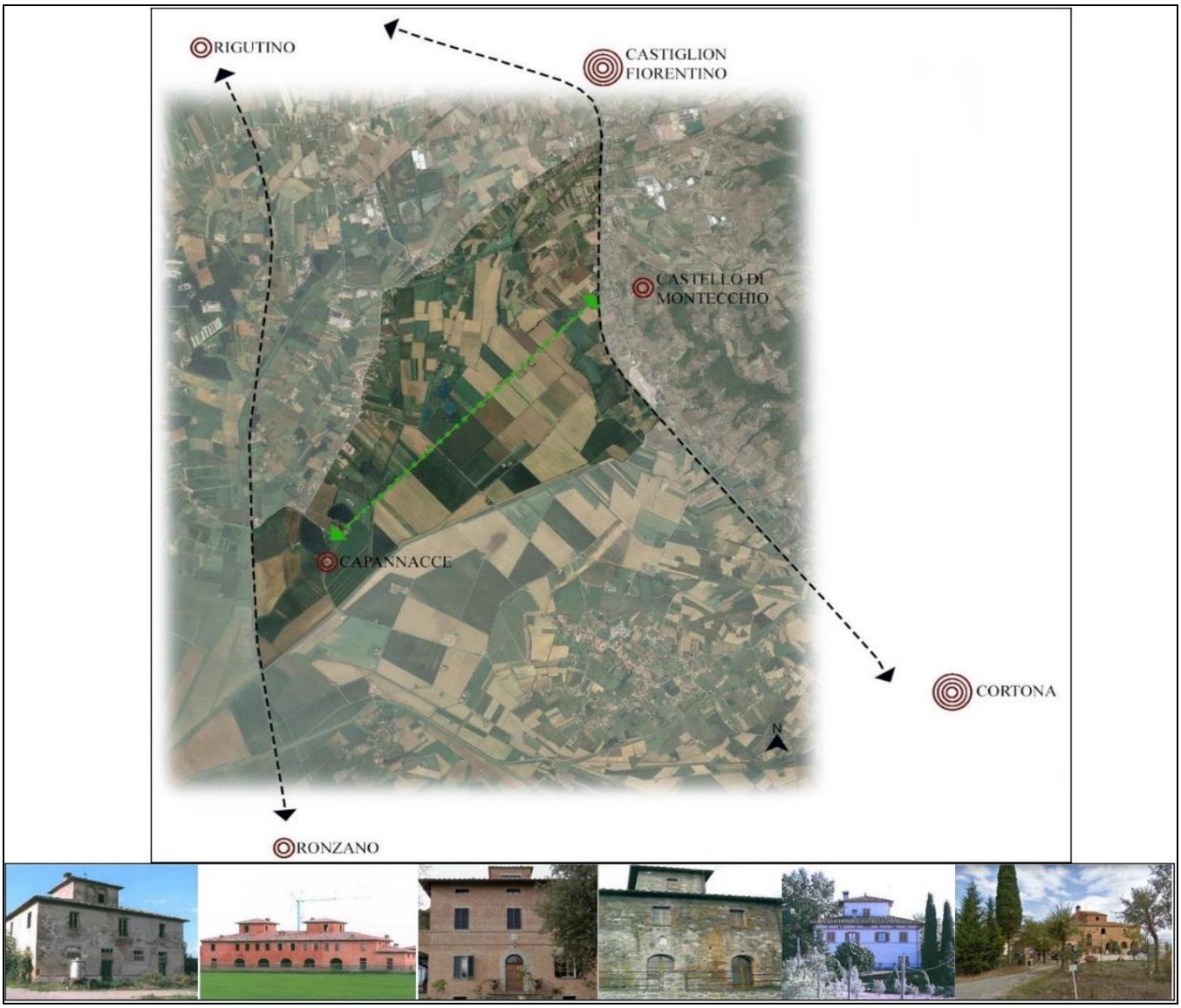

Figure 2. Stradone di Montecchio and prevailing elements
(Map: Author's Elaboration 2024; Photos sources: Regione Toscana, 2015)

The Cammino delle Pievi in Carnia (Figure 3) is a 260 km route located in the heart of Friuli's Carnia region, offering an immersive and intense journey akin to the renowned Camino de Santiago. This path allows travellers to explore the natural beauty of the region and its medieval churches. Originally composed of 18 stages, the Cammino delle Pievi was extended to 20 stages in 2013. It now includes, in addition to the Conca Tolmezzina, Val Tagliamento, Val del Lumiei, Val Degano, and Val Pesarina, the communities and territories of Alta Val But, Val Pontaiba, and Val Chiarsò, while maintaining its start in Imponzo di Tolmezzo and its end in Zuglio. The Pievi today stand as testaments to the memory of the evangelisation of ancient Alpine populations—isolated communities perched on hills and highlands. These communities, though distant, have preserved the Christian way of life, governing all aspects, not solely the spiritual.

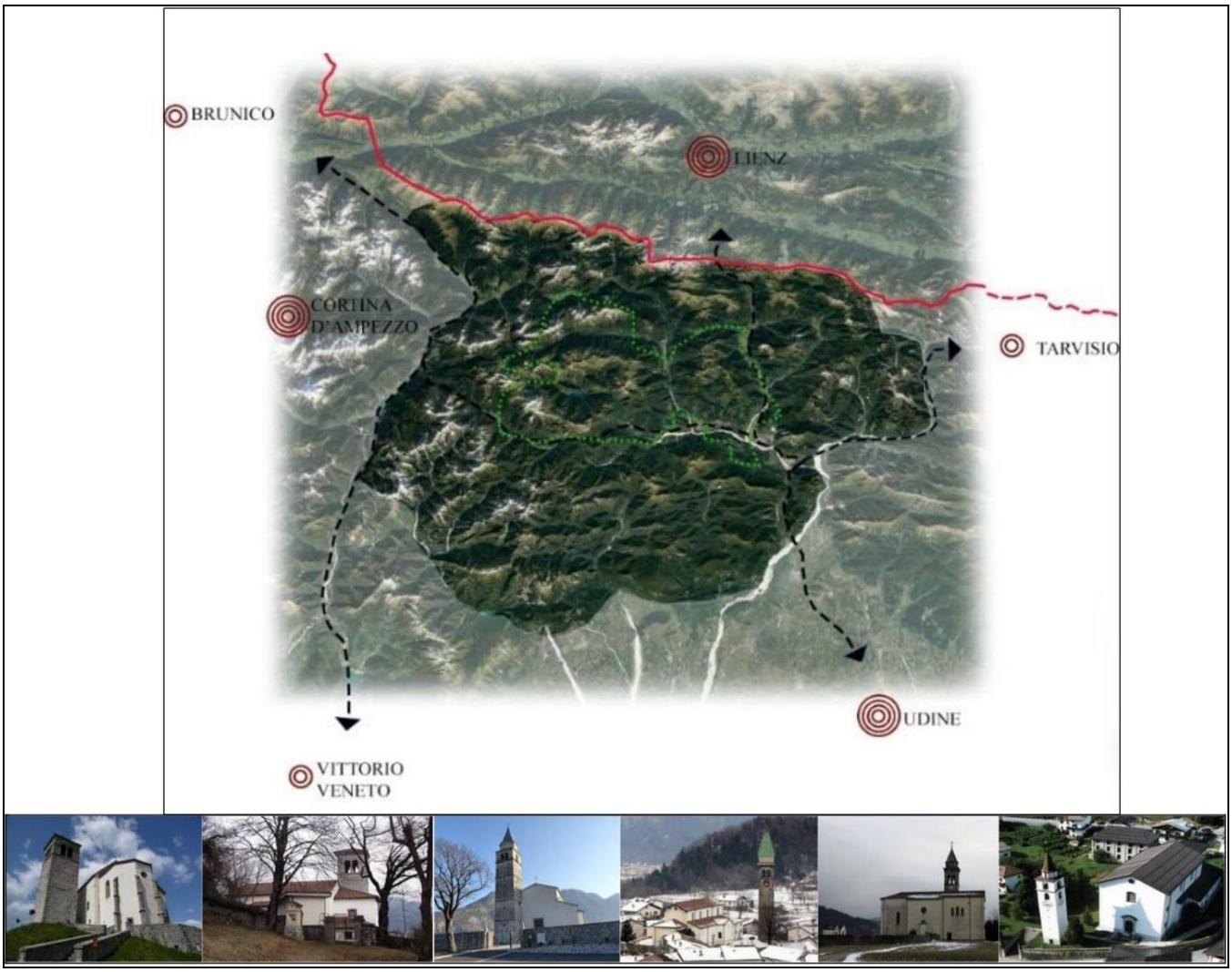

Figure 3. Cammino delle Pievi and prevailing elements
(Map: Author's Elaboration 2024; Photos sources: https://camminodellepievi.it/)

3.2. Community -Projects

Territorial experiments are often constructed with a multidimensional character, oriented towards redefining the rules and forms of local and material well-being. These initiatives combat social exclusion by increasing opportunities for settled communities and creating conditions for local economic development. In the post-pandemic era, with the exodus from cities and interventions from the National Recovery and Resilience Plan (Italian plan aimed at the country's economic recovery after COVID-19), expectations align with opportunities to build new processes in territories through bottom-up activation.

Community projects, therefore, represent a novel experimental approach. This study focused on three selected cases: the "Dolomiti Hub" project developed in Veneto in 2020, the "Borgofuturo +" project initiated in the municipality of Ripe San Ginesio in the Marche region, and the "Da mare a mare" project realised in Sicily in 2017. Table 2 summarises the main characteristics of the analysed experiments, as defined in the Data Collection Method. The table shows the comparison and study of the selected cases within the framework of bottom-up initiatives, recognising the values and objectives of each by analysing the territorial context, the environmental and landscape values of these areas, and their cultural values.

Table 2. Community-Projects (Author's Elaboration 2024)

Localisation	Association feature	Landscape Unit	Cultural Heritage Value	Previous Usability	Final Realisation
Cultural platform promoting social transformation actions	**Dolomiti Hub** Dolomiti Lab S.r.l. Social enterprise https://dolomitihub.it/	Industrial area of Fonzaso, in the province of Belluno and neighbouring villages (Veneto, Italy)	Dolomites = UNESCO World Heritage Site Venetian Villas Nature trails High-quality agriculture	historic villages and hamlets with declining populations, agricultural or disused areas	Community Centre with-co-working spaces with bistro and viewing room. Barch Art is a unique opportunity for the Fonzaso area: its history linked to its agricultural vocation. A typical structure of the Fonzaso plain, is linked to haymaking, peasant culture. Four poles and a roof, to collect stories and dry grass and feed the cows during the winter
Participatory process for inland area	**Borgofuturo+** Borgofuturo, Non - profit Association https://borgofuturo.net/	Val di Fiastra municipalities (Marche, Italy) Interventions in the Municipality of Ripe San Ginesio	The exploration of productive relations (agriculture and craftsmanship), settlement relations (historic hillside centres and valley settlements) Valorisation of the products of the Fiastra Valley and its community	Historic villages and rural settlements	Participatory pathway: Local project. Six Val di Fiastra municipalities, four territorial tables involving more than 100 local actors to define Urban Regeneration Ripe San Ginesio: mapping of unused spaces within the borough with a festival of Sustainability and Social Camp
Sea to sea: recovery of the historical route Welcoming Committee, which acts as the guardian of the route.	**Friends of the Francigena Routes of Sicily**	The Magna Via Francigena of Sicily is a historic route linking Palermo to Agrigento (Sicily Italy)	Historic villages, rural architecture, archaeological sites, terraces of naturalistic value, valuable agriculture	Historic villages undergoing depopulation, derelict or rural areas	Magna Via Francigena di Sicilia, a route inaugurated in 2017 and travelled by more than 5,000 pilgrims before the Sars-Cov-2 pandemic.

The first example (Figure 4a) is situated in the industrial area of Fonzaso, in the province of Belluno (Northern part of Italy). In 2020, a community centre emerged from the vision of an intergenerational group, featuring a co-working space, a bistro, and a cinema. The organisation, named Dolomiti Lab S.r.l. (Benacchio et al., 2022), rapidly evolved into a social enterprise, serving as a platform for aggregation, collaboration, and cross-pollination, open to the participation and contributions of both local and external human resources (Vitillo, 2018). Various aggregation events have been organised, and the structure has also participated in European project bids for the territory, providing support for participation in the above-mentioned National Recovery and Resilience Plan calls and monitoring funded projects. Among the numerous creative projects, "Barch Art" is a unique opportunity for the whole area to revive its history tied to agricultural vocation, blending its memories and landscapes into a vision only avant-garde art can trigger. Barch Art, funded by the Cariverona Foundation, aims to culturally regenerate these particular structures. They are unique agricultural structures typical of the area, related to haymaking and peasant culture: four poles and a roof on the plains' meadows, to collect stories, dry grass, and feed cows during the winter.

The second example is the "Borgofuturo+" experiment (Figure 4b): it started ten years ago by director and screenwriter Damiano Giacomelli in Ripe San Ginesio, a small village in the Marche region in Val di

Fiastra, at the foothills of the Sibillini Mountains (Central part of Italy). This location was devastated by a severe earthquake in 2016-2017, just three years before the global pandemic crisis. Initially, a festival focused on cultural and environmental themes was activated. Subsequently, Borgofuturo evolved into a municipal project known as "QUI Borgofuturo". The vacant spaces of the historic centre were made available for artisanal and socio-cultural activities aligned with the festival's philosophy through symbolic rent. Supported by the Municipality of Ripe San Ginesio, Borgofuturo has launched several innovative initiatives, including the "Social Camp", an educational project that critically explores sustainability-related themes (Giacomelli, 2022). The festival has also collaborated with the European Horizon 2020 Ruritage project, which studies rural regeneration through local cultural heritage. Additionally, a larger-scale local project involving neighbouring municipalities is under development.

The "Da mare a mare" project (Figure 4c) is the third example: it features the establishment of the "Magna Via Francigena di Sicilia," a historical route connecting Palermo to Agrigento, in the Southern part of Italy. This project was implemented by the "Amici dei Cammini Francigeni di Sicilia" Association and inaugurated in 2017. Each stage of the journey and each municipality traversed is associated with a Welcome Committee, which acts as a custodian of the route, playing a crucial role in managing the path and serving as an effective form of local self-governance (Keuffer & Horber-Papazian, 2020). A distinctive feature of these Committees is their mutual interaction, which has helped overcome the geographical, social, and economic fragmentation of inland Sicily (Comunale, 2021; Ferreri, 2022), generating continuity of exchanges and relationships between previously separated places and acting as bridges between communities and territories.

3.3. Community-Landscape Project

The research aims to combine the themes of fragility and complexity for historical centres, considering the theme of fragility as well-understood, while framing the theme of complexity within the realm of uncertainty. This involves experimenting with a middle-up-down model (Cialdea & Pompei, 2020, 2021) to incorporate the notion of "active" perception and community participation in decision-making processes.

The findings stem from the experimental project titled "*Community-Landscape*" for the Lazio Region, specifically "Il Cammino dei Briganti," which extends through the municipalities of Montelanico, Carpineto Romano, and Sezze. These municipalities are located in territories of high natural and landscape value (Regione Lazio, 2021) and possess significant agricultural characteristics. The route is notably marked by the presence of karst caves historically used by brigands as hideouts (Sconocchia, 2011), and it is significantly linked to the Via Francigena del Sud, a historically and culturally important itinerary proposed for UNESCO international recognition (Ghiara, 2020).

Table 3 summarises the main characteristics of the proposal developed in the Monti Lepini area in the Lazio region, following the principles defined in the Data Collection Method (Ruggiero, 2024).

Figure 4. Community-based lab: 4a Dolomiti Hub (Source: https://dolomitihub.it/); 4b Borgofuturo+ (Source: https://borgofuturo.net/); Da mare a mare (Source: https://www.viefrancigenedisicilia.it/MVF.php)

Table 3. Community-Landscape Project (Author's Elaboration 2024)

Localisation	Collaboration	Landscape Unit	Cultural Heritage Value	Previous Usability	Final Realisation
Carpintero Romano-Montelanico-Sezze Municipalities	**Lazio Region Landscape Plan** **Lepini Company** **University**	Lazio Landscape Plan priority areas E7, E8, E9. (Lazio, Italy))	Historical centres and cores Nature trails that cross important SPA and SCI areas Karstic formations (caves, ouzo, chasms) that through 'lived' use have defined the history of the local and territorial community. Valuable agricultural landscape with production of local DOC and PDO products	Landscape of historic centres and cores, mountain areas, rural landscape, charcoal formations	Cammino dei Briganti del Lazio, a 35 km route that crosses the three municipalities of Montelanico, Carpineto Romano and Sezze, rejoining the Southern Via Francigena. The route extends along the natural sites of the karstic caves that defined the 'lived' during the Brigandage in the 19th century, providing them with shelter.

The municipality of Carpineto Romano (Figure 5) boasts the highest number of caves in the Lazio Region, estimated at approximately 250, some of which are accessible for speleological excursions, representing a significant naturalistic and historical-cultural asset for the entire territorial system. The study of brigandage, which outlines the history of this territory, is particularly important. This phenomenon developed specifically in this area due to its unique geomorphological conformation and dates back to the early 19th century in the Monti Lepini (De Caprio, 2020).

The applied experimentation emerges through multidisciplinary views concerning the multi-criteria study of the territory, proposing the infrastructure of a historical-cultural route defined in proximity to linear and point elements, including caves and geosites. The historical narrative of land use and the "experience" along the Monti Lepini chain, through this reformulation, emphasises the importance of territorial and social dynamics in landscape transformations. It suggests approaches to landscape planning that integrate the historical-cultural asset of the territory, geographical studies, and associations, thereby allowing the definition of a route, the Cammino dei Briganti, which spans thirty-five kilometres. This route enables the discovery of traditions, "lived" places, cultural and geomorphological heritage, traditional culture, and communities through the slow enjoyment of the landscape.

Thus, a potential connection between the historical characteristics of the landscape and the creation of circuits for the accessibility of minor centres is established.

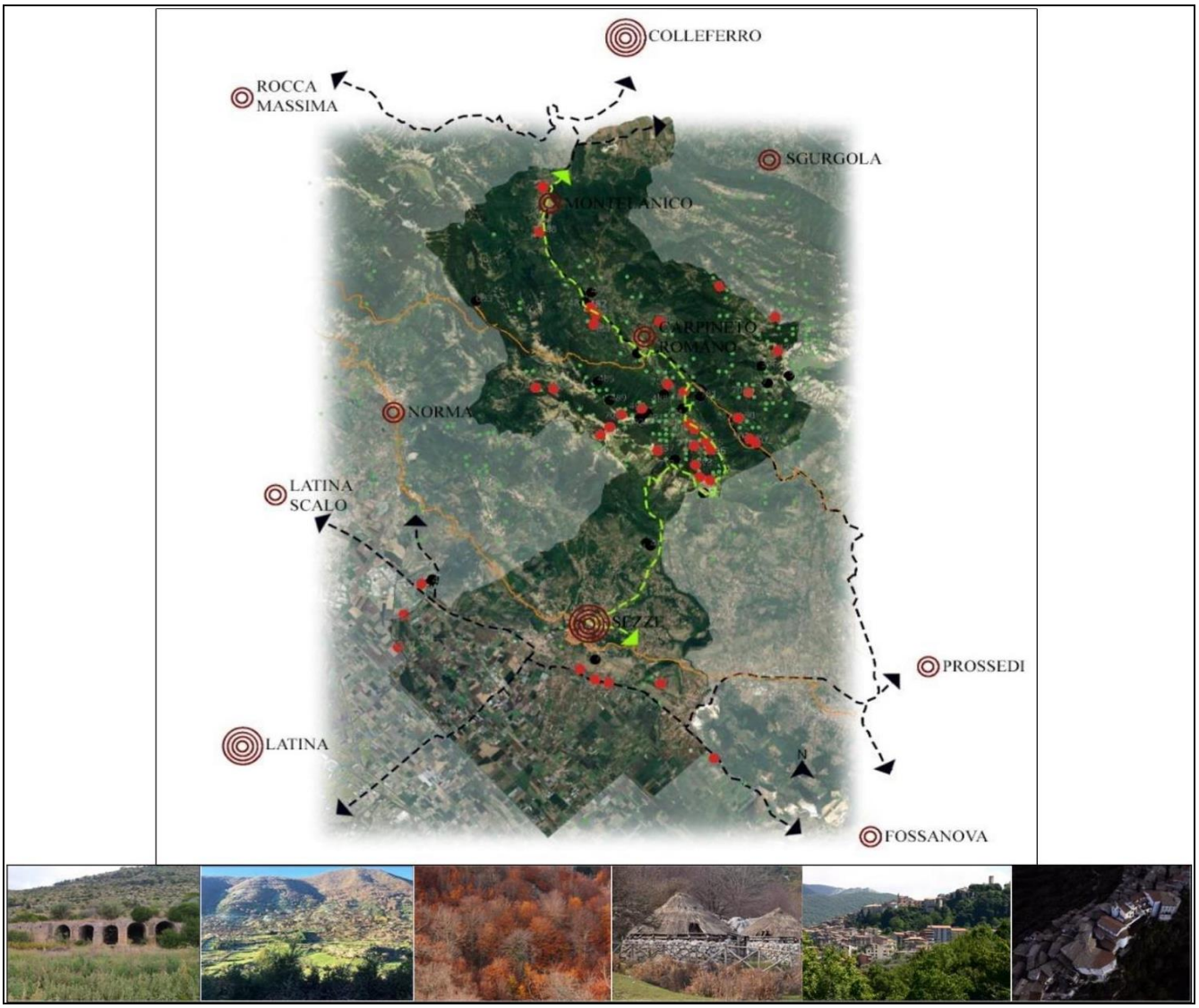

Figure 5. Carpineto Romano e il Cammino dei Briganti (Map: Author's Elaboration 2024; Photos sources: https://www.compagniadeilepini.it, Esposito, 2011; Authors)

4. Discussion

This research considers the identification of components that constitute the landscape project for "minor" centres to achieve proper integration of top-down and bottom-up processes while simultaneously fulfilling the concept of territorial enhancement.

The objective is to highlight critical issues and propose useful recommendations for constructing guidelines and suggestions for integrated participation. This involves analysing and comparing, for each model, the potential positive and negative effects derived from the examples analysed, with the most significant findings reported in this study.

The solution may increasingly qualify as a middle-up-down process, originating from the shared interests of local authorities and citizens, thereby initiating a "circle of knowledge" of the territory. While the bottom-up model develops according to an informal organisation where each stakeholder is autonomous and exchanges information limited to their sphere of interest, and the top-down model

often fails to interact with local populations, the middle-up-down model can create a continuous cycle of interaction. The technical-scientific community provides knowledge, skills, and expertise to mediate between local authorities and stakeholders. Given the rapid pace of changes, not only those related to climate but also historical-cultural shifts, this community can introduce innovative and experimental tools for a more effective reading of the territory, thus aligning more closely with the Community-Landscape Project. This integration is reflected in Table 4, which analyses the intersection of correlated positive and negative elements emerging from participatory processes, alongside data derived from an in-depth analysis of the Landscape Plan.

Table 4. Different approaches and their impacts (Author's Elaboration 2024)

IMPACTS	IMPACT'S AREA	TOP-DOWN	BOTTOM-UP	MIDDLE-UP-DOWN	
Positive Impacts	Inside local interventions	Realisation of **Territorial Studies** with in-depth studies related to the history of places **Enhancing the IDENTITY factor**	Citizen **Participation Processes** with increased sense of community **Enhancing the BELONGING factor**	In the **middle-up-down** model the figures middle figures are inserted between the up figures (Local Authorities) and the down figures (Stakeholders). The "middle" figures can be the Scientific Communities representing the "Technical Knowledge" useful to guarantee an effective integration for the Landscape Project. **Enhancing the IDENTITY/ BELONGING INTEGRATION**	
	External Influence	Strengthening Inter-Municipal Projects	Multiplication of Networks of associations	Ability to 'influence' authorities on the basis of local needs	
Negative Impacts	Inside local interventions	**Limited** local Participation	Possible identification of **local** needs	/	
	External Influence	Possible non-involvment of population in the definition phases of the Plan	Possible lack of knowledge of and/or compliance with the Plan's protective regulations	/	
Present Results	Inside local interventions	Recovery and new usability	Inside local interventions	Recovery and new usability	Inside local interventions
	External Influence	Replicability (supported by the Plan's technical regulations)	Capacity Building of Local Tourism Networks	/	External Influence
Integrative Suggestion	Inside local interventions	/	/	Implementation of effective local projects with a high degree of resident satisfaction aggregative factors favouring the inclusion of dwellings, including temporary ones	Inside local interventions

The multidisciplinary approach applied in this paper arises from an interest in fundamental infrastructures, specifically historical-cultural itineraries in proximity to linear or point elements, whether constructed or "lived," within agrarian landscape contexts. These contexts vary in opportunities and value but simultaneously face conditions of degradation and/or abandonment.

The essence of the landscape project intertwines the historical-cultural matrix with the spatial organisation of the infrastructure, emphasising the importance of visual, functional, and sequential relationships between rural landscape elements. The spatial organisation and historical-cultural infrastructure of the rural landscape are interwoven into a complex system of visual, functional, and sequential relationships. Understanding these elements and their interconnections is crucial for landscape planning to enhance cultural heritage and promote the sustainable development of the studied territories. Each project contains elements of cultural heritage, defined physically within the itinerary as linear or point assets, although varied in territorial dimensions.

5. Conclusions

The process must certainly retain its characteristic as a "planning tool," as stipulated by the cited Urbani Code. However, it could increasingly qualify as a middle-up-down process, which originates from common interests that may begin even before the enactment of the plan. It then coordinates the expression of public interest during the actual development phase, enhancing stakeholder participation while simultaneously refining territorial analyses.

In the context of landscape planning, this interaction is absolutely necessary. The middle-up-down model, in which intermediary figures (middle) are positioned between higher authorities (up) and lower stakeholders (down), can ensure greater effectiveness of the entire process.

Proposals arise from the theme of cultural heritage, with a local desire to reclaim their heritage. This includes attention to intangible assets, such as traditions, through the proposal of slow itineraries with multiple functions related to agricultural activities, the recovery of historical traces of the territory, and the restoration of infrastructures such as ancient historical-cultural routes for new recreational purposes. New solutions and possibilities derive from the ability to define potential new data and factors, currently managed in georeferenced databases within Geographic Information Systems, through broad public and scientific participation. This involves more than just mapping, identity, and/or belonging; it constitutes a functional construct for the territory that interacts between sociality and information, transforming into useful data for the enhancement of places.

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Ethics statements

Studies involving animal subjects: No animal studies are presented in this manuscript.
Studies involving human subjects: No human studies are presented in this manuscript.
Inclusion of identifiable human data: No potentially identifiable human images or data is presented in this study.

Conflict of Interests

The author declares no conflict of interest.

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Contemporary Urban Challenges for The Preservation of Values Associated with Settlements in Andalusian Mountainous Areas: The Case of Castaño Del Robledo in the Sierra De Huelva, Spain

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ABSTRACT

The landscapes linked to settlements such as Castaño del Robledo are one of the main elements of heritage interest in the complex and diverse Sierra de Huelva, a border territory between Spain and Portugal in the northwest of Andalusia. They reflect the physical and functional integration between the houses and the environment, where roads, historical infrastructure networks, walls and small buildings are intertwined with the cultivation areas, the embodiment of a very elaborate peasant culture. The aim of this work is to advance in the ways of approaching the knowledge of the singular values and fragility of these landscapes, with the main contribution of integrating a transversal view in their urban-heritage reading. The study starts with a first phase of analysis and diagnosis of the physical environmental support, the territory and the landscapes, and a second phase of evaluation to identify the challenges they currently face.

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1. Introduction

The qualification and conservation of the landscape has been attracting considerable attention from various fields of thought for several decades, and has gradually become of interest to public administrations, with the aim of preserving the material and immaterial values that landscapes treasure. These have been understood as the interaction of the conditioning factors offered by the biophysical

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supports of a given territory and the transformation processes that humans have been producing on them (Mata Olmo, 2008).

The Council of Europe Landscape Convention - CELC - (Council of Europe, 2000) has constituted a before and after in the conceptualisation of landscape as an everyday phenomenon, by understanding that not only singular and connoted landscapes but also common and even degraded landscapes are part of it. On the other hand, it has given a very important role to the population in the landscape phenomenon by focusing on the perception that the population has of the territories. As a construct of objective components perceived by different subjectivities, landscapes offer a symbiosis of natural and cultural elements that acquire different connotations for each individual gaze that gradually permeates the collective vision (Ojeda-Rivera, 2003). But the fact of such a transformation has to do with a process of artealisation, that is, a specific and singular view of a specific place resulting from the different creative contemplations that have been produced on it and that have been permeating the collective imaginary (Roger, 1997).

This is why it is often stated that landscape responds to a fact that is complex to define and delimit (Maderuelo, 2005) but, as a cultural construct, which is also related to the level of appreciation of a community with its environment measured through the quality of its landscapes and the level of knowledge and appreciation of them, landscapes could be qualitative indicators of the human development index of a society (Ojeda Rivera, 2003). It is precisely in this sense that the quality of our landscapes is also linked to the quality of life of society (Council of Europe, 2000) and this new view of landscapes is also implying their interest in being considered in heritage protection processes and in spatial and urban planning (Ugalde & Gurrutxaga, 2021).

The conservation of unique aspects associated with the landscapes of small rural settlements modelled by forms of construction and the development of agrosilvopastoral activities linked to vernacular conditioning factors and knowledge is receiving increasing attention, largely due to a combination of factors that negatively transform them, whether due to the decline of traditional activities (Ugalde & Gurrutxaga, 2021), the abandonment of the farmhouse or its inadequate transformation.

The present study focuses on Castaño del Robledo, a mountain settlement in the Sierra de Huelva, located in the central and highest part of its core area. The main hypothesis is that the heritage values respond to the symbiosis between cultural and natural aspects, that is to say, its heritage significance is not related to the monumentality of its buildings but to aspects such as the implantation in the place, the architectural solutions for the management of the topography, the climate and the water or the way of configuring singular farming ruedos. All of these are elements that reach their maximum expressiveness in rural urban transitions (Coronado Sánchez, 2020).

However, although the heritage value of the settlement is mainly limited to the urban area, the edges of the settlement and the farming ruedo are spaces that allow the heritage of this ensemble to be interpreted in all its depth and complexity. From the point of view of integrity, these spaces are the first elements of visible reference when we approach the settlement and also the most fragile, since, as they form the interface that surrounds the urban nucleus, they are the usual spaces that usually host new uses, extensions and transformations of the architecture, which are not always integrated with the whole (Coronado Sánchez, 2020). Although dimensions such as territory, agricultural space and landscape have, at least theoretically, been gaining ground in the way we look at heritage in general (Capel, 2014) and specifically that associated with historic urban areas (Jordán, Pérez-Eguíluz & De las Rivas, 2020), there is still a lack of instruments and criteria to address the planning and management of small rural historic areas from a holistic perspective that considers both the urban space and its agroforestry environment, so that contributing to this debate is revealed as the main element of interest and contribution of this research.

2. Materials and Methods

The methodology is based on several successive phases which are descending in scale and which respond to a sequence that starts with the sequence of understanding the spatial elements, then the historical-territorial and finally the landscape elements.

First, a spatial reading, i.e. of the natural foundations of the space, second, a historical reading and of territorial evolution, and third, the landscape dimension, which takes into account the scenic factors, but also the creative and common perceptions that make these spaces connoted. This methodology is based on the complexity of the landscapes and is therefore approached from a transdisciplinary perspective that makes it possible to synthesise aspects of different natures.

On the other hand, in order to recognise these spaces, we have used land registers and historical topographic maps that have been mapped, but it should be noted that very little initial documentation has been found, so that drawing and specific fieldwork on the study site has been very important.

As a last methodological phase, the research develops the analysis of representative urban images based on the study of their formal components. On the one hand, the homogeneous areas that make up the view, the structuring lines and, finally, the singularities and impacts. This analysis takes as a reference the research carried out by the Centro de Estudios Paisaje y Territorio for the analysis of the overall views of some Andalusian Historic Sites (Venegas Moreno & Rodríguez Rodríguez, 2002).

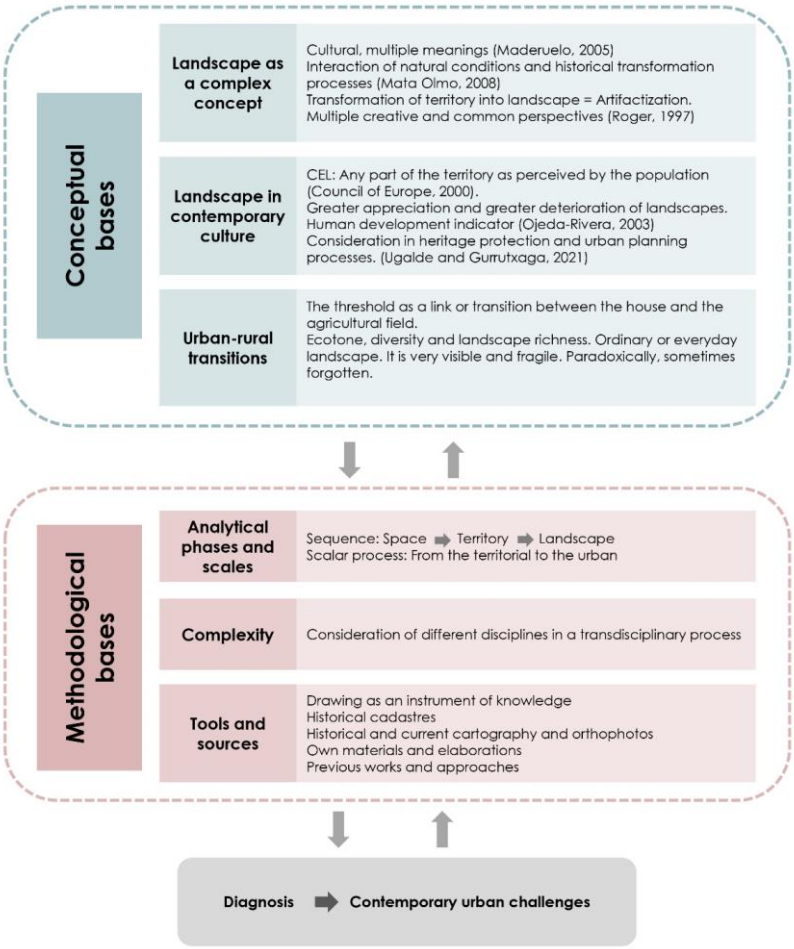

Figure 1. Conceptual and methodological framework

3. Strategies to face the transformation processes in rural areas

3.1. Castaño del Robledo in the context of the Sierra of Huelva

Castaño del Robledo, with 222 inhabitants in 2023 (Population and Housing Census, National Institute of Statistics) is one of the numerous urban centres of the Sierra de Aracena, a territory of the Sierra Morena in the northwest of Andalusia belonging to the vast Mediterranean mountain system in which its various mountain ranges share, as Braudel (1953) enunciated, common habitats, but also marked differences and singularities.

It is a peripheral territory with respect to the countryside and coastal areas and nearby Andalusian cities such as Huelva and Seville, to whose urbanites it offers water, leisure and nature (Ojeda Rivera, 2004). It has a very unique habitat with a high density of small and closely connected nuclei and an important variety of different agricultural areas in each locality, with high socio-ecological values and where the small and the diverse dominate (Rodríguez Álvarez & Rubio Tenor, 2014).

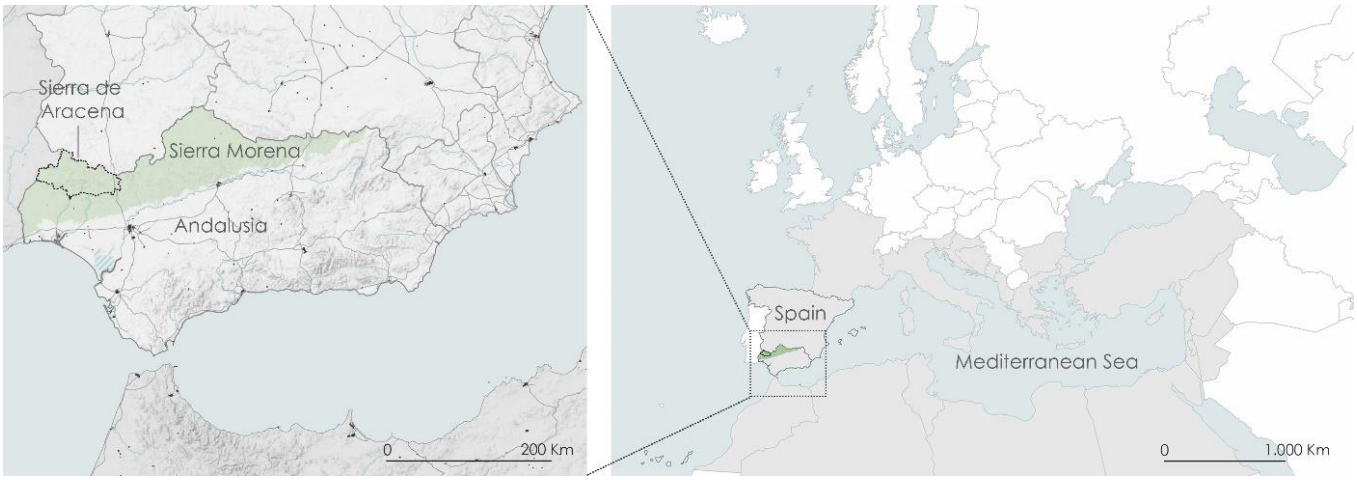

Figure 2. The Sierra de Aracena in the context of the Southwest Mediterranean (Developed by Author)

The main spatial keys to the sierra are that it is a south-facing ridge influenced by the Atlantic and the Mediterranean. Its rocky terrain is hard and impermeable, which has made reservoirs possible, with historical mining and the emergence of water through numerous springs and fountains. It has a contrasting relief with a much higher central massif, with an east-west orientation, which is also a watershed. It also has high humidity and abundant rainfall in a region like Andalusia, which is generally hot and dry. All of this creates numerous climatic tesserae depending on the altitude and the degree of sunshine that promotes the biodiversity of the Mediterranean forest and agricultural variety (Ojeda Rivera & Silva Pérez, 2000).

Historically, this territory has been a border area with Portugal and Castile, but also a place of liaison between cultures and a place of refuge. Three stages can be recognised in its formation: The first, between the 13th and 15th centuries, with few nuclei in castles and fortresses and great population instability. The second, between the 14th and 16th centuries, when, once the borders had been pacified, a process of creation of small settlements was generated, which took advantage of the riverbanks and communal woodlands to establish themselves, organising small groups of houses and small associated agricultural spaces (Pérez-Embid, 1999). The third, between the 17th, 18th and 19th centuries in which, under the Enlightenment thinking (Albarreal et al., 2008; Cascales, 2017), some of the small settlements grew and a territory of small and medium-sized hamlets and villages was formed together with diversified agricultural areas due to the introduction of new crops and the creation of an important commercial network between the Spanish Meseta (to the north of the area) and the cities of Seville and Cadiz, at the height of trade with America. (Dominguez Ortiz, 2000).

At the end of the 19th century, the population ceiling of the sierra was reached, as can be seen from the population registers in Spain, which are recorded in different historical cadastres (National Institute of Statistics) and from there its progressive decline due to various processes of population exodus, first to the nearby mining emporiums such as Minas de Riotinto and in the middle of the 20th century during the Franco dictatorship, the creation of development poles in Huelva and Seville (Moreno Alonso, 1982).

Since the 80s of the 20th century, in democratic Spain, there has been a rediscovery of the sierra both institutionally, with the declaration of the Sierra as a Natural Park and of numerous settlements as Historic Sites, and also by rural tourism, producing a paradox since, despite the increased interest in the sierra, the rates of inequality for the serranos are still high compared to urban areas (Ojeda Rivera & Silva Pérez, 2000; Ojeda Rivera, 2004).

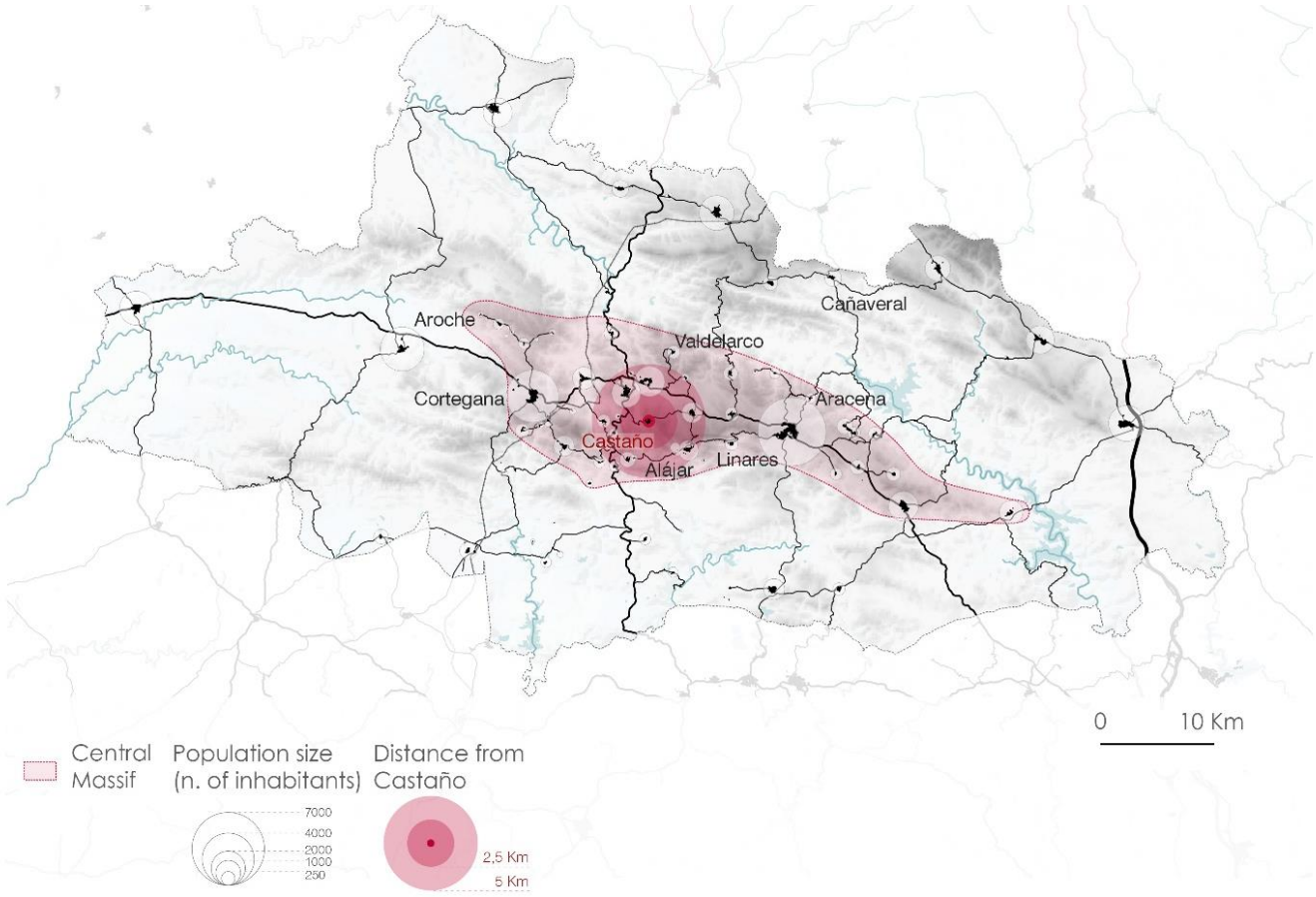

Figure 3. Castaño del Robledo in the context of the Sierra of Huelva (Developed by Author)

Castaño del Robledo constitutes the heart of the central area, at the highest and most central point of the Sierra, situated in a valley that leaves the Sierras del Castaño, the highest point (+961 m) behind it to the northeast. It is in the physical centre of the central area. It was an ancient village that in the 18th century became independent as a town and came to play an important role in the Sierra due to its success in the production of sausages, carpentry and chestnut fruits (Núñez Roldán, 1987). As a result, it maintained strong historical relations with the nearby towns of Santa Ana, Galaroza, Alájar, Jabugo and Fuenteheridos, over which it acted as a territorial hub in the 18th century, until the territorial logics associated with the new transport networks, together with other factors, marginalised the settlement between the late 19th and early 20th centuries (Cascales & Márquez, 2012).

3.2. Configuration of the urban-rural fabric

From a reading of the characteristics of the historical and spatial evolution of their hamlet (Cascales & Márquez, 2012; Cascales, 2017) supported by historical cartographies, it can be deduced that the first houses of humble dwellers that emerged in the settlement were installed on platforms close to springs and streams, which guaranteed fertile land for cultivation that was complemented by the use of the mountains. There is first documentary evidence of the settlement in the 15th century, when they formed the small hamlet of El Robledo, which grouped them together as a single entity (Pérez Embid, 1999). Probably already at this time there was a small hermitage at the midpoint of the different nuclei, which would later give rise to the Church of Santiago, whose construction was promoted by the humanist Arias Montano in the 16th century, who also created the first school in the sierra in this settlement, as can be seen from the general responses of the parish priest in the survey carried out by the royal geographer Tomas López in 1795 (Ruiz González, 1999).

Between the 15th and 17th centuries, the first growth, very timid, took place from the initial nuclei towards the church, but the population took off in the 18th century, as shown by the need to build a new church and the recognition of the settlement as a town, continuing this population boom in the 19th century (Pérez-Embid, 1999). According to the characteristics of the architecture, the growth is produced from the initial nuclei to the two churches: the old church (16th century) and the new church (18th century). As a unique case in the sierra, it takes place along a line of maximum slope due to the passage of a stream that crosses the village from the northeast to the southwest. For its part, the settlement basically consists of two nuclei, the largest and that of the Calvario neighbourhood, located to the west.

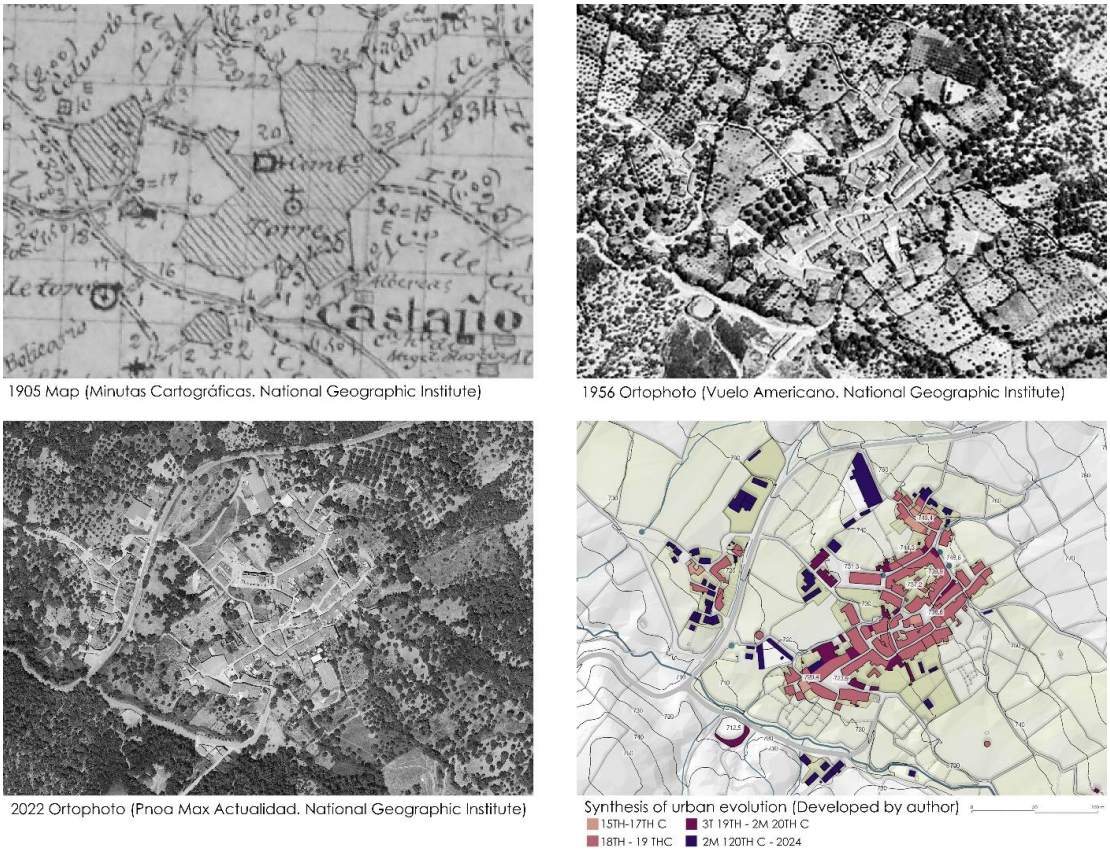

Figure 4. Urban evolution of Castaño del Robledo (Indicated sources)

In addition to the reasons already given, the importance of the 18th century should be stressed, since, following the humanist trail left by figures such as Arias Montano in the 16th century, with scientific contributions in all fields of knowledge, including botany (Vallejo Villalobos et. Al, 2015), Enlightenment thinking was assimilated, generating a new territorial order with the formation of the network of towns and villages in the sierra, but also of the agricultural areas (Pérez-Embid, 1999). As can be seen from the study of plots and uses (Figure 4), the agricultural area has a plot size of less than 3 hectares. Historically, they introduced products that are highly valued today, such as special varieties of potatoes, tomatoes and oranges, irrigation systems and enclosures, as recorded in the Ensenada Cadastre in 1752 (Ministry of Culture, 2024). In a second territorial gradient, between 3 and 10 hectares, the trasruedos were created, incorporating intermediate plots of different crops. As already mentioned, chestnut trees in the shady and higher areas and olive groves and holm oaks in the sunny areas. All these forms a large forest that interconnects the different villages of the central massif of the sierra (Coronado Sánchez, 2020).

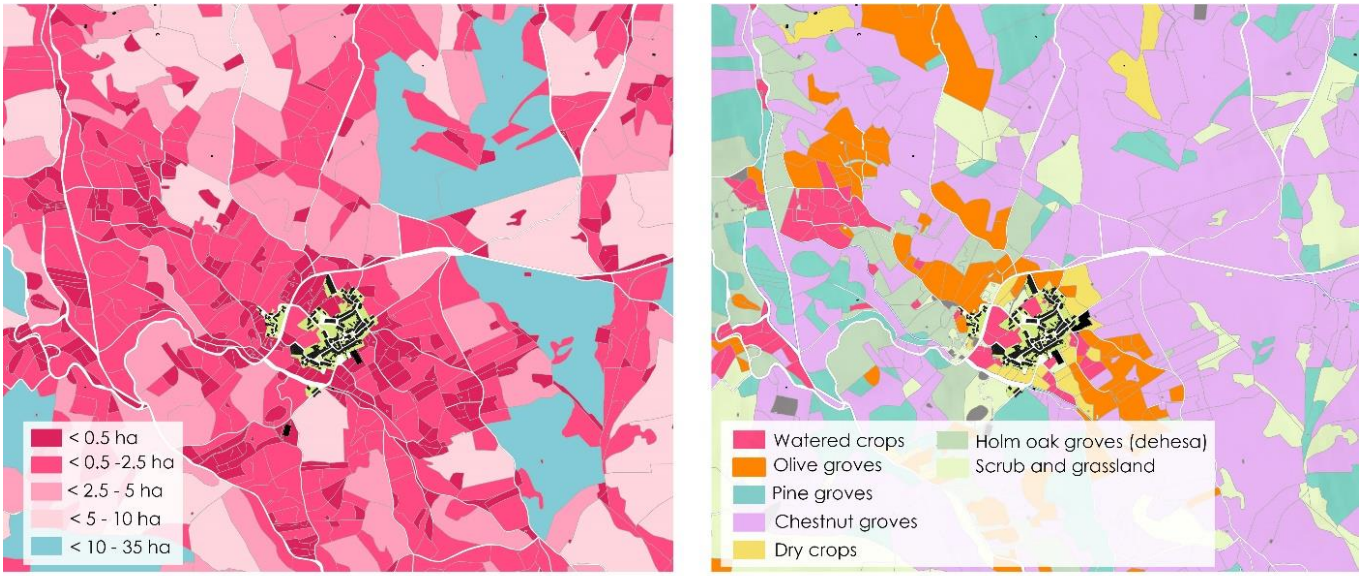

Figure 5. Relationship between the parcel and the types of crops grown in the farming ruedo in Castaño del Robledo. (Developed by Author).

In the mid-19th century, when Castaño del Robledo lost its central role in the manufacture of sausages and wood, the population began to decline (Núñez-Roldán, 1987) and as a result, urban growth between the mid-19th century and the mid-20th century was very small and focused basically on small additions and alignments towards squares and singular streets. From the middle of the 20th century, a road dividing the two nuclei and the farming ruedo was introduced, leading to a progressive deterioration of this space, with the appearance of industrial warehouses on a larger scale than the small hamlet, residential uses, housing extensions or enlargements of inadequate volumes. All of this will lead to the breakdown of the relationship between the settlement and the farming ruedo, all of which can be seen in the different historical cartographies (figure 5).

3.3. The relationship of the settlement with the environment

In addition to the aspects that it shares with most of the mountain nuclei - a special territorial culture of water, orography and climate - the singularity of Castaño is notable not only for being a nucleus with a polynuclear structure due to its origin linked to several settlements and subsequent growth processes

(Feria Toribio et al., 2002) that have generated a special relationship between the houses and the corrals linked to them, which translates, among other aspects, into the integration of the built and the cultivated.

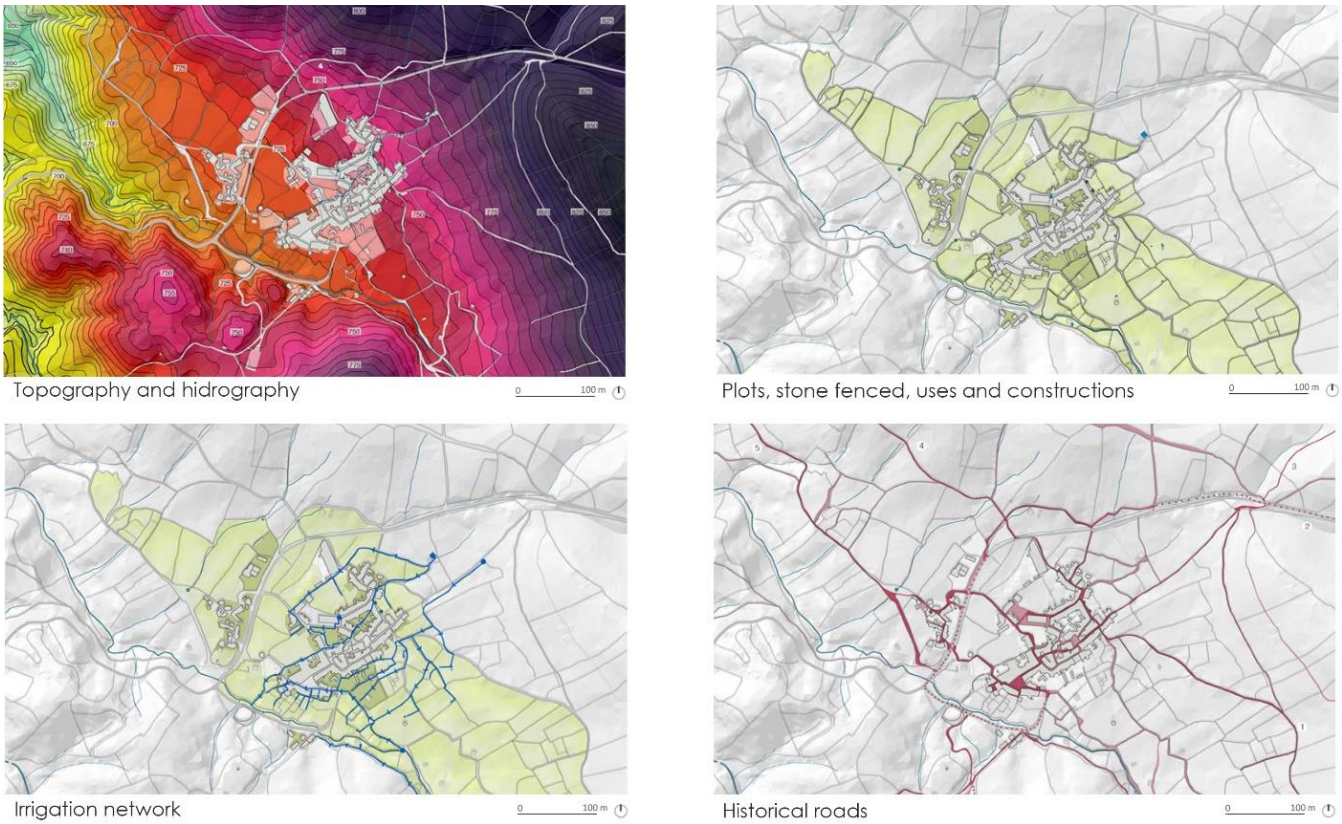

Figure 6. Analysis of the relationship of the settlement with the environment

From the analysis developed, the topography and hydrography form part of an intimate correspondence (Figure 6), which shows how the settlement is located perpendicular to the direction of the valley, which means that there are streets with a significant slope and very long, as opposed to other practically flat transversal streets. Secondly, the plots of land, the stone enclosures, the uses and constructions of the ruedo, form a singular layout. The historical irrigation network, which is organised from the springs following the natural fall of the land and allows for the incorporation of irrigated areas both in the areas of corrals that remain inside the settlement, around the north-western edge. Finally, the dense network of historic roads, which have a complex hierarchy and linked Castaño with other villages. Water establishes a very important order in the urban configuration and there is a complementarity between the management of the land, the network of paths and the plots enclosed by walls which, together with the urban fabric, give unique qualities to the landscapes (Coronado Sánchez, 2020).

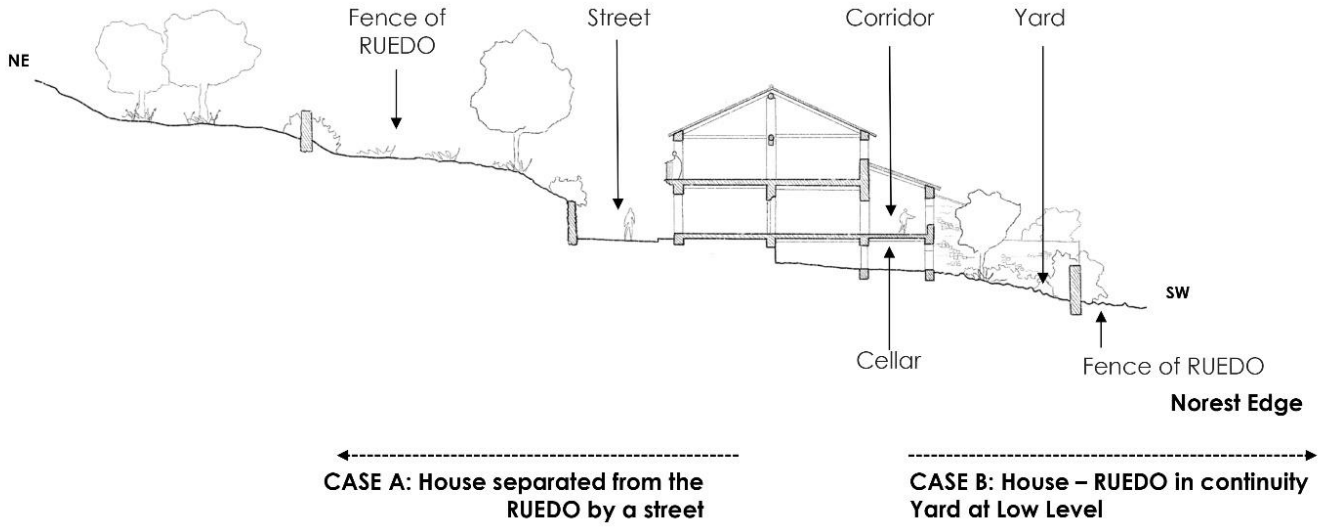

Figure 7. Most representative types of edges in Castaño del Robledo (Developed by Author)

The historical configuration of the settlement has given rise to different types of urban edges (Figure 7), which establish a sequence of several different types of spaces. First, in case A we can see sharp edges where the house is separated from the enclosures of the ruedo by a street. Second, the most representative case in Castaño is the one where there is continuity between the house and the farming ruedo. We can observe, however, two different variants: A sequence between the farmyard and the enclosure of the ruedo, which is situated at a lower level, and a more complex sequence of farmyard, domestic orchard and then the enclosure of the ruedo. Both cases, oriented to the southeast or southwest, have corridors and cellars open to the respective corrals.

This is a very distinctive feature of the transformations of the house in Castaño del Robledo that took place throughout the 18th century, when it was transformed and became larger and more complex. Several levels are incorporated, large roof eaves parallel to the natural slope of the land and types of spaces that mix agricultural and domestic functions (Cascales Barrio, 2017). Corridors and cellars are created, as well as a sequence of outdoor spaces of corrals, courtyards and vegetable garden areas until reaching the enclosures of the farming ruedo, made by means of stone masonry walls, commonly known as "dry stone". The urban fabric of the settlement is also conditioned by aspects related to the paving of the streets and the water networks that interconnect the agricultural area with the interior of the settlement.

The urban fabric and its urban-rural transition spaces favour a very rich visual relationship between the interior of the urban complex and the exterior, through the half-height walls that almost always form part of the near plane and, behind them, an important variability of orchards, pasture areas and chestnut woods as a visual filter and envelope for an equally interesting vernacular architecture.

Figure 8. Views of Castaño del Robledo. View from the air (top) showing the two churches and the corridors of the houses on the edge of the village. Intermediate view (centre), where the corridors of the houses and the corrals and orchards in front of them can be seen. Close-up view (bottom) on a street approaching the main nucleus, where the visual interrelationship with one of the churches can be seen. (Developed by Author)

Likewise, the incidence of these urban-rural transitions in the everyday landscapes of the locality is very important due to the high visual exposure they acquire in the different views, both in the intermediate and close-up planes. In them, the elements analysed are put in relation to each other: adaptation to the topography, the plot of the ruedo and types of crops, water management and the articulation with the network of roads which results in a very singular type of urban fabric.

In the aerial and intermediate views (Figure 8), we can see in the foreground the orchards of the ruedo, the settlement where the two churches stand out against the profile of the settlement and finally, in the background, the chestnut forest that changes throughout the year. The corridors of the houses open to their corrals stand out as a distinctive feature of the architecture, as well as the continuity of the roofs.

In the close-up views approaching the settlement, the "visual windows" appear as they represent the intervisibility that occurs between different parts of the settlement due to its genuine urban structure that incorporates large ruedo spaces interspersed between the houses. In this case, we can see in the foreground the stone walls, the cobbled floors and the historic water conduit. In the background, the church tower appears between the treetops and roofs.

3.4. Diagnosis and contemporary challenges

In the general analysis of the settlement (Figure 9) from the perspective of its visual qualities, it is possible to identify the most recurrent characteristics of the settlement and its surroundings as well as the main singularities and impacts that are present in most of the views:

On the one hand, a set of very clear areas can be distinguished, some of them allude to the urbanised fabric and others refer to surfaces that are linked to the soil and vegetation. In the urbanised space, the different urban nuclei that make up the settlement can be distinguished, surrounded by the farming ruedo as the first space of smaller plots of land and cultivated areas. This space is then enveloped by different areas of wooded land, which correspond to the orographic elements that delimit the site: to the north, the olive groves and chestnut groves (1), to the southwest, the holm oak and cork oak groves (2) and to the southeast, the holm oak, cork oak and chestnut groves (3). Regarding the built fabric, one of the singularities of Castaño lies in the important incidence of the edge space formed by the corrals, which are very abundant, some of them in the interior of large interior blocks.

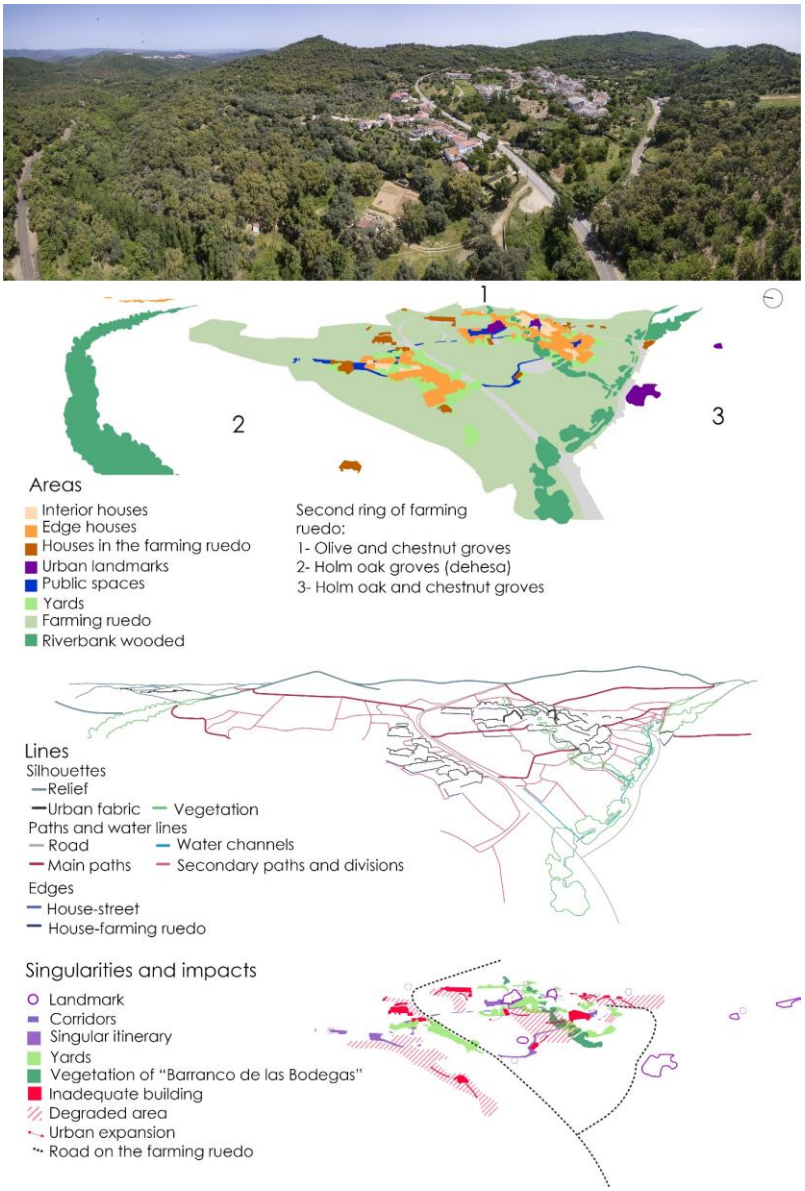

Figure 9. General analysis of urban-rural transitions in Castaño del Robledo (Developed by Author)

As for the structuring lines, the different profiles of the hills and mountain ranges are very present, almost always present when viewed from the south. On the other hand, the gallery forest marks the end of the great platform where the urban nuclei and the ruedo are located, accompanying the riverbed which tends to get lost both to the east and to the west. The organic meshed structure also has an impact: the main paths and crop-organising walls, the watercourses and associated vegetation and the silhouettes of the buildings.

The corrals define an axis on the western edge that runs through the interior of the settlement and seems to branch out transversally at different altitudes and towards the fronts of the houses. Likewise, the singular constructions that often accompany small open spaces tend to form an interconnected circuit that could give rise to an interpretative network associated with a network of urban-rural open spaces.

As singular buildings, the two temples stand out in the ensemble, separated by large corrals and visually intercommunicated by their two podiums - viewpoints that rise above the ensemble and give these buildings greater monumentality. On the southern slope is the bullring and the cemetery, as well as two chapels to the northwest and southeast. The fountains are also important in the urban organisation, distributed throughout the different neighbourhoods and usually accompanied by small or larger open spaces, and elements typical of agricultural activity which, although in a certain state of abandonment, constitute a reference point in the cultural memory of this town.

Figure 10. Main urban impacts in Castaño del Robledo, associated with urban-rural transition spaces. View from the southwest. (Developed by Author)

However, in the last two centuries, according to the historical analysis carried out, the tendency after the construction of the road, already aggressive, has encouraged the construction of buildings outside the logic of the grid and the adaptation to the topography, generating different visual impacts on the most sensitive fronts. On the western edge, warehouses have been built in the main access to the settlement, while the lower part, less dynamic in recent decades, is now in a certain state of deterioration and abandonment after buildings of inadequate volumes fell into disuse in the mid-20th century, such as the slaughterhouse and the feedlot above the farmhouse in the south-western part of the main nucleus. The southeast front has been the site of large facilities that have been damaging it, to which have been added extensions of houses on the corrals, remounts and other constructions and in specific areas to the northwest of the main nucleus and the nucleus of the Calvario neighbourhood, there are dynamics of urbanisation of second homes that also stress these edges.

In summary, we can highlight the characteristic elements of the urban-rural transitions that provide unique qualities to this settlement, expressed in the relationship between the farmhouse and the environment, through the corrals of the houses and the network of paths, fountains, irrigation infrastructures and cultivated enclosures that form an interface with the mountain ranges surrounding the settlement. It is also important to highlight the visual impact of these edge spaces in different views of the settlement, which means that they are very present in the everyday landscapes of the inhabitants but are also fragile to negative transformations. However, there are also numerous problems. The first is the road that was built some decades ago, separating the two nuclei that make up the settlement and crossing the ruedo. This has led to the gradual degradation of this space with the construction of industrial buildings and housing which do not respect the historical territorial order, and which contrast excessively in terms of volume and size. Furthermore, facilities have been built on the

south-eastern edge, which also have a significant impact. Finally, some areas of the ruedo are abandoned and the historical irrigation systems are being lost, which is accompanied by processes of abandonment of the hamlet.

4. Discussion

One of the first elements of debate to be addressed in this work is that despite the social valuation that landscape and vernacular architecture are acquiring, abandonment, changes in use and the urban dynamics of populations have progressively deteriorated this extensive heritage, influenced also by the abandonment of the rural environment, This is an issue that in general in the international context is in full debate on the role that rural territories currently play in an egemonic urban context dominated by the needs of the cities, which contributes to their mythification and in the end to a certain marginalisation (AMO and Koolhaas, 2020), relegated to the role of providers of resources (water, food, nature and leisure) but with high rates of inequality with respect to the more populated and central areas of the system (Ojeda Rivera, 2004).

The second element of debate concerns the place in which the heritage values of small rural mountain settlements are deposited. The analytical process developed allows us to verify the initial hypothesis that these values are linked to aspects that have to do with their location and relationship with the environment, which have been producing complex solutions for overcoming limitations and making the most of the facilities, aspects that are mainly appreciated through the interior and exterior urban landscapes characterised by smallness and detail and not so much by the singularity of monumental elements understood in isolation, since it is precisely in the relationships between material and immaterial, natural and historical that the character of each landscape is configured (Mata Olmo, 2008). It would therefore be desirable that urban planning and heritage management processes pay attention to the importance of the material and immaterial value of aspects such as the urban fabric, the characteristics of vernacular architecture (wide eaves and continuity of roofs, various levels in buildings, corridors, cellars, corrals, systems of openings or corrals) and the farming ruedos and their components (local produce, paths, water conduits, stone enclosures, fountains, etc.).

It has been shown that the real access to these landscapes and their quality depends to a large extent on the way they are treated in urban planning, in the architectural work, in the maintenance of the farming activities of the farming ruedos and in the environmental quality. For this reason, transdisciplinary analysis and diagnosis processes focusing on the landscape, such as those proposed here, not only help knowledge and dissemination but also allow us to identify their essential characteristics as well as degraded or threatened areas to be corrected, integrating the morphological but also the scenic vision (Jordán-Salinas et. al., 2020).

Urban-rural transitions are influenced by all the processes associated with the periphery, which is becoming more complex today as it tends to be a new diffuse fabric that complicates the traditional relationships between settlements and their agricultural or natural environments. A type of phenomenon that breaks the traditional geographical structure referred to by some authors as metastasis (Naredo, 2000) or Postmetropolis (Soja, 2000) and makes our everyday contexts reach a generic character that brings them closer to non-places (Augé, 1993) perceived as third landscape (Clement, 2018) or landscape of the periphery. In this context, agricultural spaces are increasingly marginalised and at high risk of losing their cultural and environmental values, and it is therefore advisable to take different types of actions from spatial and urban planning for their preservation (Hamrita et. Al, 2021).

These landscapes need visions and strategies for action at the territorial scale for the creation of territorial corridors that interconnect and protect the ruedos between localities. Also, strategies for the promotion of proximity agriculture, not only to maintain a tradition with high symbolic and emotional value for the inhabitants of the sierra, but also (García-Martín, 2023) as a resource to strengthen the economy of the sierra.

The second challenge they face concerns the improvement of heritage protection systems. On the one hand, of the elements that distinguish the architecture of the urban hamlet and, on the other, of the elements that make up the agroforestry environment, such as the plot structure, roads, irrigation systems and fountains that stand out in the analysis. On the other hand, a way to combat the abandonment of this heritage, which is difficult to maintain for a rural economy, requires thinking about programmes to support rehabilitation (De las Rivas-Sanz et. Al, 2022) and local crafts and construction systems, linked to specific housing actions combined with multisectoral strategies such as employment, improvement of services and cultural offerings, among others (Donadei, M. et. Al, 2023).

In spite of this, the presence of degraded spaces, which are especially concentrated on the urban edges, allows us to deduce that urban regeneration strategies should lead, in general, to their necessary integral reform both from the point of view of buildings and of the free spaces on plots, as well as configuring criteria and guidelines for the landscape adaptation of new interventions (topography, scale, materials, full and empty spaces, etc.) and rules to protect urban voids of landscape interest. To this end, the first challenge to overcome is the deficit of planning instruments and technical means (De-Santiago-Rodríguez, 2023) which, like Castaño del Robledo, is a generalised situation that these rural settlements suffer from, which generates added difficulties for the management of heritage and for urban adaptation to contemporary needs from the integral logic offered by planning.

From the point of view of the environment and the promotion of the landscape experience, the diversity of heritage elements and the urban and landscape interest would allow the improvement of access systems to the heritage and landscapes, providing an interrelation between the various elements and the system of open spaces with the possibility of configuring itineraries and places to stay, The project would also help to generate an active preservation of the heritage values associated with them through awareness-raising and appreciation of the public.

5. Conclusions

Landscape is a living concept in a constant process of transformation, inseparable from its essential role as an environment in which the lives of the inhabitants develop and as such, a symbiosis between aspects related to the natural foundations, the historical and territorial construction processes that the inhabitants have been developing and the common or creative perceptions that have been shaped on them and for this reason, its incorporation into urban and heritage processes is of increasing interest.

The urban transitions of rural settlements and specifically of the settlement under study harbour interesting values as elements that interrelate the interior of the settlement and the farming ruedos of the immediate surroundings, through various urban-rural construction solutions from the house, the corrals and the agricultural enclosures together with a network of elements that correspond to each other (the paths, the types of enclosures, the fountains and irrigation networks and the walls and small agricultural constructions). All these forms a territorial hinterland of great heritage interest and with a high impact on the everyday landscapes of the settlement, although it is in a process of degradation due to processes of abandonment and deterioration and inadequate interventions on these spaces of high visual fragility.

From the research carried out, reflections and transversal analytical mechanisms are provided for understanding the spatial, territorial and landscape keys of these transitions, and some important challenges for their urban and heritage consideration emerge, which can be shared with other rural mountain settlements and which have to do with the territorial dimension, a global and complex conception of urban-rural heritage, urban rehabilitation and regeneration, the development of planning instruments applicable to these rural contexts and the promotion of a landscape experience that responds to the complexity of mountain landscapes.

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

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Conflict of Interests
The author declares no conflict of interest.

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Towards A City of Good Dwelling

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ABSTRACT

One of the main issues in contemporary urban planning is the fragmentation of urban spaces (Batty 2009) due to the relentless processes of land transformation. This phenomenon can lead to the creation of isolated urban islands and a lack of high-quality public areas. Such weaknesses particularly affect the socio-economic conditions of marginal areas within the existing city, especially those on the outskirts near rural areas. Public spaces (Low et al 2006) are essential for social interaction, community building, and improving the overall quality of urban life. They are spaces where cultural, economic, and social activities converge, contributing to the city's vibrancy and inclusiveness. Are considered the key of the new processes of urban regeneration and it contributes significantly to the making of the city of "good dwelling" (Beauregard 2020). To obtain the conditions for a good dwelling, it is proposed to apply the seven principles contained in the "Manifesto della Città del Buon Abitare"(Colarossi et al 2023): the city of good dwelling must assume the general principles of hospitality, urbanity and beauty of its public spaces. The paper proposes as innovative approach, the use of an urban planning tool with which it is possible to apply the principles of the Manifesto of the city of good living and which is called "Plan-program of public space planning and public and private services" (P.A.S.S.i.). The effort of this research is to identify a general planning tool for the redevelopment to the existing city. The multi-scalar approach of the research tool simultaneously allows an overall vision of the program and a qualitative control of each individual project.

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1. Introduction

Decades, perhaps many decades, will be needed to remedy the catastrophe and urban planning culture from the 1950s-60s to the present day has produced in the recent new urban areas of cities in Italy developed during that period.

The post-war period saw the rise of modernist planning principles, which emphasized functionality, zoning, and the separation of land uses. This approach led to large-scale redevelopment projects that

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often-disregarded historical context and local character (Jacobs 1961). Key problems included the need for housing near city centres leading to unregulated urban transformations (Beauregard 2015), social fragmentation due to the separation of residential, commercial, and industrial zones (Hall 1988), and environmental neglect with a focus on vehicular traffic and infrastructure that contributed to pollution and diminished green spaces (Staley 2020).

In contemporary urban planning, it is crucial to shift our focus to the existing city rather than solely concentrating on new developments. The existing urban fabric holds significant opportunities and challenges that must be addressed to enhance overall quality of life and sustainability (Murray & Williams 2020). Nowadays the answer of each urban planner is: what steps should be taken to regenerate the existing city?

It is essential to start with a concept of the city, an idea that can guide proposals on what, how, and when to undertake urban regeneration. This concept should address parts of the existing city, generally constructed in the last seventy years; a city that presents to those who traverse its public spaces "everyday landscapes" (European Landscape Convention, 2000) that are banal, degraded, and unwelcoming. These are spaces that many inhabitants—tens or hundreds of thousands—traverse and view daily, yet fail to see, having become habituated and unaware. These are the everyday landscapes of great ugliness.

The quality of living (Gehl 2010) is deeply interconnected with the quality of the urban landscape and its public spaces. High-quality urban environments are essential for nurturing a strong sense of belonging and attachment to one's surroundings. Research proposes seven criteria and principles to establish the basic physical conditions necessary for quality living in a city's public spaces. These principles are titled as follows:

Table 1. Synthesis of 7 Principle of Manifesto

Principle	Description
Quality of Good Dwelling	Ensure high standards of living spaces, providing comfort, safety, and accessibility.
Centrality	Develop central hubs that serve as focal points for community activities and services.
Small Cities within the City	Promote self-sufficient neighborhoods that offer all necessary services within walking distance.
Walkability versus Drivability	Prioritize pedestrian-friendly environments over car-centric infrastructure.
Collective Memories	Preserve and celebrate the cultural and historical heritage of urban areas.
Urban-Rural Pact	Foster a balanced relationship between urban and rural areas to support sustainable development.
Active Participation	Engage residents in the planning and decision-making processes affecting their urban environment

These principles aim to create public spaces that enhance the quality of life by addressing key aspects of urban living, fostering community engagement, and promoting sustainability

All seven principles are interconnected and interdependent: together, they form a system of principles for creating a city of good living. Collectively, we have defined these principles as the "Manifesto of the City of Good Dwelling."

The development of urban regeneration and redevelopment plans and projects for the cities of San Severo (FG), Bologna, Velletri (RM), and for two design competitions in Putignano (BA) and Legnano (MI), provided opportunities to experiment with the application of the principles outlined in the "Manifesto".

During these experiences, it was also possible to identify and refine the contents of those plans and projects, as well as to develop appropriate innovative urban planning tools and strategies for the timing and methods of implementing interventions. These project strategies are appropriate and useful as they are tailored to the needs of urban regeneration planning, or rather, to a "small-scale urbanism."

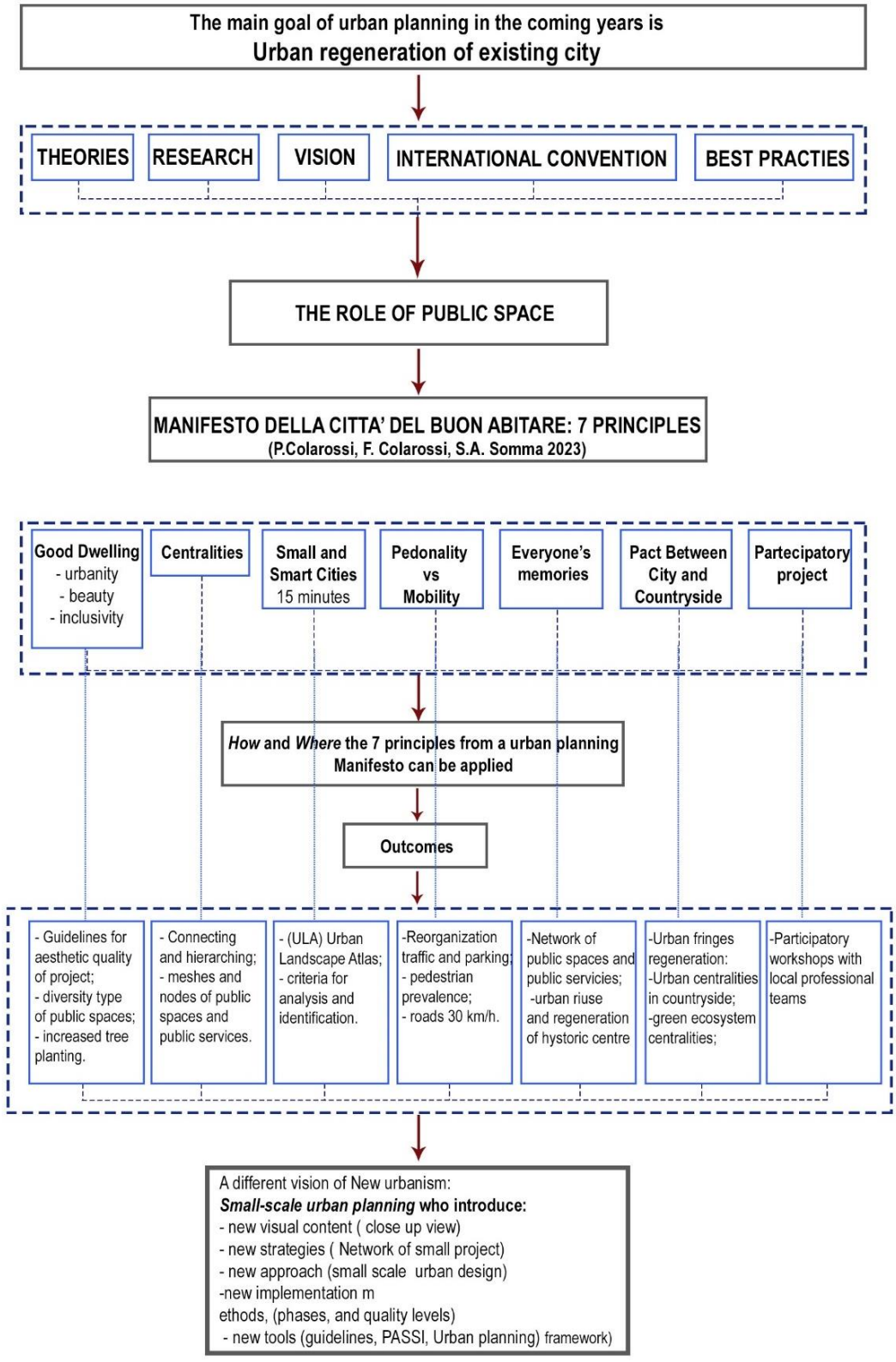

Figure 1. Methodological process (Developed by Authors)

The diagram represents the entire and complex methodological process, of which the text presented here is the third and, for now, final phase.

In the first phase, the process of awareness and evaluation of the low-quality living conditions in recently developed urban area, built in the last sixty to seventy years, is illustrated, along with the ideas and proposals from the international urban planning culture aimed at improving these conditions, highlighting the significant role of public space.

In the second phase, based on a synthesis of the findings and reflections from the first phase, a system of seven principles for good living (Colarossi et al 2023) was proposed, which should form the foundation for urban redevelopment and regeneration interventions.

The third phase focused on testing the application of the seven principles of the City of Good Living in several Italian cities of varying sizes. The main outcomes of this experimentation are discussed in the text presented here. These results form the basis for further experiments, following a process of successive insights and refinements, towards the creation of a necessary new urban planning: a small-scale urban planning for quality living.

2. Innovative Urban planning tool

For the quality of living, as mentioned, a crucial role is entrusted to public space. Or rather, to primary systems of public spaces (centralities), as will be clarified further. The focus on small-scale (Talen 2024). urbanism is essential for improving the quality of living in contemporary urban environments. To operationalize this approach, the following strategies and tools can be employed many aspects like: flexible zoning regulations and human-centered design principles should prioritize mixed-use developments, pedestrian-friendly infrastructure, and universal accessibility. Incorporating sustainable, resilient infrastructure and leveraging smart city technologies will enhance urban management. Additionally, initiating small-scale pilot projects and using prototypes can help to test and monitoring urban transformation and new concepts, ensuring effective and adaptable urban planning solutions. Overall urbanism of small scale is the one through which it is possible to address the qualities of living because it requires a close examination of the city, which traditional urban planning tools (general urban plans and related implementing tools) struggle to achieve.

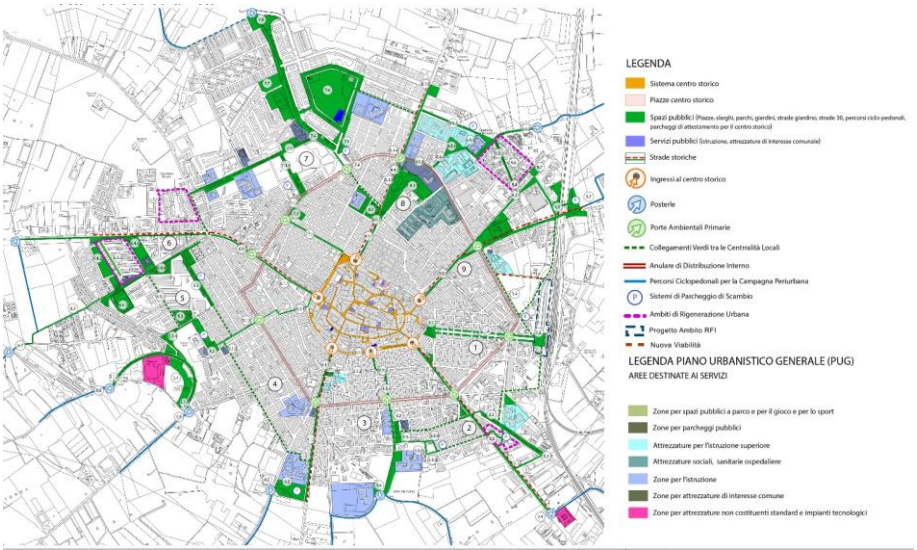

Figure 2. The design of centralities (General Arrangement Urban Scheme - GAUS) in the Urban Regeneration Program Document (DPRU) for San Severo (Developed by Authors).

This tool, although innovative, is compatible and complementary to the usual tools of urban planning technique and current legislation. It is a tool for the regeneration of the existing city that contains an overview of its future arrangement, to be achieved through a system of interventions; a necessary degree of flexibility, that is, a balance between prescriptions and directions and ease and speed of integrations and modifications; finally, a proper attention to the scale of intervention projects, which means urban design (or rather: urban landscape), which is the competence and the adequate and necessary scale to design the qualities of the urban landscape. This tool should be formalized as a document attached to General Regulatory Plans and Urban Plans for Sustainable Mobility and coordinated with them. In the experiences presented here, all the principles of the Manifesto have been applied in relation to specific context situations.

The following paragraphs describe the contents of the tool applied to the selected case studies, which were chosen based on eco-social context type, city, neighbourhoods, and design competition. The selection of diverse case studies was intended to test the applicability of the method.

2.1. Qualities of Good Living

The Urban Arrangement Scheme of a centrality is always articulated in projects: one project for each of the public spaces that make up the system of that centrality (fig. 3). Centralities are such because the best urban qualities are concentrated or should be concentrated in the public spaces and services that compose them. For each of the component projects, Guidelines are developed, which are directions for drafting the implementing projects with contents that can be used by the municipal administration in drafting the Design Guidance Document.

In the development of the Guidelines, in all cases presented here, three qualities for good living have been assumed as design principles and directions: hospitality, urbanity, and beauty. (Colarossi 2008) That is to say, public spaces and public and private services for everyone, suitable for location, quantity, and formal and functional social quality. In particular, for the quality of beauty, primarily two project strategies have been used, connected with each other: the type-diversity of public spaces and tree plantations.

Gli spazi pubblici componenti il sistema della Centralità Locale Via Palmiro Togliatti – Parco Baden-Powell sono:

- *7.1. Sequenza connessione Centro Storico / Parcheggio della Centralità Via Gaetano Salvemini / Tratto di Via Palmiro Togliatti (lunghezza circa 800 m.) fino a Via Fortore/ Via Fortore (fino alla Campagna Periurbana - Posterla Via Fortore, lunghezza circa 1650 m.)*
  - *7.1.1. Via Giuseppe De Cesare (da Piazza Luigi Allegato fino a Viale Due Giugno)*
  - *7.1.2. Viale Due Giugno nel tratto dall'innesto di Via Giuseppe De Cesare fino all'innesto con Via Gaetano Salvemini*
  - *7.1.3. Via Gaetano Salvemini fino a Via Palmiro Togliatti.*
- *7.2. Piazza IV Novembre*
- *7.3. Via Palmiro Togliatti*
- *7.4. Via Fortore (dall'incrocio con Viale 2 Giugno fino alla Posterla Via Fortore)*
- *7.5. Piazza dell'Amicizia*
- *7.6. Parco Baden-Powell, Via d'Orso e strade di margine del Parco*
- *7.7. Parco 8 marzo*

Figure 3. One of the centralities of the Urban Regeneration Plan (DPRU) of San Severo with the list of projects comprising the system (Developed by Authors)

The type-diversity of public spaces requires enriching the meager catalog of different possible types of public spaces that they can find in the recent city: streets (primarily reserved for motor vehicles), parking lots (usually expanses of asphalt), and public green spaces (areas usually devoid of a recognizable and attractive design). Therefore, traditional spaces such as Squares, Avenues; Gardens and Parks will be part of a centrality's public space system, as well as: Walkways (streets or tree-lined paths reserved for pedestrians); Garden streets (pedestrian streets or 30 km/h streets with a strong presence of greenery and conceived as places to linger); Residents' trees (parts of avenues or garden areas intended for tree planting by residents); Meeting corners, Micro-place, and Micro-gardens (arrangements of small equipped places for gathering to be created along sidewalks of sufficient width or within squares or gardens or in parking lots - (fig. 4); Green gates (equipped places to signal the passage between different neighbourhoods or different parts of the city); Pedestrian walks in the peri-urban countryside (paths derived from historical streets and trails); Green connections between centralities (30 km/h streets with protected pedestrian and cycling paths).

Figure 4. Type of public spaces: garden street (top) and two meeting corners (Developed by Authors)

A good type-diversity of public spaces acts as a factor not only of environmental quality but also of beauty in relation to the recognizability and characterization of a centrality compared to others and also in relation to the possible spread of small interventions that, organized as a system in a unitary design of a centrality, can produce, as a whole, significant positive effects of urban quality.

Tree planting should be used as a strategy to introduce a first level of beauty into the public spaces of the recent city. Planting many, many trees. Trees that are always beautiful in themselves (which tree can be said to be ugly?) and which, because they grow rapidly enough, can beautify the spaces of the city even by hiding or minimizing views or artifacts of low quality. Trees that mark and support the

fabric of streets, avenues, and paths and mark and highlight the squares and gardens and parks of centralities; and contribute with their beauty also to environmental quality by creating the "urban forest", that is, the complex of trees in a city capable of beneficial effects: biodiversity, cooling, oxygenation, fine dust reduction.

2.2. Centralities and Small Cities within the City

The General Arrangement Urban Scheme (GAUS) proposes and represents the design of centralities and connections between them in a unified and comprehensive vision for the city. Centralities, in summary, are formed by a network in which public spaces (with their public and private services), such as squares, parks, and gardens, constitute the nodes, while streets, avenues, and paths are the meshes; a network that structures and characterizes an urban area definable as a small city within the city.

A small city (Moreno 2021) where the maximum distances to reach the spaces and services of the centrality are of the order of 700-1,000 m (pedestrian travel times of about 15 minutes). Identifying possible small cities and possible locations of centralities requires analyses and evaluations of the landscape of an urban area through readings of the morphological characteristics of the orographic substrate; urban fabric morphology; the location and mutual distances of public and private services, public spaces, and landscape, environmental, and historical-archaeological assets (identification of possible or current aggregations in a system); the preferences, habits, and traditions of use of public spaces and services by residents; and finally, the maximum lengths of pedestrian routes. These are analyses and evaluations aimed at identifying public spaces and public and private services that could form primary systems, that is, identifying the different centralities and components of each centrality.

Preliminarily, for these purposes, it will be necessary to proceed with the elaboration, for a city or part of a city, of an "Atlas of the urban landscape" in which to classify the public spaces and the related existing public and private services according to a hierarchy of four levels: base level or fabric; neighbourhood centrality level (meeting spaces or proximity services distributed within a small city and not insertable in the system of a local or urban centrality); local centrality level (centralities of a small city with spaces or services of local scale); urban centrality level (role of urban centre, city centre).

Using the classifications of the Urban Landscape Atlas, the different centralities (local or urban) can be identified, and hypotheses of arrangement can be proposed for each one by drafting the General Arrangement Urban Scheme, the individual Urban Arrangement Schemes of the centralities (UASC), and the Guidelines to guide the quality of implementing projects.

In the case of San Severo, the PASSi covers the entire city with a General Arrangement Urban Scheme (GAUS). The design represented by the GAUS (fig. 2) is the result of the identification and design of nine local centralities and one urban centrality (the historic centre). In turn, the design of the centralities is the consequence of urban morphology and current functional arrangement: a radio centric morphology, structured by some roads that connect the historic centre (also the centre of the proposed arrangement) with the surrounding neighbourhoods in concentric bands and finally with the countryside. The structure of the functional arrangement is given by alignments of commercial and tertiary activities mainly along historical streets, some aggregations of education services, and areas of public greenery.

The result is an overall design, obviously radio centric in structure, built by centralities whose catchment areas (maximum distances of about 750 meters) cover the entire recent city and all have as a dorsal axis a sequence with, on one side, an entrance to the historic centre (memories of all) and on the other, an entrance to the peri-urban countryside (called "posterla", a small equipped public space - city-countryside pact) from which walks to the peri-urban countryside start using existing rural roads (fig. 5). The length of the sequences of paths between entrances to the historic centre and those to the countryside varies between 700 m and 1,000 m approximately.

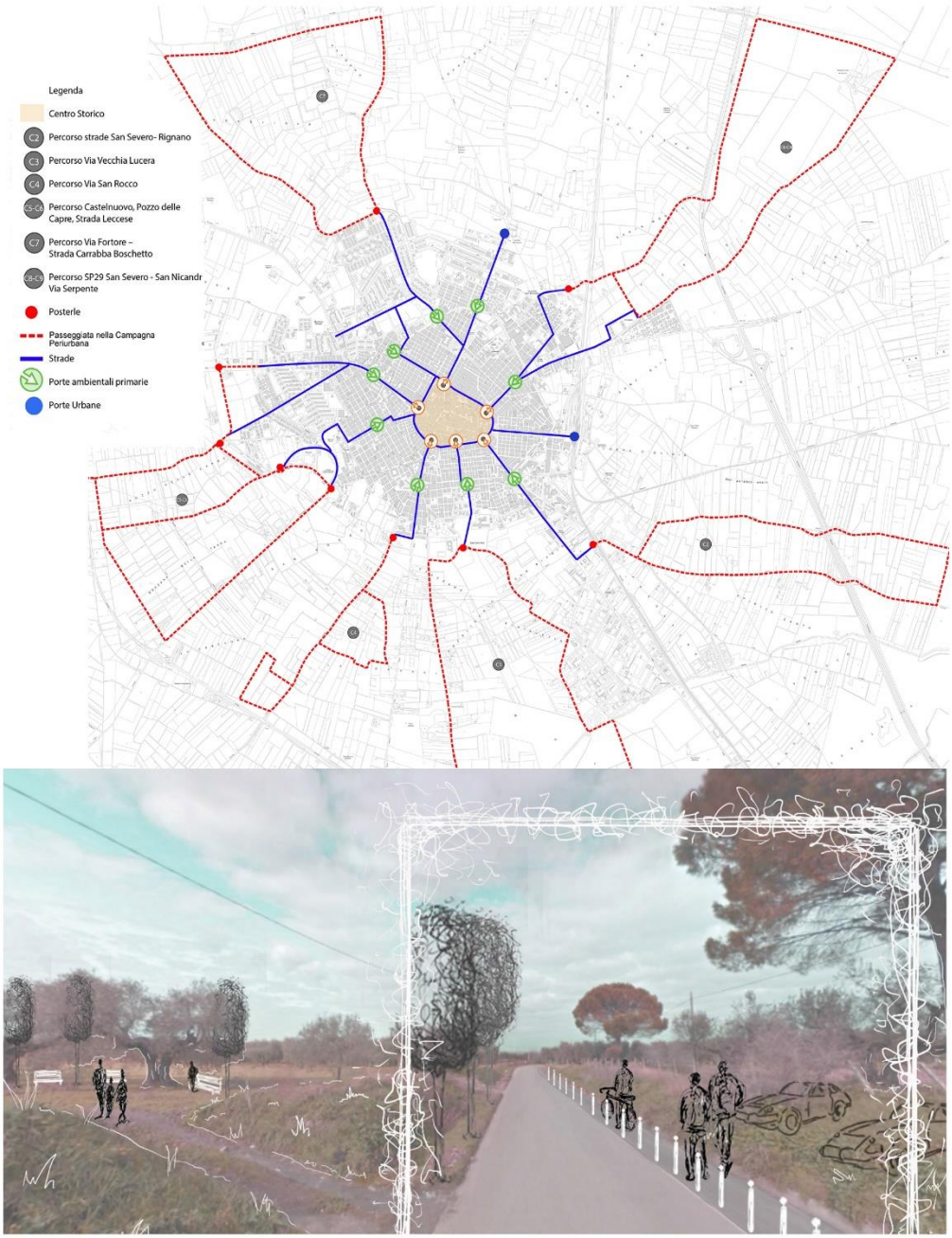

Figure 5. The city-countryside relationship in the Urban Regeneration Program Document (DPRU) of San Severo (Developed by Authors)

For the design of the system of public spaces and public and private services that forms a centrality, the main keywords should be: connecting and hierarchizing. For the first: connecting, in a unitary system design, parts of an urban area (of a small city) different in social, functional, and formal values: connecting urban areas with the countryside, commercial streets with parks and gardens, services with squares and walks (fig. 5). For the second: hierarchizing, that is, giving identity and recognizability to the centrality through the overall design of the system of public spaces and services of the centrality. For

example, by adopting simple layout schemes easily receivable in the mental maps of residents: linear, annular, cardo-decuman.

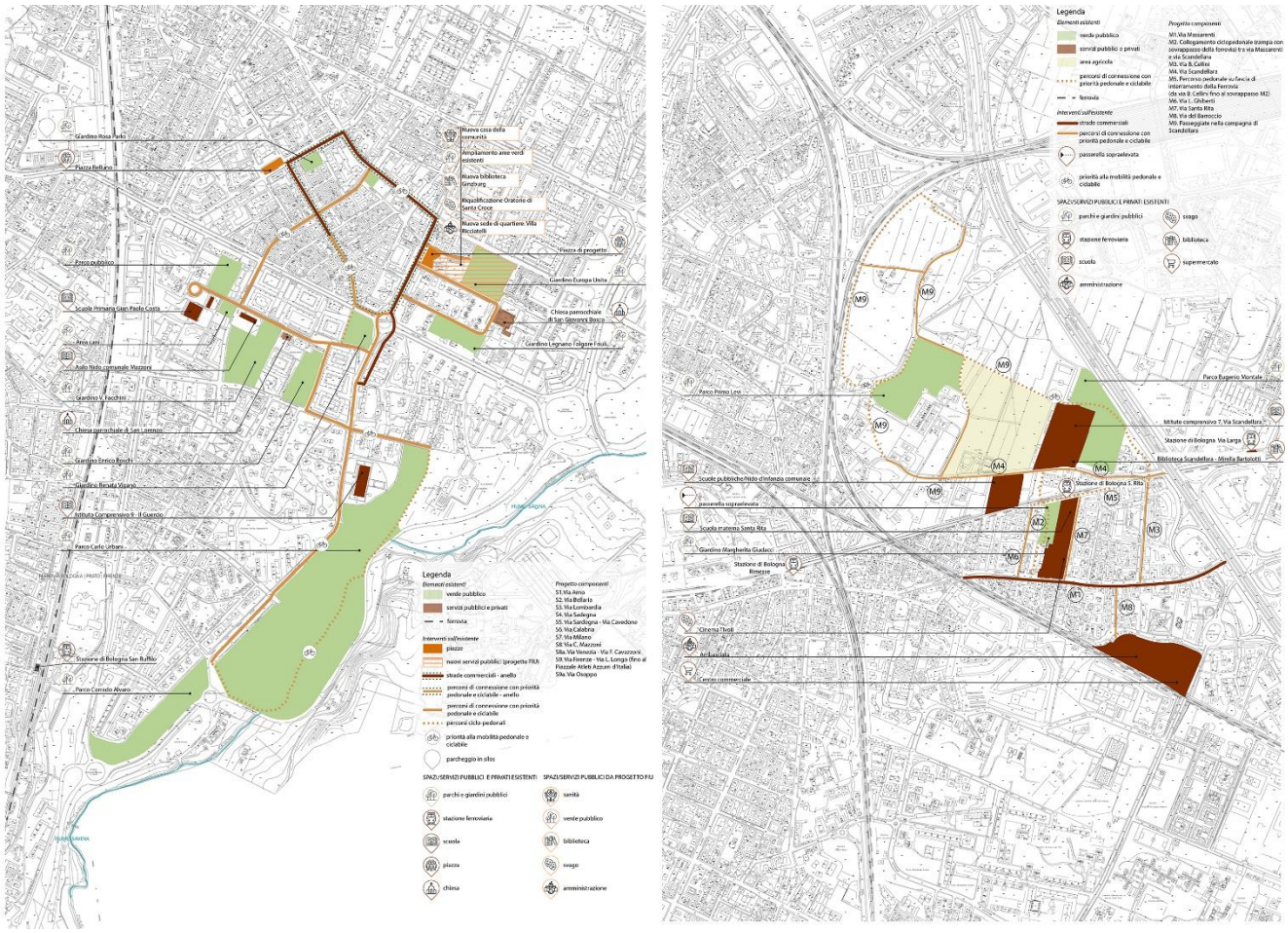

Figure 6. Connection and hierarchization in the Urban Arrangement Schemes (UAS) of centralities. System of commercial streets and system of greenery and public services (Savena area) and commercial street and areas of peri-urban countryside (Massarenti - Scandellara area) in Bologna (Developed by Authors)

But, primarily, through interventions to improve the quality of those spaces. So that each small city will be identifiable and recognizable for the character of its centrality (fig. 6). The implementation of an UASC can also occur using incremental temporal strategies based on the availability of economic resources. Incremental strategies both in implementation and in the levels of quality of interventions. Incremental in implementation because it will be possible to implement over time the overall design of an Arrangement Scheme of a centrality for functionally autonomous parts, but always part of a single system (of a unitary design). Incremental in quality levels because, following the Guidelines of an Arrangement Scheme and the principles of Tactical Urbanism, it will be possible to intervene multiple times on the same public space to improve the qualities of hospitality, urbanity, and beauty over time, until achieving the result.

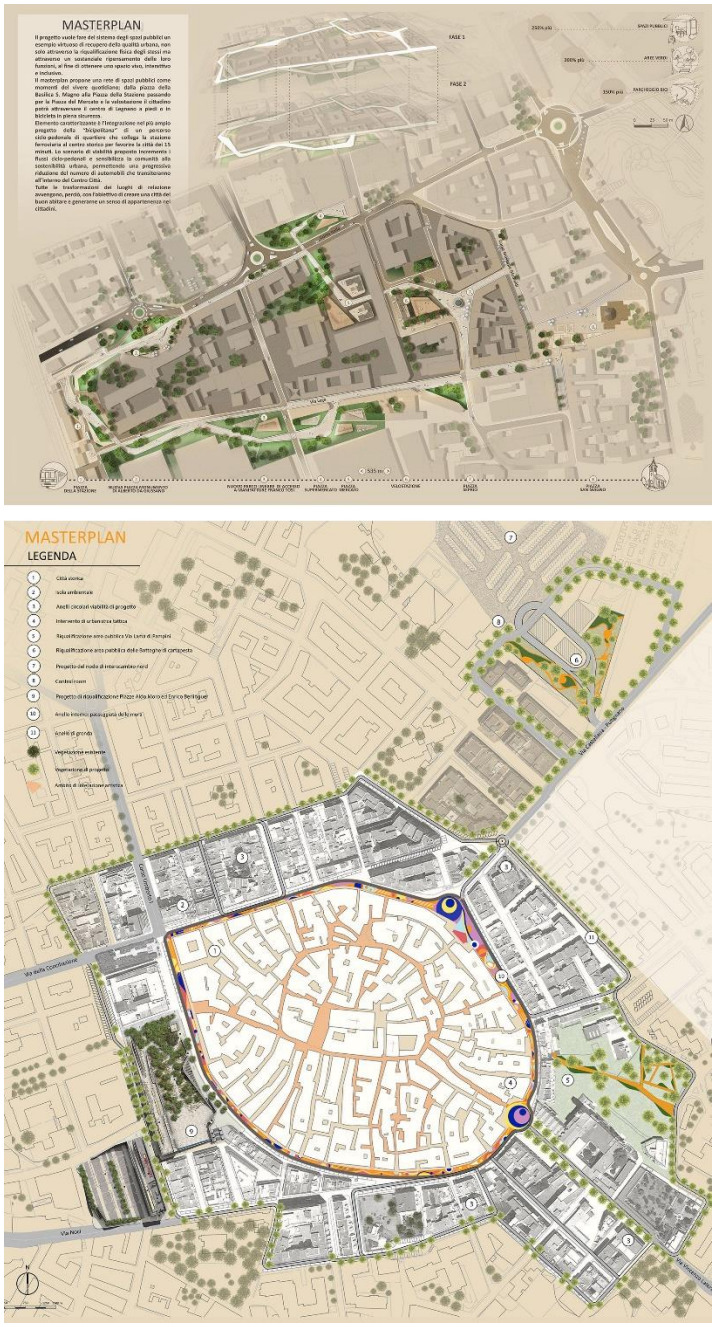

Figure 7. Identity and recognizability of centralities: Legnano, above, and Putignano (BA), below (idea competitions) (Developed by Authors)

2.3. Walkability versus Drivability

The urban quality of the system of public spaces in a centrality also depends on the quantity, location, and safety level of spaces dedicated to pedestrians. This always requires traffic and parking restructuring interventions in favor of pedestrian paths or areas for residents to linger.

Generally, this involves acting on the existing state and introducing a 30 km/h speed limit for all roads belonging to the centrality system, with interventions such as widening sidewalks, potential pedestrianization of secondary streets, and modifications and rationalization of parking.

For the latter measure, it's essential to maintain, as much as possible, a balance between eliminated parking spaces and newly created ones.

In this case as well, incremental strategies for interventions should be adopted, especially concerning the necessary transition towards the new arrangement and the gradual acceptance of changes in residents' established habits. Temporary experimental tactics should also be employed for testing the proposed interventions, potentially modifying specific local proposals for road and pedestrian arrangements based on the results (fig. 8).

Figure 8. Interventions for improving the pedestrianization-motorization relationship proposed for the Massarenti area in Bologna (existing state and proposed arrangement plan of a section of Via Massarenti and view from below with existing state on the left and proposed arrangement on the right) (Developed by Authors)

2.4. Collective memories

Every historic centre or place that should be considered as a centrality, indeed, as the centre of centralities. This applies to the historic centre centrality as well as to the project of an Urban Arrangement Scheme (UAS): development of an Urban Landscape Atlas, the design of the

organizational framework for Public and Private Spaces and Services (fig. 9), Guidelines for implementing projects, and implementation strategies.

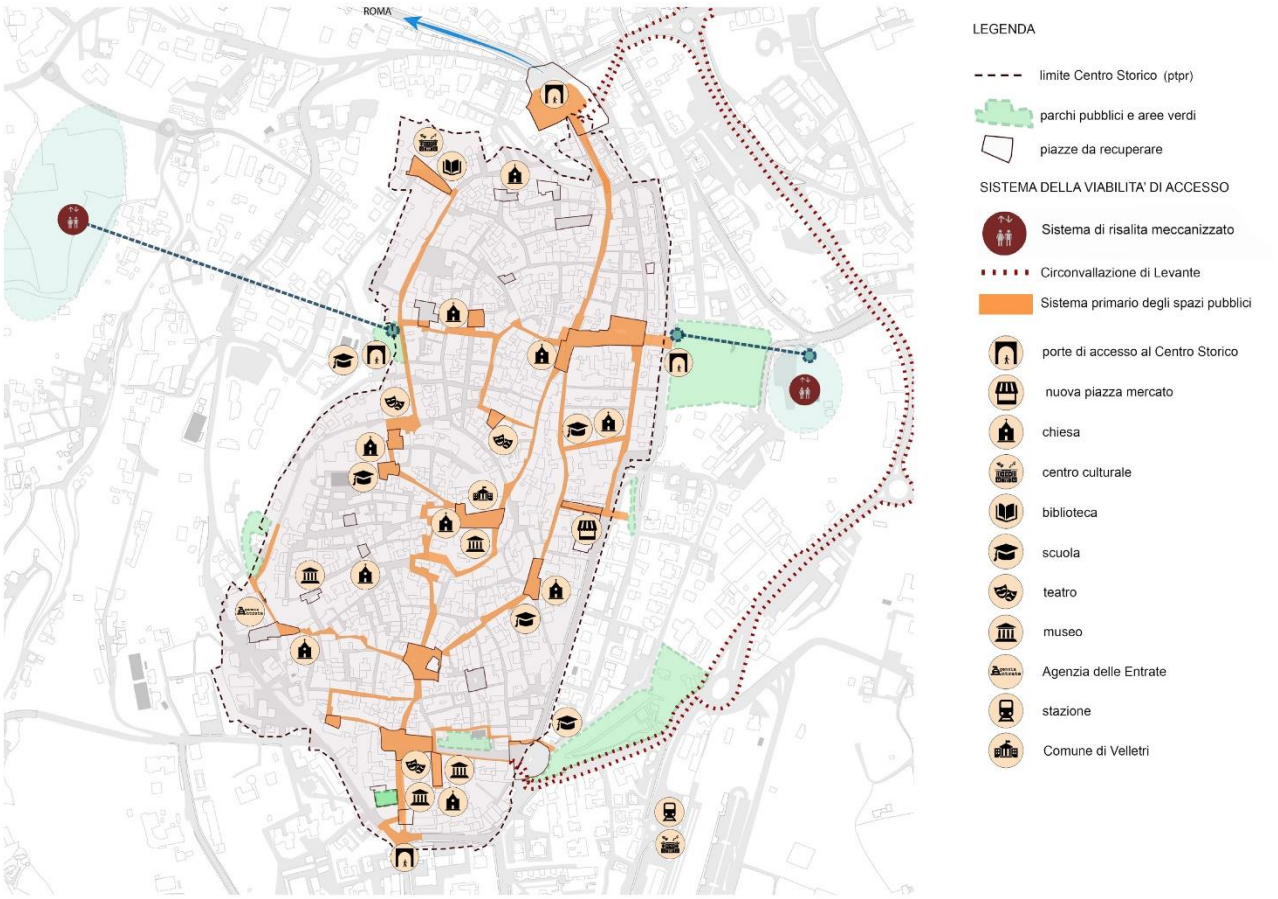

Figure 9. Urban Arrangement Scheme for the "Historic Centre" centrality of Velletri. - (Developed by Authors)

Therefore, the contents of recovery plans for a historic center should also include necessary attention to public space as a factor in the preservation and redevelopment of the collective memory of all. In the application for the historic center of Velletri, the suggested guidelines aim at creating a structure of spaces recognizable for their aesthetic qualities and urban furniture designed to establish a cohesive and unified language; Elements such as paving, trees, and street furniture that contribute to creating a cohesive and recognizable environment are fundamental in defining a unified language that respects and enhances the historic character of the center.

2.5. Pact Between City and Countryside

A new relationship between the city and the countryside entails a mutual redevelopment between urban areas and peri-urban countryside areas.

For those urban areas located on the outskirts of the city, peri-urban agricultural areas could contribute to the quality of good living. These areas, with their environmental and aesthetic qualities, could play a role not only in production but also, with appropriate path and service arrangements, in attracting residents.

This can be achieved in two ways:

1. Some centralities can be formed on the edges between the city and the countryside. By utilizing narrow strips of land on the urban outskirts to locate services and public spaces that may not be feasible within the urban fabric, the city can have a significant presence towards the countryside. These areas can also host services for agricultural productions and small public spaces equipped as gateways between the city and the countryside (city-countryside gates).

2. Similarly, to the Urban Landscape Atlas (ULA), drafting an Atlas of the peri-urban landscape would allow for the creation of a rural network of circular paths and interconnected green spaces, enhancing accessibility and promoting walks, starting from the city-countryside gates. This network would consist of pathways as links and significant nodes of historical, archaeological, environmental, scenic, and productive interest in the peri-urban landscape (fig. 5).

2.5. Active Participation

In the implementation of all the aforementioned principles of the Manifesto in the experiments presented here, processes of participation and consultation of stakeholders should be considered and promoted. This applies both to the formation of Urban Arrangement Schemes (UAS) and over time for their implementation. Particularly, active participation processes for the care and maintenance of public spaces should be encouraged.

For example, in San Severo, a Laboratory called the "Mosaic of San Severo" was successfully experimented with, where approximately fifty local technicians contributed their ideas to the formation of various Urban Arrangement Schemes for centralities. In some of these schemes, the establishment of "Participation Workshops" has been planned, serving as places for discussion and debate among citizens, associations, committees, and the municipal administration.

3. Results

Currently, the "planning schemes" together with the "guidelines" and the "project scenarios" assume the role of a new tool for territorial and urban planning. They are proposed as the primary instrument for Urban Regeneration and territorial transformation, enabling the rapid implementation of its component projects. Furthermore, they promote a homogeneous vision of the interventions to be planned and, most importantly, greater versatility over time in their execution.

The experience with the urban planning tool of the General Regulatory Plan established by Law No. 1150/42, to date, demonstrates that cities require a more dynamic instrument capable of transforming the territory and regenerating existing structures. In fact, the economic opportunities granted in recent years by Regional and National Funding Plans, distributed broadly across all Municipal and territorial Administrations in Italy, have allowed those municipalities that had pre-emptively equipped themselves with a Framework Plan of interventions to access these funds.

The ongoing experience with the National Recovery and Resilience Plan (PNRR), which finds ample confirmation in previous Regional Operational Plans (POR) and the European Regional Development Funds (ERDF), demonstrates that municipalities lacking such a tool risk being unable to access these funds, thereby losing a crucial opportunity to requalify their public spaces and consequently ensure quality of life of their citizens. Through the development of PASSI, the municipalities of San Severo (fig.5) and Velletri (fig.9) have had the opportunity to realize part of the specific projects outlined within the scheme, initiating a regeneration process that not only involves the urban area but also improves the socio-economic aspects of the citizens.

4. Conclusions

Until now, urban planning has been perceived as an abstract activity of city and landscape programming, with few or at least slow impacts on the territory. This criticism cannot be entirely refuted, although it should be excused by the length of the administrative procedures that follow. The main flaws of Italian regulatory instruments are well known, particularly their rigidity in comparison to the difficulty of predicting an urban future that the regulations aim to determine. Additionally, they have a limited ability to determine and control the quality, including the aesthetic quality, of implementations, especially concerning public spaces.

These flaws can be reduced and minimized by reversing the traditional approach that involves preliminary regulatory planning from which the intervention project subsequently derives, along with all the aforementioned issues.

To address urban transformations that increasingly focus on adapting to climate change and evolving lifestyles in the city, it is essential to reconsider how urban regeneration can ensure a level of living quality that meets the well-being of its residents. Research in this regard proposes a continuous study of new forms of urban planning and their potential future impacts on the city.

In this sense the principles of the "Manifesto" and the results of the experiments applying those principles, previously discussed here, fall within the framework of an underlying idea about the necessity/opportunity to start building principles, content, and methods for a new urbanism: an urbanism of small scale.

An urbanism that places people (cultures, desires, perceptions) and their living conditions (aesthetic, functional, and social qualities of living spaces) at the centre of its objectives.

Urbanism of small scale is therefore one that adopts the scale of neighbourhoods, proximity, and public spaces to effectively and concretely implement the qualities of good living.

In summary, an urbanism of small scale requires the definition of new content, new strategies, new techniques, and new implementation methods.

New content, which may arise from the necessary close examination needed to identify urban issues and define proposed solutions.

New strategies, where the qualities of living are achieved through small-scale interventions, which together produce significant positive effects.

New techniques required for the requalification of urban design practice at a small scale (urban design in small dimensions).

The methodology presented offers an opportunity for the urban regeneration of all those areas that today no longer require extensive territorial expansions, but rather a careful requalification of existing urban structures, which are often lacking in the qualities of beauty, urbanity, and hospitality that constitute a city conducive to good dwelling.

New implementation process for subsequent increments of interventions and for subsequent levels of quality.

The characteristics thus outlined of an urbanism of small scale, in turn, require new content and new techniques in the formation of urban plans.

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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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Exploring the Vital Role of Colors and Shapes in Architectural Design and Education

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ABSTRACT

This study investigates the crucial influence of color and form on architectural design and architecture education, highlighting how these elements shape the aesthetics of the built environment and impact human experiences. The central problem addressed is the need to understand the interaction between color and form in creating spaces that evoke specific emotions and cultural narratives, contributing to an architecture that goes beyond functionality. The importance of this study lies in demonstrating how the careful integration of these elements can enrich the built environment and improve the quality of architectural education. The methodology adopted includes the analysis of case studies and expert opinions, along with the exploration of innovative methods in the teaching of architecture, which combine practical learning, virtual simulations and interdisciplinary collaboration. The results indicate that an in-depth understanding of the dynamic relationship between colors and shapes allows architects, but also society in general, to enhance their creativity, contributing to a more culturally significant and aesthetically impactful built environment.

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1. Introduction

The exploration of colors and shapes within the realm of architectural design and education presents a fascinating intersection of art, psychology, and technology. This study aims to highlight how these fundamental elements—colors and shapes—extend beyond basic aesthetic considerations to significantly influence both the visual appeal of structures and the emotional responses they evoke in occupants. By analyzing the interplay between these elements, this research underscores their vital role in shaping the human experience within built environments. This article embarks on an in-depth examination of how these fundamental elements—colors and shapes—play a pivotal role in crafting the aesthetics of our built environment, influencing not just the physical space but also the human experience within it.

The significance of this research lies in its potential to bridge the gap between aesthetic theory and practical application, offering architects and designers insights into how they can effectively use color

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and form to create spaces that resonate on both a psychological and cultural level. The significance of color and shape in architecture goes beyond mere decoration; it is a powerful tool that architects wield to evoke emotions, narrate cultural stories, and shape spatial experiences. Despite the recognition of these elements in design, there remains a need for more comprehensive studies that explore the depth of their impact on users. This research contributes to filling that void by providing a thorough analysis supported by case studies and expert insights, emphasizing the necessity for architects to integrate thoughtful color schemes with geometric shapes in their work.

Through a meticulous analysis of case studies and expert opinions, this paper aims to underscore the necessity of integrating thoughtful color schemes with geometric shapes to forge compelling architectural narratives. This approach not only enhances the aesthetic quality of architecture but also plays a crucial role in ensuring that the spaces we inhabit are not only functional but also emotionally and culturally enriching.

Numerous successful initiatives demonstrate the utilization of gaming strategies to address specific urban challenges. For instance, the Commission for Architecture and the Built Environment (CABE), which was renamed as the 'Design Council' in 2011, in partnership with the British Council, has developed a variety of games in collaboration with gaming industry experts. These games serve as participatory instruments for exploring and shaping the future of local areas. A notable example is the 'Urban Ideas Bakery game,' a tool crafted to engage local community members in pinpointing unique challenges within their regions, devising creative architectural solutions to these social problems, and ultimately putting these plans into action (Brković Dodig,Marta, N. Groat, Linda 2019). Games act as platforms for conveying insights into the complex interaction between economic, social, political, cultural, and environmental factors that intricately mold spatial design (Salama, 2013: 22).

At the core of architectural aesthetics lies the intricate interplay between form (shape) and color. This relationship is not arbitrary but is deeply rooted in human psychology and cultural contexts. Colors possess the inherent ability to influence mood and perception, a principle widely recognized and utilized in various fields, from marketing to interior design. In architecture, this relationship is particularly important as it dictates how spaces are perceived and experienced, which in turn affects the well-being and satisfaction of individuals who interact with these spaces.

In architecture, the application of color can transform the ambiance of a space, making it feel warm and inviting or cool and serene. Similarly, shapes—be they the sweeping curves of a modernist structure or the rigid lines of a Brutalist edifice—communicate different messages and evoke distinct feelings. The careful selection and combination of these elements can create environments that not only meet the functional needs of their users but also evoke deeper emotional responses, contributing to the overall quality of life.

Together, these elements dictate the narrative of a space, guiding the emotional and psychological journey of its inhabitants. This study proposes that by understanding and strategically utilizing the interplay between color and shape, architects can create more meaningful and engaging spaces that resonate with users on multiple levels, ultimately enhancing the human experience within these environments.

The article delves into how architects leverage the synergy between colors and shapes to elicit specific responses and convey meaningful stories. It is through this lens that we appreciate architecture not just as a functional art but as a medium that reflects and shapes society's cultural narratives. The strategic use of color and form can highlight historical significance, represent cultural identities, or forecast future societal trends. This dynamic interplay is evident in landmark buildings and everyday structures alike, revealing the depth of thought that goes into architectural design.

Furthermore, the discussion extends into the realm of architectural education, highlighting innovative methods that foster a comprehensive understanding of the interplay between colors, shapes, and design. Scholarly works in architecture and urban planning often come from experts who are intensely focused

on specific areas within these fields. For example, some researchers might delve into city planning by applying gaming perspectives (Tan, 2018), while others deeply investigate the nuances of participatory design in architecture (Hofmann, 2014). Traditional architectural education has evolved to incorporate hands-on learning experiences, virtual reality simulations, and cross-disciplinary collaboration. These approaches not only enrich the learning experience but also prepare aspiring architects to think critically and creatively about the use of colors and shapes in their work. By engaging with these elements at a foundational level, students can develop a nuanced appreciation for their impact on design and human experience.

Acknowledging the dynamic relationship between colors, shapes, and architectural design opens up new avenues for creativity and innovation. It challenges architects to think beyond conventional boundaries and consider how their work contributes to the cultural and emotional landscape of the built environment. As this article will demonstrate through case studies and expert insights, the thoughtful integration of colors and shapes is crucial for creating spaces that resonate with people on a profound level. In doing so, architects not only enhance the aesthetic appeal of their creations but also contribute to a more enriched, culturally significant built environment. At the heart of this investigation lies the question: How can interactive game-based learning tools effectively teach architectural styles and the use of colors and shapes in design to different age groups?

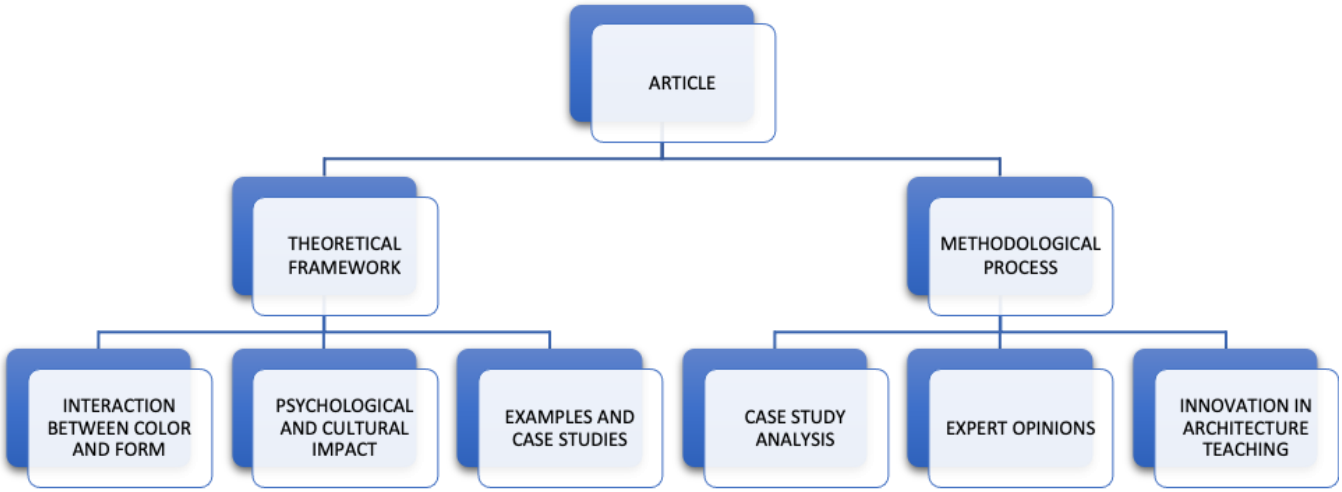


Figure 1. Structure of the Study

2. Materials and Methods

2.1. The Essence of Color and Shape in Architecture

At the heart of architectural aesthetics lie two fundamental elements: color and shape. These components are not mere embellishments but are essential tools that architects use to define space, create atmosphere, and evoke emotional responses. The choice of colors and shapes within a building's design goes beyond subjective preference; it reflects an understanding of how these elements interact with human psychology, influence perceptions of space, and contribute to the overall experience of the environment.

2.1.1. Psychological Impact of Colors

Colors have a profound impact on human emotions and behaviors. The psychology of color is a field of study that investigates how different hues can influence our mood, feelings, and even physiological

responses (Ittens, 1973). In architecture, the application of color theory is crucial, as it can transform the ambiance of a space. Warm colors, such as reds, oranges, and yellows, are often associated with energy, warmth, and comfort, making them ideal for spaces intended to stimulate interaction and activity. Conversely, cool colors like blues, greens, and purples are linked to calmness, serenity, and concentration, making them suitable for areas where peace and focus are desired (Birren, 1976).

2.1.2. Influence of Shapes on Perception

Shapes, the forms that define the structure and layout of space, also play a significant role in architectural design. Geometric shapes—circles, squares, triangles, and their derivatives—carry inherent meanings and associations. Circles, with their endless loop, suggest continuity and protection, often used in architecture to create a sense of inclusion and community. Squares and rectangles, representing stability and reliability, are the foundation of most architectural designs, shaping the basic layout of buildings and rooms. Triangles, with their dynamic angles, can introduce a sense of movement and direction, guiding the flow of space and energy within a structure (Alexander, 1977).

The integration of color and shape in architecture is not merely a matter of aesthetics but a thoughtful consideration of how these elements can enhance or alter the perception of space. Architects use color and shape in tandem to achieve specific effects, whether to make a room appear larger or smaller, to highlight architectural features, or to mask imperfections. The right combination can create depth and texture, add character, and influence the spatial dynamics of an environment.

2.1.3. Architectural Identity Through Color and Shape

Beyond their psychological and perceptual effects, colors and shapes contribute to the identity of architectural works. Iconic buildings around the world are often recognized by their distinctive color schemes and shapes. These elements serve as a visual language that architects use to express ideas, convey messages, and embed cultural and historical narratives within the fabric of their designs (Lynch, 1960). Through the strategic use of color and shape, buildings can reflect the identity of a place, embody the vision of their creators, and resonate with the experiences of their users.

2.1.4. The Interdisciplinary Nature of Color and Shape in Architecture

Understanding the role of colors and shapes in architecture requires an interdisciplinary approach, integrating knowledge from psychology, art, design, and cultural studies (Zevi, 1989). This holistic perspective allows architects to craft spaces that are not only visually appealing but also emotionally resonant and culturally relevant. It emphasizes the importance of considering the human experience in architectural design, ensuring that spaces are not only functional but also enriching and meaningful (Schulz, 1980).

The exploration of color and shape in architecture is a testament to the complexity and richness of architectural design. These elements are vital in shaping the aesthetics, functionality, and emotional impact of built environments. As we delve deeper into the subjects that follow, we will uncover the nuanced ways in which architects harness the power of colors and shapes to create spaces that are not just structures but experiences that engage, inspire, and move the human spirit. This introduction sets the foundation for a journey through the interplay of color and shape in architecture, highlighting their indispensable role in crafting the built world around us.

2.2. How the dynamic relationship between colors and shapes can inspire creativity?

The game methodology encourages students to experiment with various combinations of colors and shapes, pushing them to think beyond conventional design solutions. This exercise fosters creativity by allowing students to see how unconventional color and shape combinations can still adhere to or even redefine traditional architectural styles. For instance, using non-traditional colors for a Gothic style building in the game might challenge students to maintain the style's essence through form and detailing while innovating with color.

Games used in academic settings that concentrate on architecture and urban planning are recognized as powerful instruments for collaborative education, successfully promoting active participation among students (Salama, 2013).

In the realm of architecture, where the tangible meets the intangible and form intertwines with emotion, the dynamic relationship between colors and shapes not only serves as the foundation for aesthetic and functional design but also as a springboard for creativity and innovation. This chapter delves into how the nuanced interplay of these elements inspires architects to transcend conventional design boundaries, fostering a fertile ground for architectural innovation that marries practicality with profound emotional and cultural resonance.

The architectural process is inherently creative, yet it is the thoughtful manipulation of colors and shapes that propels this creativity into uncharted territories. Colors have the power to transform spaces, influencing mood and altering perceptions of scale and temperature, while shapes dictate the flow and functionality of those spaces, guiding human interaction within them. When architects harness these elements with intention and insight, they do more than create buildings; they craft experiences that engage, inspire, and move the human spirit.

Innovation in architecture often emerges from challenging the status quo, and the exploration of colors and shapes provides a vast playground for such challenges. Architects who experiment with unconventional color palettes or who daringly combine geometric forms often find themselves at the forefront of architectural discourse, pushing the envelope of what buildings can represent and how they can affect those who inhabit them. This exploration is not without its risks, but it is precisely in taking these risks that architects contribute to the evolution of their craft.

The influence of digital technologies has further amplified the potential for creativity through colors and shapes. Advanced software allows architects to simulate and visualize complex interplays of light and shadow, color, and form, enabling a level of experimentation previously unattainable. These technologies have democratized innovation, allowing architects not only to dream up extraordinary designs but also to see them realized.

Moreover, the global and multicultural world of contemporary architecture encourages a cross-pollination of ideas, where influences from one culture or era are reinterpreted through the lens of another, often with surprising and innovative results. This melding of influences, mediated by the universal languages of color and shape, highlights the role of architecture as a bridge between diverse cultures and historical periods, underscoring its power to communicate and connect across boundaries.

Yet, for all the emphasis on innovation and creativity, the use of colors and shapes in architecture is ultimately grounded in the pursuit of creating spaces that resonate on a human level. It is here, in the design of spaces that cater not just to the physical needs but also to the psychological well-being of individuals, that the true genius of architectural innovation lies. Whether through the calming hues of a hospital intended to soothe anxiety or the vibrant colors of a school designed to stimulate learning and curiosity, architects utilize colors and shapes not merely as tools of design but as instruments of human-centric innovation.

In resume, the exploration of colors and shapes in architecture transcends mere aesthetic considerations, embodying a profound vehicle for creativity and innovation. As architects continue to explore these elements with both reverence and daring, they not only redefine the boundaries of their profession but also enhance our collective experience of the built environment. The future of architecture, rich with color and form, promises not just buildings that stand as testaments to human ingenuity but spaces that reflect the full spectrum of human experience, bridging the gap between the functional and the sublime. By manipulating colors and shapes to evoke specific styles and moods, students practice making architectural decisions that align with real-world requirements. This hands-on experience is invaluable, as it translates theoretical knowledge into practical skills. The game's interactive nature allows immediate feedback and reflection, helping students understand the consequences of their design choices in a controlled, risk-free environment.

Overall, the game methodology leverages the synergy between colors and shapes to enhance architectural education by providing a playful yet profound way to explore and understand architectural styles. This not only makes learning more engaging but also equips students with the creative skills necessary to succeed in the ever-evolving field of architecture.

2.3. Cultural Narratives and Spatial Experiences

According to Henri Bergson (1859-1941), memories are intricately tied to specific moments or human actions, intertwined with representations that resonate with us. These representations often revolve around iconic landmarks that serve as the essence of a city, dispersed throughout its territory. Understanding these memories and iconic places is crucial for grasping the architectonic styles within the city. Our game methodology can aid in this comprehension by providing interactive experiences that immerse participants in the city's cultural fabric, fostering a deeper connection and understanding of its architectural heritage.

In the realm of architectural design, colors and shapes are not merely aesthetic choices; they are profound tools for conveying cultural narratives and crafting spatial experiences that resonate with the inhabitants. The architectural canvas becomes a medium through which stories of the past, present, and future are told, shaping not only the physical environment but also the societal context in which a structure exists.

Colors and shapes serve as a language that architects use to communicate and connect with people on a cultural level. For instance, the use of specific colors can evoke cultural or historical significance, such as the vibrant blues and whites found in Mediterranean architecture, symbolizing the sea and the sky. Similarly, shapes can reference cultural symbols or historical events, making the architecture itself a narrative medium. The pyramid shape, for example, immediately evokes images of Egypt and its rich history, while circular designs can suggest unity and community, prevalent in indigenous architectures around the world.

The interplay between color and shape significantly influences how spaces are perceived and experienced. Architects skillfully manipulate these elements to guide the movement within a space, highlight areas of importance, and create atmospheres that provoke specific emotional responses. The strategic use of warm colors can make a vast space feel more intimate and welcoming, while cool colors can lend a serene and contemplative air to a busy urban environment.

Furthermore, the geometry of a building—its lines, curves, and edges—can dramatically affect how people move through and interact with a space. Sharp, angular lines can create a dynamic and energizing environment, whereas smooth, flowing curves can foster a sense of calm and fluidity. The manipulation of shapes and colors can also alter perceptions of scale and distance, making spaces appear larger or smaller and influencing the spatial experience.

Just to ilustrarte what we are talking about and the meaning of Reflecting Cultural Identity we all know that landmark buildings around the world showcase how colors and shapes can embody cultural identities and values. The Guggenheim Museum in Bilbao, with its undulating titanium curves, reflects the fluidity and innovation of contemporary culture, while the red and gold palette of Beijing's Forbidden City encapsulates the power and majesty of Imperial China.

The thoughtful integration of colors and shapes in architectural design serves a dual purpose: it conveys cultural narratives and enhances spatial experiences. By understanding and harnessing the power of these elements, architects can create spaces that not only stand out aesthetically but also offer deep cultural resonance and a profound sense of place. This approach not only enriches the architectural landscape but also fosters a deeper connection between the built environment and the people who inhabit it, ensuring that buildings are not merely structures but meaningful spaces that reflect and celebrate cultural identity and human experience.

2.4. The Interplay Between Form and Color

In the intricate tapestry of architectural design, the symbiosis between form (shape) and color transcends mere aesthetic concerns, embedding itself deeply within the psychological and cultural fabric of human experience. This interplay is not a novel concept; rather, it is foundational, having evolved through centuries of architectural practice and theory. The manner in which architects wield form and color significantly influences not only the physical manifestation of their creations but also the emotional and psychological resonance these structures invoke within their inhabitants.

It is believed that basic geometric shapes can convey different emotions and moods, which can be symbolized by specific colors. This concept forms the foundation of the game methodology used to teach architectural styles to people outside the university setting. By associating shapes with colors that evoke similar moods, participants can better understand and recognize architectural styles through playful exploration (Holmes & Zanker, 2013).

The dialogue between form and color in architecture is intricate, with each element capable of evoking a wide spectrum of responses based on its application. Form, with its inherent capacity to define space and dictate flow, carries with it the power to shape human experiences and behaviors within architectural environments. Whether through the imposing rigidity of rectilinear forms or the fluidity of curvilinear shapes, the form can either invite movement and exploration or command stillness and reverence. Similarly, color, through its psychological impact, can alter perceptions of space and mood. The application of warm hues can transform an environment into a welcoming haven, while cool tones might imbue a space with a sense of calm and focus.

Historically, the convergence of form and color has been pivotal in defining architectural eras and movements. From the ornate gold and intricate forms of Baroque churches to the stark white cubes of Modernist structures, each period in architectural history has utilized this interplay to convey its unique ethos and aesthetic principles. These historical precedents underscore the enduring importance of understanding the relationship between form and color in architectural design, an understanding that remains crucial in contemporary practice. We live surrounded by colors. That is how the world is (Huchendorf, 2007).

In the modern architectural landscape, this interplay has been enriched by technological advancements and a deeper understanding of human psychology. Architects today have at their disposal an unprecedented array of materials and technologies that allow for more complex and nuanced explorations of form and color. Digital design tools enable the simulation and visualization of architectural ideas, allowing for a more thorough investigation of how form and color interact before physical construction begins. This technological evolution has not only expanded the palette of possibilities but

also introduced new challenges and considerations in design, including sustainability and the impact of built environments on human well-being.

The psychological impact of form and color is now a central consideration in architectural design, informed by a growing body of research in environmental psychology. Colors wield significant emotional influence, affecting how we perceive and experience space over time. This visual interpretation of space can evoke sensations ranging from strength to softness, from intensity to tranquility, as highlighted by Birren (2006). Moreover, in architecture, colors play a pivotal role in conveying the essence of different styles. Recognizing the color palettes associated with various architectural movements can aid in identifying and understanding these styles, enriching our appreciation of architectural diversity and historical context. Studies have shown that the architectural form can significantly affect human emotions and cognitive functions, influencing everything from stress levels to productivity. Color psychology further enriches this narrative, offering insights into how colors can affect mood, mental health, and even physiological reactions. These insights have profound implications for architectural design, suggesting that the thoughtful integration of form and color can contribute to healthier, more vibrant living and working environments.

Culturally, the application of form and color in architecture serves as a narrative device, telling stories of place, identity, and community. Through the strategic use of these elements, architects can create buildings that not only respond to their physical context but also reflect and celebrate the cultural and historical narratives of their surroundings. This aspect of architectural design underscores the responsibility of architects to consider the broader cultural implications of their work, ensuring that their projects contribute positively to the social and cultural fabric of their communities.

As the field of architecture continues to evolve, the exploration of form and color remains a vibrant area of inquiry and innovation. The ongoing dialogue between these two elements promises to yield new insights and possibilities, challenging architects to think creatively and critically about how they shape the built environment. By embracing the dynamic interplay between form and color, architects can continue to create spaces that are not only visually compelling but also deeply resonant with the human experience, spaces that reflect the complexity and richness of life itself.

3. Analysis and Results

3.1. Workshop Case Study

Throughout 2022 and 2023, we conducted workshops (Fig.1) outside of the university setting for adults and children with the aim of introducing some of the architectural styles found in the city of Covilhã, Portugal, as well as discussing the significance of colors and shapes in architecture and urban spaces, and how they relate to the sensations they convey.

To further elaborate on the methodology, the workshops were carefully designed as a series of interactive sessions aimed at engaging participants in both a practical and educational manner. The study was structured into three main phases: preparation, implementation, and data analysis.

In the preparation phase, we developed specific activities and materials that would allow participants to explore architectural concepts hands-on. This included selecting appropriate tools such as "Tangram" and "Jenga," which served as analogs for urban form and structure, to ensure that participants could tangibly interact with the ideas being presented. Additionally, we prepared pre- and post-workshop surveys to quantitatively measure the participants' knowledge before and after the sessions. Structured interviews were also prepared to gather qualitative insights into the participants' experiences and learning outcomes.

In this scenario, an in-person game emerges as a collaborative and imaginative tool, effectively engaging both children and adults outside the academic realm. This approach aims to impart knowledge about architectural styles. It serves not only as a means of education but also as a method to involve

communities in preserving and enhancing cultural landscapes. Through such interactive experiences, the game facilitates the transmission of the values intertwined with these architectural styles (Garcia-Fernandez & Medeiros, 2019).

During the implementation phase, the workshops were held at the C3D Space - Makerspace Covilhã within the Covilhã Municipal Library, drawing around 200 participants divided into groups of 25 spanning all age groups. Each group engaged in three workshop sessions, with activities designed to encourage creative expression and a deeper understanding of the architectural styles being taught. Data collection during these sessions was comprehensive, involving not only the collection of participants' drawings and models but also detailed observational notes, recordings of group discussions, and direct feedback from participants. These data points allowed us to gather a broad spectrum of information, from the participants' cognitive engagement to their emotional reactions to the architectural concepts presented.

Cities are often perceived merely as chaotic collections of concrete buildings and tangled streets. However, they are indeed vibrant ecosystems rich with stories, forms, and heritage that are typically overlooked. A series of three innovative workshops offered a distinctive chance to reshape how various groups, from children to the elderly, perceive and engage with urban spaces, thereby deepening their connection to these environments.

In the analysis phase, both qualitative and quantitative data were analyzed to assess the impact of the workshops. The qualitative data, including participant drawings, observational notes, and interview responses, were analyzed thematically to identify common patterns and insights related to the participants' learning experiences. The quantitative data, derived from pre- and post-workshop surveys, were statistically analyzed to measure the improvement in participants' ability to classify architectural styles and understand the emotional impacts of colors and shapes. This mixed-methods approach provided a robust framework for evaluating the effectiveness of the workshops, allowing for a comprehensive understanding of how participants engaged with the material and how their perceptions evolved throughout the process.

The initial workshop employed the games "Tangram" and "Jenga" to explore urban form and structure. Just as Tangram pieces fit together to form complex shapes, buildings in a city work in conjunction to shape their environment. This interactive and cooperative activity led participants to recognize the city as a dynamic mosaic, constantly in flux.

Overall, this study was conducted with a focus on creating an engaging, educational environment that was both interactive and reflective. The data collection methods were designed to capture a wide range of participant experiences, providing valuable insights into the effectiveness of the workshops and the potential for game-based learning methodologies to enhance architectural education.

In the second workshop, which utilized a "Pedagogical Suitcase," attendees delved into the city's historical and cultural aspects. Through crafting and interacting with puzzles or memory games that highlighted key landmarks, historical events, and notable personalities, the activities went beyond simple fun. They served as a portal to the past, breathing life into the heritage of the city and making its rich history palpable and engaging.

The third workshop positioned participants as urban artists, tasked with portraying the characteristics of the city's landmark buildings through various artistic methods. They examined intricate architectural details, the stories told by different colors, and the unique textures of each building, leading to a newfound appreciation and understanding of their architectural significance.

These workshops were held at the C3D Space - Makerspace Covilhã within the Covilhã Municipal Library, drawing around 200 participants divided into groups of 25, spanning all age groups. Although originally part of doctoral research, these gatherings surpassed their scholarly purpose, enriching participants' collective perception of their city.

Bruno Zevi argued that architectural representation has always been constrained by the limitations of available tools (Zevi, 1989). Today, while digital drawings and sketches can appear almost unbelievable to the modern eye, the fundamental process of image creation remains consistent.

In conclusion, the combination of qualitative and quantitative data collected through these workshops provided a rich and detailed picture of how different age groups engage with architectural education. The mixed-methods approach ensured that both the emotional and cognitive aspects of learning were captured, offering valuable insights into the role of game-based learning in architectural education.

In our game methodology workshops, drawings play a crucial role in representing, storing, and transmitting important architectural information. By visually engaging participants with sketches and models of different architectural styles, we can more effectively teach and illustrate the distinctive features and emotional impact of various designs. The act of drawing itself encourages participants to explore architectural styles deeply, while the interactive nature of the game methodology makes learning accessible and enjoyable.

Figure 2. Workshops with children and andults, held at Covilhã (2022-2023) (Photo Rúben de Matos)

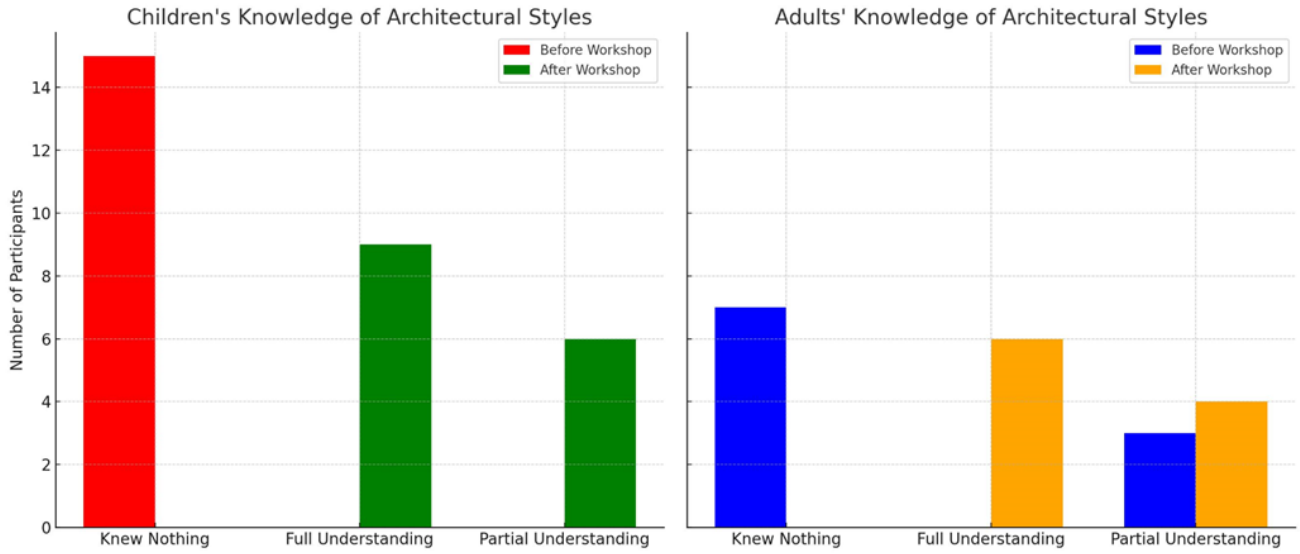
Children's Knowledge of Architectural Styles (Graph.1)

- Before the workshop:
  - 15 children knew nothing about architectural styles.
  - Before the workshop, no children could correctly classify architectural styles.
- After the workshop:
  - 9 children could easily classify all styles.
  - 5 children correctly classified 6 out of 8 styles.
  - 1 child correctly classified 3 out of 8 styles.
  - After the workshop, a significant improvement was observed:
  - 60% could easily classify all styles.
  - Additional improvements brought the total average effectiveness to about 77%.

Adults' Knowledge of Architectural Styles (Graph.1)

- Before the workshop:
  - 7 adults knew little to nothing (3 knew about 4 styles, 4 knew less or none).
  - Initially, adults had some basic understanding, but none could fully classify all styles correctly.
- After the workshop:
  - 6 adults correctly answered all styles.
  - 2 adults correctly answered 6 out of 8 styles.

- 2 adults remained with lower understanding
- After the workshop, there was a notable improvement.
- 60% of the adults were able to correctly answer all styles.
- Additional improvements brought the total average effectiveness to about 80%.



Graphic 1. Workshops with children and andults, held at Covilhã (2022-2023) (Photo Rúben de Matos)

Collectively, the workshops not only offered insights into the structural and aesthetic components of the city but also strengthened participants' connections to its historical heritage and introduced them to new artistic interpretations of familiar surroundings. These experiences did more than educate; they enhanced the communal bond with the urban setting. This approach sparked interaction, creativity, memory-sharing, and revealed the potential for collaborative endeavors to foster a comprehensive and enriched understanding of urban life.

3.2. Innovative Methods in Architectural Education

The focal points of gaming and education often revolve around player motivation and engagement, extensively investigated by scholars (Boyle et al., 2012; Viola, 2018; Wouters et al., 2013). These areas encompass two vital components: the impact of games on enhancing students' drive to learn and the inherent motivations and anticipations that drive individuals to engage in gaming pursuits. For an aesthetic experience to come to life, there must be a meaningful relationship between the subject and the object, guided by time and perception (Eco, 1987). In our game methodology for teaching architectural styles, it's crucial to establish this connection by immersing participants in hands-on exploration of iconic forms and structures. By creating a playful yet informative interaction between participants and architectural designs, the game methodology helps them develop a deeper understanding and appreciation of various architectonic styles. This interactive approach enables learners to connect emotionally with the subject matter, facilitating a comprehensive learning experience.

Kennedy (1973: 331) points out that architecture and education, both at institutional and functional levels, not only present challenges but also create substantial obstacles to effective collaboration between architects and educational specialists. This game methodology will help to make an easy link between Learning and teaching, between professionals and people in general.

In the pursuit of innovative educational methodologies within architectural education, integrating game-based learning presents an exciting avenue for teaching architectural styles, as well as understanding the influence of colors and shapes on architectural feelings and moods. This game, adaptable for digital platforms or traditional hands-on materials, is designed to engage students in a dynamic exploration of architectural elements, fostering both knowledge acquisition and creative thinking.

Game Overview: "Architectonic Moods & Styles Explorer"

Objective: Players navigate through various architectural styles and create buildings that evoke specific feelings and moods, utilizing a strategic selection of colors and shapes.

Game Setup:

Digital Version: A software application where players can design buildings using a library of shapes (geometric, organic, etc.) and colors. The game includes a gallery of architectural styles (Gothic, Baroque, Modernism, etc.) and a mood board for inspiration (serenity, excitement, melancholy, etc.).

Traditional Version: Using cardboard cutouts of different shapes and colored papers or markers, players manually create models. Printed cards represent different architectural styles and moods, serving as prompts for the players.

Gameplay Mechanics

Learning Phase: Players begin with a brief interactive tutorial (digital) or a guided session (traditional) on architectural styles and how colors and shapes influence mood and perception in architecture.

Challenge Rounds: Each round, players draw a card or receive a digital prompt detailing a specific architectural style and desired mood (e.g., "Create a Modernist library that evokes serenity"). Players then have a set time to design a building that aligns with these criteria using the available digital tools or physical materials.

Design and Justification: Upon completion, players present their designs to the group, explaining their choice of shapes and colors and how these elements combine to reflect the given style and mood.

Feedback and Reflection: In the digital version, an AI-powered tool provides instant feedback on how closely the design matches the style and mood, along with suggestions for improvement. In the traditional version, peers and instructors offer feedback, fostering a collaborative learning environment.

Scoring: Designs are scored based on creativity, adherence to the architectural style, and the effective conveyance of the specified mood. Points accumulate over several rounds, and the player with the highest score wins.

Reflection and Learning: Each session concludes with a reflective discussion, allowing players to articulate what they have learned and how they might apply these insights to future architectural projects.

Educational Outcomes:

Through engaging with "Architectonic Moods & Styles Explorer," students gain a deeper understanding of the historical and cultural contexts of various architectural styles. They learn how to strategically use colors and shapes to elicit specific emotional responses, enhancing their design skills. The game encourages critical thinking and creative problem-solving, as students must navigate the constraints of each challenge to produce coherent and innovative designs. Additionally, the collaborative and competitive aspects of the game foster a dynamic learning atmosphere, encouraging students to learn from one another and to see architectural design from multiple perspectives.

Adaptability and Expansion:

The game is designed to be flexible, allowing for updates with new styles, moods, and challenges. In the digital version, expansions can include interactive elements such as virtual reality (VR) walkthroughs of

player-created buildings. In the traditional version, new materials and tools can be introduced to diversify the design possibilities. This adaptability ensures that the game remains a relevant and engaging educational tool in the ever-evolving field of architecture.

The "Architectonic Moods & Styles Explorer" game embodies a pioneering approach to architectural education, blending the realms of interactive learning and creative design. As we've seen through various implementations, this game not only demystifies complex architectural concepts but also enriches students' understanding of the emotional and psychological impacts of architectural elements. The dual versions of the game—digital and traditional—ensure that it is accessible and adaptable to diverse learning environments and technological availabilities.

This innovative game-based methodology has proven its efficacy in fostering an engaging and immersive learning experience. Participants leave with a robust toolkit of knowledge and skills, from recognizing architectural styles and their historical significances to applying color theory and design principles in creating emotionally resonant environments. Moreover, the game's scoring system and competitive element add an enjoyable challenge that encourages deeper engagement and collaboration among students.

As architectural education continues to evolve, the "Architectonic Moods & Styles Explorer" serves as a scalable model that can be continuously updated and expanded to include new technologies and pedagogical strategies. Future iterations could incorporate augmented reality (AR) or virtual reality (VR), offering even more immersive experiences that could simulate real-world architectural design processes. The use of games as a methodology offers a novel approach for involving the community in discovering the architectural elements of their city (Duke and Greenblat, 1979).

Ultimately, the success of this educational tool highlights the potential of game-based learning in transforming educational landscapes—not just in architecture, but in various fields where complex, abstract concepts can be made tangible and engaging through innovative teaching methodologies. This approach not only prepares students to excel in their academic pursuits but also equips them with the critical thinking and creative problem-solving skills necessary to succeed in their future careers. As educators and innovators, our challenge is to continue refining and expanding these tools to meet the ever-changing needs of learners in a dynamic world.

4. Discussion

4.1. Critical Review of Results and Theoretical Framework Implications

The workshops conducted as part of this study provided a unique opportunity to explore the impact of colors and shapes on architectural perception across different age groups. The results, as demonstrated by the significant improvement in participants' ability to classify architectural styles and understand the emotional impacts of colors and shapes, support the hypothesis that interactive, game-based learning methodologies can enhance architectural education. This finding aligns with the theoretical framework that posits the integration of psychological and cultural dimensions into architectural design as crucial for creating spaces that resonate with users on multiple levels. The observed improvement in participants' knowledge, particularly among children and adults who initially demonstrated limited understanding of architectural styles, suggests that the interactive and hands-on nature of the workshops effectively bridged the gap between abstract architectural concepts and practical application. This outcome supports the initial hypothesis that engaging participants through interactive methodologies would lead to a deeper understanding and retention of architectural knowledge. The successful application of these methodologies also highlights their potential for broader use in architectural education, particularly in community settings where traditional academic approaches may be less effective. However, a critical review of the results also reveals areas for further investigation. For instance, while the majority of participants showed significant improvement, there was still a subset of participants who did not achieve the same level of understanding. This suggests that while the methodology was effective for most, it may

need to be adapted or supplemented with additional support for those who may require different learning approaches. This aspect underscores the importance of developing flexible educational strategies that can accommodate diverse learning needs within architectural education.

4.2. Implications of the Results

The implications of these results are significant for both architectural education and practice. The study's findings suggest that incorporating colors and shapes into the design process, informed by a deep understanding of their psychological and cultural impacts, can lead to the creation of more meaningful and resonant architectural spaces. This has direct implications for architects who seek to create designs that not only fulfill functional requirements but also engage users on an emotional and cultural level. The success of the workshops in enhancing participants' understanding of these elements demonstrates the potential for broader application of such methodologies in professional practice, particularly in community-driven architectural projects where public engagement is crucial. Furthermore, the results reinforce the importance of integrating interactive and experiential learning methods into architectural education. The positive response from participants across different age groups indicates that such methods can effectively engage diverse audiences, making architectural education more accessible and relevant to a wider population. This has potential implications for educational institutions, which may consider incorporating similar approaches into their curricula to better prepare students for the challenges of modern architectural practice.

4.3. Evaluation of Methodology and Tactics

The methodology employed in this study, particularly the use of game-based learning tools, proved highly functional in achieving the study's objectives. The interactive nature of the workshops allowed participants to engage with architectural concepts in a tangible way, leading to a more profound understanding and retention of the material. The use of games like "Tangram" and "Jenga" not only made the learning process enjoyable but also facilitated the exploration of complex ideas in a manner that was accessible to participants of all ages. However, the functionality of the methodology also raises important considerations for its broader application. While the hands-on, interactive approach was effective for most participants, the variation in outcomes suggests that the methodology may need to be adapted for different learning styles and abilities. This points to the need for a more nuanced approach to educational design, one that considers the diverse needs of learners and provides multiple pathways for engagement and understanding.

4.4. Response to the Hypothesis

The aim of the article was to explore how interactive, game-based methodologies could enhance understanding of architectural styles, colors, and shapes among a diverse group of participants. The results of the study strongly support the initial hypothesis that these methodologies would lead to significant improvements in participants' architectural knowledge and their ability to apply this knowledge in practical contexts.The study successfully demonstrated that engaging participants through interactive workshops not only improved their knowledge but also deepened their appreciation for the emotional and cultural dimensions of architecture. This outcome is consistent with the theoretical framework that emphasizes the importance of integrating psychological and cultural insights into architectural design. Moreover, the positive feedback from participants indicates that the methodologies used were both effective and enjoyable, suggesting that similar approaches could be widely adopted in both educational and professional settings.

5. Conclusion

In navigating the complex interplay of colors and shapes within the architectural realm, this article has illuminated the profound impact these fundamental elements exert on both the aesthetic and emotional dimensions of space. As we have explored, the careful selection and integration of colors and shapes are instrumental in conveying cultural narratives, evoking desired moods, and defining the character of architectural works. From the psychological influence of colors on human perception and emotion to the cultural significance embedded in architectural forms, it becomes evident that these elements are far more than mere components of design; they are essential tools through which architects communicate, innovate, and express the intangible. The exploration of architectural styles, alongside the innovative methodologies in architectural education, underscores the dynamic evolution of how we understand and implement colors and shapes in design. By embracing new technologies and interdisciplinary approaches, architects and educators are fostering a rich environment of experimentation and discovery, enabling the next generation of architects to push the boundaries of what is possible. Furthermore, the drive towards innovation, as highlighted in the discussions on creativity and the utilization of digital tools, reflects a broader trend in architecture towards more personalized, responsive, and emotionally resonant spaces. In this light, the role of colors and shapes transcends mere aesthetics, acting as a bridge between the human experience and the built environment, between our past cultural heritage and future aspirations.

In conclusion, the thoughtful integration of colors and shapes in architectural design emerges not only as a critical factor in achieving harmony and beauty but also as a catalyst for emotional engagement and cultural expression. As we look towards the future of architecture, it is clear that the continued exploration of these elements will play a pivotal role in shaping innovative, meaningful, and responsive spaces. Architects, armed with an understanding of the psychological and cultural dimensions of colors and shapes, are well-positioned to create environments that not only meet the functional needs of society but also enrich the human spirit, weaving the fabric of our shared spaces with threads of color and form that resonate deeply with our collective psyche. In doing so, architecture transcends its physical boundaries, becoming a testament to the enduring power of human creativity and ingenuity. The use of colors and shapes was particularly pivotal in our workshops, serving as a visual and intuitive guide to understanding different architectural elements and styles. These visual tools helped demystify the subject matter, making it more accessible and enjoyable. Moreover, discussing the meanings behind various architectural forms deepened the learners' appreciation of how architecture interacts with cultural and historical contexts, enhancing their overall learning experience. This approach not only educates but also inspires creativity and a deeper appreciation of our built environment. After our workshop experience and results, also after our research, we can say that integrating game methodologies into the teaching of architectural styles has proven to be a remarkably effective educational strategy for both children and adults.

Conflict of Interests

The author declares no conflict of interest.

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Adaptive Reuse of Abandoned Churches in the Walled City of Famagusta, North Cyprus

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ABSTRACT

There are so many abandoned heritage buildings worldwide and due to the lack of function and maintenance, they are ruined, deteriorate easily, and are forgotten. Similarly, abandoned valuable religious buildings faced vandalism deliberately because of the decreasing demand for use or lack of their communities. Some churches in Islamic countries are left useless and with no function, and North Cyprus is one of them. The Walled City of Famagusta has many historic religious buildings like cathedrals and churches. This research aims to develop proposals for the adaptive reuse of abandoned churches in the Walled City of Famagusta to overcome their current problems. The methodology of this historical research is qualitative and comparative. The data collection techniques are based on literature review and observation. This research will bring new perspectives on these churches' conservation for architects, historical researchers, and conservationists.

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1. Introduction

Famagusta, one of Cyprus's most important coastal cities in the medieval period, was once an international trade centre for the Levant and Western European merchants. Throughout history, many people with diverse cultures and different religious beliefs travelled and settled down in Famagusta and made their buildings with their architectural techniques and varying styles. Some roofed and restored churches survived the earthquakes and Ottoman bombard attacks and have been reused by changing their functions from churches to mosques. The most elegant one is St Nicholas Cathedral which was converted into Lala Mustafa Pasha Mosque by adding a minaret in 1571. Another example is SS Peter & Paul Church which was converted into a mosque and renamed Sinan Pasha Mosque or Buğday Mosque. St Anne Church, Nestorian Church, Armenian Church, Twin Churches, Jacobean Church, Mustafa Pasha Mosque, and Ayia Zoni Church are roofed churches that remained in the

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Walled City of Famagusta. Although few of the mentioned churches have a function, most of them are left abandoned like a store or even empty without any function. Unfortunately, The Cathedral of St George of the Greeks, St Symeon Church, The Church of St George of the Latins, The Church of the Franciscans, The Church of St Mary of Carmel (Carmelite Church), and Ay Nicolaos Church are abandoned ruins and these churches have no roofs nor any function for a very long time. Some unnamed and ruined churches and underground churches in Famagusta are unknown to the locals and even the experts in North Cyprus (Babazadeh-Asbagh, 2023b, pp. 1-2).

1.1. Problem Statement

Over the years, several natural disasters like severe earthquakes, wars such as the Ottoman Empire attack, and climate conditions affected the cultural heritage of Famagusta. Some of these churches luckily survived the earthquakes and bombs during the Ottoman siege, while some others were ruined. Subsequently, some of the churches have been conserved and restored, but unfortunately, most of them are still abandoned. Some abandoned churches are in good physical condition, but some are ruins without roofs. Lack of function and maintenance increase the speed of deterioration which causes them to be forgotten. Currently, there are roofed and ruined churches in the Walled City of Famagusta. Some of the roofed churches are in good structural condition and are in use, while others are abandoned. As they have not been used for a very long time, the maintenance problems, lack of security, lack of lighting, and vandalism together with weather problems cause the faster decay of these churches. The ruined churches have the same problems and face vandalism much more easily because of inadequate security. Furthermore, the absence of a roof on these buildings exposes them to adverse weather problems causing more decay to the interior wall paintings and decorations of these churches. The inadequate way-finding options for the ruined churches also accelerate their neglect (Babazadeh-Asbagh, 2023b, pp. 3-4).

1.2. Aim, Objectives, and Research Questions

This research attempts to answer these research questions: What are the current problems of the abandoned churches in the Walled City of Famagusta? Which functions are more suitable for each church for their adaptive reuse as a conservation method? This research aims to propose the best function for each abandoned church in the Walled City of Famagusta for their conservation and solving their current problems. To achieve this goal, the current problems of the aforementioned churches are analysed through a literature survey. As case studies, the abandoned churches in the Walled City of Famagusta, their material and structural decays, interventions, and current problems have been mapped and classified. This research aims to document and analyse the current problems of the churches in the Walled City of Famagusta to propose adaptive reuse for overcoming their problems (Babazadeh-Asbagh, 2023b, p. 5).

1.3. Methodology

This research has been based on a comprehensive literature survey on resources about adaptive reuse in general and examples of adaptive reuse in churches worldwide. Also, the history, conservation interventions, and current problems of the churches in the Walled City of Famagusta are discussed in detail. A field survey has followed the literature survey, which has led to the data collection of the case studies. Data collection on the physical conditions of the studied churches has been done through documentation of them. Photographs have been taken, measured plans, sections, and façades have been drawn and site maps have been prepared and digitalised. The data collected through literature survey and field survey have been utilised to develop an approach for adaptive reuse of the churches in the Walled City of Famagusta in particular and other similar cultural heritage sites with similar problems in general. This study adopts a comparative and qualitative survey through an in-depth evaluation of the aforementioned churches. Mapping, analysing, and classifying the architectural

characteristics and current problems of these churches were used to develop a proposal for the adaptive reuse of each case study. The data for this study were analysed based on the literature review about adaptive reuse in general and worldwide examples of adaptive reuse of churches, personal on-site observations, on-site analyses, photographs, precise measurements, mapping, and field surveys. It also presents a novel approach to analysing their architectural characteristics, and this engenders a better understanding of the values and importance of these churches in the Walled City of Famagusta (Babazadeh-Asbagh, 2023b, pp. 6-7).

1.4. Significance of the Study

The results of this research help to find proper functions for the abandoned churches in the Walled City of Famagusta, especially those remaining after the disappearance of their communities to be reused more sustainably. The adaptive reuse proposed in this study benefits the churches in the Walled City of Famagusta by being introduced to visitors more properly, and the access to the interior of these churches by giving them new functions saving them from the danger of being forgotten and neglected. It also increases the tourist value of the Walled City of Famagusta which will contribute to the improvement of the economy of the city and consequently the country. The proposals for the adaptive reuse of the churches in the Walled City of Famagusta can be used for other abandoned churches worldwide suffering similar problems to solve their problems as well (Babazadeh-Asbagh, 2023b, p. 5).

1.5. Scope and Limitations of the Study

This study investigates the current problems of the abandoned churches located inside the Walled City of Famagusta, including one underground church outside the Walled City. The research scope for these case studies is limited to architectural, structural, and material features, conservation and restoration interventions, and current problems. As some of these churches have not been documented properly, and have already been ruined, there is a limitation in accessing the original plans, sections, and façades of some of these case studies. Most of the underground churches were not documented, so there are only assumptions about their date of construction and who built them. The lack of documentation is the most serious limitation of this study for the author (Babazadeh-Asbagh, 2023b, pp. 5-6).

1.6. Data Sources

The data collection methods are based on the survey of published literature related to architectural features, and especially adaptive reuse of cultural heritage. There are some relevant references, including peer-reviewed articles and books. These resources include books borrowed from the Özay Oral Library of Eastern Mediterranean University (EMU), Ahmet Vural Behaeddin Library, The Library of the Architecture Department of EMU, online PDF books and articles downloaded from the Web of Science index. This research has been based on a comprehensive literature survey on resources about adaptive reuse in general and especially in the worldwide examples of churches and also about the history of the churches in the Walled City of Famagusta, like the first-hand resources, reliable documents, and original publications of Camille Enlart, George Jeffery, Edward I'Anson, Theophilus A. H. Mogabgab, Michael J. K. Walsh, and Peter Edbury (Babazadeh-Asbagh, 2023b, p. 7).

1.7. Data Analysis

A field survey has followed the literature survey, which has led to the data collection of the case studies. The plans, sections, and façades of the churches in Famagusta were measured and mapped by the author using manual measuring techniques with a laser meter and digitalised with the AutoCAD Software programme. Data collection on the physical conditions of the case studies has been done

through documentation. Photographs have been taken, measured drawings have been drawn and site maps have been prepared. The data collected through literature survey and field survey have been utilised to develop an approach for adaptive reuse of the churches in the Walled City of Famagusta in particular and other similar cultural heritage sites with similar interpretation problems in general (Babazadeh-Asbagh, 2023b, p. 8) (See Table 2).

1.8. Structure of the Research

The first part of this research is about defining the adaptive reuse of cultural heritage buildings in general and analysing some examples of adaptive reuse in churches worldwide. The second part of the study is about the architectural characteristics and current problems of the abandoned churches in the Walled City of Famagusta. After analysing each church in detail, the proposed functions are mentioned for their adaptive reuse. The images of the plans, sections, and façades, old and current pictures of the aforementioned churches and the tables of their current problems are supplementary data for proper proposals of the adaptive reuse of the churches in the Walled City of Famagusta. The last part of this study is the proposals for the adaptive reuse of each church according to its architectural characteristics and current situation. The conclusion discusses the recommended adaptive reuse functions for each church in the Walled City of Famagusta and this study's contributions to other similar cultural heritage, especially abandoned churches worldwide to solve their problems (See Table 1).

Table 1. Research Structure (Author's Compilation).

INTRODUCTION
⬇
Summary of the history of Cyprus, Famagusta, the Walled City of Famagusta, & the churches there.
Definition of the research problem & setting up the research questions.
Definition of aim & objectives, explaining the significance, scope & limitations of the study.
Definition of methodology consisting of data sources & data analysis (Table 2).
Summary of the structure of the research (Table 1).
THEORETICAL FRAMEWORK Theoretical Reviews on Adaptive Reuse of Cultural Heritage Buildings
⬇
Definition & objectives of adaptive reuse of cultural heritage buildings in general.
Summary of the adaptive reuse of the churches worldwide.
Mentioning the worldwide examples of the adaptive reuse of the churches.
ANALYSING THE CASE STUDIES Architectural, Structural, and Material Features of the Churches in the Walled City of Famagusta
⬇
Summarizing the history of medieval churches in the Walled City of Famagusta.
Analyzing the architectural, structural, material features, and problems of the Churches in the Walled City of Famagusta (Figure 1, Table 7).
Evaluation of the architectural characteristics of the churches located inside the Walled City of Famagusta & one underground church (out of the Walled City) in Famagusta: Evaluation of the plan of the churches in general and in Famagusta (Figure 1, Table 3), Evaluation of architectural characteristics of the churches in the Walled City of Famagusta (Table 4), Summarizing functions of the churches in the Walled City of Famagusta in different periods (Table 5).
Conservation of the Churches in the Walled City of Famagusta: Summarizing the conservation interventions of the churches in Famagusta (Table 6),

The Technical Committee on Cultural Heritage in Cyprus (TTCCH), The United Nations Development Programme – Partnership for the Future (UNDP-PFF), Summarizing the reports of UNDP in the Walled City of Famagusta in October 2012, January 2015, and October 2018.
Evaluation of the current problems of the churches in the Walled City of Famagusta: Summarizing the current problems of the churches in the Walled City of Famagusta (Table 7).

PROPOSALS
Adaptive Reuse of the Churches in the Walled City of Famagusta
Proposals for adaptive reuse of each church in the Walled City of Famagusta (Table 5).

⬇

Conclusions

Table 2. Data Analysis (Author's Compilation).

LITERATURE SURVEY

⬇

Reviewing the literature from: • Books, journal articles, theses & dissertations from libraries of EMU: Özay Oral Library & Ahmet Vural Behaeddin Library of the Architecture Department, • Online resources were downloaded from the Web of Science index. • Comparing the different examples of adaptive reuse of churches worldwide.

FIELD SURVEY

⬇

Personal observation of the author based on: • Site analysis of the churches in the Walled City of Famagusta: Using a laser meter to measure the sizes (length, width, height and area) of the churches for digitalizing the plans and sections via the AutoCAD Software and extracting the maps as PNG files to be used in the Microsoft Word Programme in tables and proposed posters and websites, • Analyzing the architectural characteristics of the churches in the Walled City of Famagusta: Using comparative tables in the Microsoft Word Programme for the plans (Figure 1, Table 3, Table 4) and functions (in different periods and suggested functions for the adaptive reuse of some) of the churches in the Walled City of Famagusta (Table 5), • Analyzing the current problems of the churches in the Walled City of Famagusta: Using comparative tables in the Microsoft Word Programme for the previous conservation interventions (Table 6) & current problems (Table 7) to suggest proposals for an interpretive plan of the churches in the Walled City of Famagusta.

Results

⬇

Proposals for the Adaptive Reuse of the Churches in the Walled City of Famagusta.

2. Adaptive Reuse of Cultural Heritage Buildings

2.1. Adaptive Reuse

Adaptive Reuse is defined by Merriam-Webster Dictionary as "the modification and reuse of an existing structure (such as a warehouse) for a new purpose". "The adaptation and reuse of vernacular architecture should be carried out in a way that respects the integrity of the structure, its character and form while being compatible with an acceptable standard of living" (Charter on the Built Vernacular Heritage, 1999, Article 5 of the Guidelines in Practice). Adaptive Reuse is the complete transformation of a building and is synonymous with remodelling, conversion, adaptation, reworking, rehabilitation or refurbishment. Adaptive reuse involves changes in functionality, which may be added or removed, and

circulation routes, directions, and relationships between spaces may or may not change (Plevoets & Van Cleempoel, 2011). Eugène-Emmanuel Viollet-le-Duc was the first to mention the theoretical approach to adaptive reuse as a way to preserve historic buildings, arguing that using buildings was the best way to preserve them in the 19th century. While architects were busy dealing with modern architecture, constructing new buildings and forgetting about historic buildings in the first half of the 20th century (Plevoets & Van Cleempoel, 2012), they considered reusing historic buildings as an amusing challenge in the second half of the 20th century. Therefore, since the 1970s, adaptive reuse has become a popular topic at conferences, publications, books, and symposiums in the field of conservation and architecture (Plevoets & Van Cleempoel, 2011; Babazadeh-Asbagh, 2018, pp. 203-204; Babazadeh-Asbagh, 2023e, August 5).

Adaptive reuse is the process of converting items that are no longer needed or useful into new items that can be used for a different purpose. Adaptive reuse of historic monuments is more than just preserving assets or restoring them for new or continued use. Adaptive reuse is the replacement of old buildings to adapt them to current needs and the environmentally friendly use of new users (Latham, 2016, pp. 56-57). The conditions that must be taken into account when considering the reuse of a church are the type of building and suitability for reuse, the original type and scale of the church, the external structure, internal spaces, rededication of sacred spaces, modernisation and postponement, maintenance requirements, and site considerations. Adaptive reuse of churches is difficult, but the potential for church reuse can also be determined by researching and documenting examples of previously successful reuse tactics (Kiley, 2004, p. 57). Since sustainability in the preservation of historic buildings is a social pillar, adaptive reuse has become an important issue in cultural heritage preservation. Adaptive reuse of historic buildings can support the conservation process by improving heritage maintenance and preservation (Babazadeh-Asbagh, 2023b, p. 78).

Cultural heritage can play a strategic role in achieving the Sustainable Development Goals, and this is widely recognised around the world by the United Nations (UN), United Nations Educational, Scientific and Cultural Organisation (UNESCO), International Council on Monuments and Sites (ICOMOS), and many regional and national institutions. To preserve historical assets and revitalise them from a circular economy perspective, the principles set out in international and national recommendations need to be translated into new approaches and tools (Cucco, Maselli, Nesticò, & Ribera, 2023, p. 202). Adaptive reuse is the process of renovating old buildings for new uses. In European cities, existing residential buildings are often renovated and converted into office buildings while preserving their historical value. The biggest challenge in adaptive reuse is balancing historic preservation with sustainable design. Different construction techniques and materials are used in historic buildings, depending on the period of construction and geographical zone (Rodrigues & Freire, 2017, p. 94). Adaptive reuse in heritage projects is the renovation, rehabilitation, redevelopment, and restoration of one or more buildings to meet the changing needs of a community. Cultural heritage projects include both legally protected (listed) and non-protected buildings. While the original purpose of the building no longer survives, the goal of the project is to preserve the unique historical and cultural features of the building (Binder, 2003). Adaptive reuse is a way to maximise the remaining utility of existing assets. Adaptive reuse allows components to be salvaged from ageing buildings through demolition programming (Sanchez, Rausch, & Haas, 2019, p. 1).

The reuse of historic buildings requires solving complex decision-making problems that affect the tangible and intangible assets of multiple stakeholders (Chen, Chiu, & Tsai, 2018, p. 12). In recent years, adaptive reuse of historic buildings has become widespread around the world. Due to the flexibility of the approach to reusing historic buildings, the selection of alternatives gradually became the focus of discussions with decision-makers. Properly preserving the value of historical buildings and maximising their usefulness is one of the most important challenges in cultural heritage preservation, taking into account various aspects such as culture, economy, and physical conditions. Historic buildings contain multiple target values (Teo & Huang, 1995; Tiesdell, 1995) including not only tangible values such as

physical structures and the natural environment but also intangible values such as social and cultural differences and priorities researching different stakeholders (Ferretti, Bottoro, Mondini, 2014; Kutut, Zavadskas, Lazauskas, 2014). Consequently, the factors influencing the selection of reuse alternatives are becoming increasingly complex. Considering only certain specific factors often creates conflicts between the selected alternatives and the preservation value of historic buildings being overlooked (Teo & Huang, 1995). Using an adaptive reusability model, Langston, Francis, Wong, Hui, and Shen (2008), Langston, Yung, and Chan (2013), and Yung, Langston, and Chan (2014) evaluated the functionality and reusability. They predict when ancient buildings will occur by analysing factors such as the life cycle of ancient buildings, actual age, service life, economy, society, physical environment, natural environment, function, technology, law, and time (Amit-Cohen, 2005; Tweed & Sutherland, 2007).

Although some studies highlight the effectiveness of the reuse of historic buildings as a sustainable mechanism to motivate investors to invest in upgrading underutilised historic buildings, adaptation reuse approaches are becoming more popular in building resilient urban areas (Aigwi, Egbelakin, & Ingham, 2018; Aigwi, Egbelakin, Ingham, Phipps, Rotimi, & Filippova, 2019; Ball, 2002; Bromley, Tallon, & Thomas, 2005; Pearce, DuBose, & Vanegas, 2004; Rohracher, 2001). Performance-based planning ideology can be applied to assess pre-determined priority aspects and criteria can be subjectively evaluated to establish quantitative boundaries for acceptable levels of adaptive reuse when considering the decision-making process regarding the classification of underutilised historic buildings for adaptive reuse interventions. Therefore, the two main components of performance-based planning in the context of prioritising historic buildings for adaptive reuse interventions should include: (i) reuse priority dimensions and criteria that provide a detailed description of desired adaptive reuse outcomes; (ii) a methodology for defining the impact of acceptable impact limit metrics on desired adaptive reuse outcomes (Aigwi, Egbelakin, Ingham, Phipps, Rotimi, & Filippova, 2019).

Nowadays, urban planners and city dwellers desire ecologically sustainable and vibrant communities. Imaginative and innovative approaches to the built environment in general and existing buildings in particular are key to achieving future sustainability. Urban heritage buildings are of particular interest as they may be underutilised or abandoned. Nonetheless, they are important to the heritage of local and, in some cases, international communities. The unique historical and cultural features of a building constitute its heritage. Heritage extends beyond the project itself to the surrounding area and is often a public or shared asset, recognised for its contribution to the economic and social development of the area (Guzmán et al., 2017; Hosagrahar et al., 2016; Rypkema & Cheong, 2011; Throsby, 2016; Vileniske, 2008; Zhang, 2012). Historic buildings include former places of religious worship, aristocratic/ royal residences, community meeting places, industrial production sites, early modern office buildings, and military installations. It is important to look for sustainable solutions in the urban development of these buildings (Foster, 2020, p. 1).

2.2. Adaptive Reuse of the Churches Worldwide

The church building is often the largest roofed space in a village or town, which has the potential to be reused for a variety of uses and activities when it is not in use as a religious building like a church anymore. Small churches in rural areas can host flexible arrangements and multi-uses for the local community, while large churches in urban texture can be reused providing layered arrangements in existing vacant spaces or newly added structures. Sharing concepts and adaptive reuse, if operated successfully, can have a positive effect of concentrating resources and generating additional income for the maintenance of the church buildings, while also returning churches to play a more central role in the community once again (Hobohm, 2008, pp. 2, 104). However, for abandoned churches without any government funding or donations, adaptive reuse can help to provide the funds for maintenance, repair works and conservation activities (Martineau, 2004; Hobohm, 2008, p. 36). Adaptive reuse is a process that changes a disused or ineffective item into a new item that can be used for a different

purpose. Adaptive reuse of historic monuments is more than just the conservation or rehabilitation of property for new or continued use. Adaptive reuse is the replacement of an old building to adapt to the current needs and environmentally friendly uses of new users (Latham, 2016, pp. 56-57).

The conditions that must be considered when contemplating the reuse of churches are building typology and reuse suitability, church archetypes and sizes, exterior structure, interior spaces, reconsecrating sacred space, modernisation and deferred maintenance requirements, and site considerations. Although adaptive reuse of churches is challenging, reuse potential for churches can also be declared by researching and documenting examples of previously successful reuse tactics (Kiley, 2004, p. 57). Many church buildings had been redundant even in times of prosperity they were underused due to few activities within the church (Douglas, 2006, p. 164). Three primary urban church property archetypes can be generalised for discussion: large churches completely built on their sites, medium-sized churches on large parcels including grounds and parking or other outbuildings, and large complexes consisting of a church, school, convent or other large ancillary uses, all together in a campus setting (Kiley, 2004, pp. 59, 60).

2.3. Examples of the Adaptive Reuse of the Churches Worldwide

Some churches are completely allocated for alternative uses, while others are used partly as a church and host different uses in other rooms or spaces. An example is Karmeliterkirche (Karmeliter Church) in Frankfurt, Germany, which was converted into a museum in 1984. St Stephen Church in London, England was reused as a personal residence in 1986. St Matthew Church in London, England was used as a nightclub in 1992. Mönchenkirche (Mönchen Church) in Jüterbog, Germany was converted into a library in 1992. Lutherkirche (Luther Church) in Berlin, Germany was subdivided into several flats in 1997. Eastback Chapel in Pembroke, Pembrokeshire, Wales, United Kingdom (UK) was reused as an antique centre in 2001 (Hobohm, 2008, pp. 37-39; Matzig, 1997, pp. 7, 17, 44, 59).

A church at Marrick Priory, a Benedictine nunnery in Richmondshire, North Yorkshire, England was converted into a refectory, with a meeting room, a kitchen, an office, and two dormitories with washrooms in the 1970s. The Church of St Peter in Wentworth, Cambridgeshire, England was subdivided into a worship space in the chancel and a multi-purpose community hall in the nave in 1993. It has two toilets, one for ambulant disabled use, a small kitchen, and a vestry area at the nave. St Paul's Church in Walsall, West Midlands County, England was re-ordered in 1994-1995 consisting of several retail outlets, community and conference facilities, a coffee shop, and a worship area. There was a mezzanine gallery for retail and catering purposes, meeting rooms, and a multipurpose conference hall on the top level with glass screens. The Church of St Paul's Road in Cambridge, England was reused in 1996 for non-worship activities, creating five meeting rooms on two levels of the nave including kitchens, a lift, a toilet, storage facilities, and a church office. All Saints Church in Hereford, Herefordshire, England was converted into a café in 1997. It consisted of a freestanding pod, the vestry, the café kitchen, servery, toilet facilities, and a gallery for seating on top. At St John's Church in Moggerhanger, Bedfordshire County, England a community shop was installed in the vestry in 2000. Similarly, some spaces of the church are used as meeting places with tea and coffee served.

The Church of St Michael in Cambridge, England was re-modelled in 2001 as a café, a community centre, and a church. A kitchen, toilet facilities, several rooms, and the church office occupied the nave and aisles. Kneesall Church in Nottinghamshire, England was reused as a village hall in 2004 with a glazed screen separating the chancel from the nave and a kitchen and storage space were added to the church. The Chancel of St Mary's Church in Burston, Norfolk, England was used as a church, and the nave was separated from the worship area being used as a hall by a neighbouring school. At Holy Trinity Much Wenlock Church in Shropshire County, England new disabled access, a kitchen, toilet facilities, and a new meeting room were being provided. The Church of St Paul's Old Ford in Bow, London, England was re-developed for a church-led shared use scheme in 2004. A new entrance to the church,

an escape door, and a new external fire escape staircase were added, and some alterations to the roof changed the external appearance of this church. A café, reception, lavatories, an art gallery, a gym including changing rooms, a sauna, an office, and reception in the attic, a lift for wheelchair access, and stairs were added inside the church. St Andrew's Church in Mickfield, Suffolk, England was restored in 2004 and converted into a private residence with a meeting place, a kitchen, and bathroom facilities serving as a multipurpose space for worship and community activities. The Church of St Mary and St Rhadegund in Whitwell, Isle of Wight, England opened a satellite post office for several mornings per week inside the bell tower in 2007.

At All Saints Church in Sheepy Magna, Leicestershire, England, a post office and community help desk, WC, and tea serving area were being installed. In St Bega Church in Eskdale, Cumbria, England, a satellite post office opened twice a week, and Discover Eskdale Centre informed visitors about the history of the Lake District, they also served tea and coffee. St Giles Church in Shipbourne, Kent County, England and Church of St Mary the Virgin in Rolvenden Kent County, England held markets for farmers in the nave. In St Andrew Church in Sutton-in-the-Isle, Cambridgeshire, England a tithe sale was organised every month. The Church of St Martin-in-the-Fields in Westminster, London, England was restored in 2008. All additions in alteration works were below the ground floor consisting of a café and a gallery in the crypt, a shop, a centre for homeless people, and rooms for the Chinese community in an adjacent courtyard. At Terrington St John Church in Norfolk, England and St Mary's Church in Chipping Norton, Oxfordshire, England there were rooms for priest residents. The first floor of the tower of All Saints Church in Snodland, Kent, England used to be a rectory. An extension to St Mary and All Saints Church in Willingham, Cambridgeshire, England was an anchorhold, a cell for a religious hermit. In St Lawrence Jewry Church and St Mary Le Bow Church in London, England, there were vicarages with roof gardens and car parking areas. Furthermore, the crypt of St Mary le Bow Church was reused as a café. The Church of St Margaret in Rishangles, Suffolk, England was converted into a private residence as a holiday home consisting of a living room, kitchen-dining area, four bedrooms, several bathrooms, and a sitting room (Hobohm, 2008, pp. 48-99; Williams, 2004).

According to the location of the churches, they are either urban or rural churches. The adaptive reuse functions are grouped into cultural, residential, institutional, office, commercial, and community functions. Cultural functions are like theatre, concert hall, museum, cultural centre, elderly day centre, city heritage centre, arts centre, historic foundation, and high school. Residential uses include the conversion of churches into single-family homes, multi-unit apartments or condominiums, inns, hostels or hotels, and special-needs developments for the elderly and disabled people. Former churches can be developed into office spaces, either as a multi-office complex for a single user or as suites with shared facilities for a group of users. Commercial uses span a wide variety of food, service, and merchandising activities and include retail stores, nightclubs, bars, and restaurants. Matching local community and non-profit institutional space needs with a vacant building may prove to be an effective means of preserving a church, as it can potentially tap into fundraising sources available for non-profit use. Churches have been converted into community centres, day-care facilities, heritage centres, elderly day centres, museums, schools, and libraries. Minimal alteration options include community centres, theatres, or clubs. Residential conversions tend to be the most significant in terms of physical alterations to the interior and exterior of a church. Although the best use of a church is the religious function of a house of worship, it can be reused with a different function if it has special or unique attributes. The site, structure, and size of the church are important factors for successful reuse (Kiley, 2004, pp. 71-82, 105-113).

3. Architectural, Structural, and Material Features of the Churches in the Walled City of Famagusta

At first, the plan of the churches had two general forms; centralised plan, and rectangular forms which were originally basilicas. Romanesque churches were built with the Latin cross or cruciform, symbolising the cross of Jesus Christ. He is the perfect man of God and the church is the house of God, therefore,

the plan of the church should have the divine proportion (Babazadeh-Asbagh, 2023a, p. 114). The Gothic period was an age of vision, and the Gothic cathedral was described as an illusionistic image of the Celestial City. The church is, "mystically and liturgically, an image of heaven", and it is the "house of God and the gate of Heaven" and the cathedral is the "symbol of the kingdom of God on earth gazed down upon the city" (Von Simson, 1988, pp. xviii, xix, xx, xxi, 8). "A cathedral was the bishop's church, hence the city's church; and what the art of cathedrals meant first of all, in Europe, was the rebirth of the cities". "The inside arrangement of the cathedral differed from that of the monastic basilica; the cathedral space acquired greater unity within" (Pfaff, 1983, pp. 93, 284).

Churches are classified by Mustafa Uysun into five groups: a) single-naved churches, b) double-naved (twin-naved) churches, c) three-aisled (basilica) churches, d) free-cross (cruciform) churches, d) cross-in-square churches. Single-naved churches consisted of a nave and a large apse where the main space was a simple rectangular chamber. This type was used particularly for churches and the simple rectangular plan was mainly used for chapels. Most of these churches have an East-West axis with an apse at the East end and the ceiling was generally in the form of barrel vaults along the main axis. Access to these types of churches is usually through a single door in the West wall, and most either have no separate narthex or only a small veranda with room for one or two people. The apse is generally higher than the nave and features a screen. Double-naved churches were used throughout the Byzantine Empire for centuries. The naves are separated from each other by one or more simple openings or by arcades of pillars and arches. Most have barrel vaults extending East to West end, and there are apses at the end of both naves. The cruciform plan churches were built on sacred sites or over the relics of martyrs and for martyrions in the capital and other parts of the Byzantine Empire. Cross-in-square churches were typical of medieval Byzantine architecture which gradually spread throughout the empire to become the standard church plan of the Middle Ages. Four columns support the dome over the central square area, and there are vaults on four sides of the dome that form the cross-plan roof. The areas between the arms of the cross are covered by a cross vault or small domes. The four columns define the central space that is dominated by the dome (Uysun, 2014, pp. 53-54; Uysun, 2017, pp. 18-19).

The plan of the churches in the Walled City of Famagusta has two general forms; cruciform shape and square plan. The churches with the basilica or axial form plan have a rectangular form of a cross and the circular, octagonal or central type has a square form plan. Most Gothic churches have a cruciform-shaped plan which is derived from the symbol of the Latin cross. The axis of these plans is East-West emphasising the West façade externally as the main entrance and the internal emphasis is on the Eastern apses. The East side is the direction of the rising sun which is believed to be the direction of the Holy Jesus Christ rising like the sun. Some other Gothic churches that were affected by Byzantine Architecture have the Greek cross plan. In these churches, the apse is usually on the East side and opposite to that there is the main entrance on the West front (Babazadeh-Asbagh & Uluca-Tümer, 2018, p. 419; Babazadeh-Asbagh, 2023a, pp. 123-124). The plan of the churches in the Walled City of Famagusta has two general forms; rectangular and square form. The rectangular-shaped plans have two categories; cruciform shaped with a nave and a transept, or East-West axial plan with a nave and two aisles. As the plan of cruciform-shaped churches looks like the cross, there is usually one entrance on the West façade, one on the North and one on the South elevation. The churches with square-shaped plans usually have three entrances, the main one on the West façade, one on the North and one on the South elevation (Babazadeh-Asbagh & Uluca-Tümer, 2018, pp. 438-439; Babazadeh-Asbagh, 2023a, p. 124).

All of the churches in the Walled City of Famagusta have the apse on the East side, so most of the case studies have their main entrance on the West façade. However, Ay Nicolaos Church and Ay Zoni Church have their main entrances on the South façade facing the main roads. Furthermore, SS Peter & Paul Church, St George of the Latins Church, and Templars' Church have their main entrances on the North façade facing the main roads. The North portal of SS Peter & Paul Church faces the royal palace,

the North elevation of St George of the Latins Church faces the main road, and the North portals of the Templars' Church were probably open to another adjacent building, as Camille Enlart believed, which is now ruined completely, and that open area is used as a car park currently. Thus, maybe the main road or adjacent important buildings facing these churches were the reason why the main portals of the mentioned churches were built on the South or the North façades instead of the West façade, which is more common in the Gothic churches. Almost all of these churches have entrances in three directions: West, North, and South, and only the Nestorian Church has been an exception which does not have any portal on the South side that is facing the current main road.

All of the churches have at least one entry on the West side, but Ayia Zoni Church and Ay Nicolaos Church are the exceptions, which do not have any entrances on the West façade. Some of the churches have three portals on the West façade, like St Nicholas Cathedral, SS Peter & Paul Church, Cathedral of St George of the Greeks, and Nestorian Church. Maybe because these were the biggest churches in size in the Walled City, they were built with three portals on the West façade, which were all opened in important ceremonies. Probably the form of the plan of these churches with one nave and two aisles was the reason for having three portals on the West façade and three apses in the East direction. None of these churches has the main entrance on the East side, but St Anne Church and Nestorian Church each have one small door on the northeast side, both of them were added later than the construction date. All of these churches have one entrance on the North side, but Templars' Church has three entrances on the North elevation, and Ayia Zoni Church and Ay Nicolaos Church do not have any entrances on the North elevation. All of the churches have one entrance on the South side, but the Nestorian Church does not have any entrances on the South side and Ay Nicolaos Church has two entrances on the South elevation (Babazadeh-Asbagh & Uluca-Tümer, 2018, pp. 438-440; Babazadeh-Asbagh, 2023b, pp. 54-55) (See Figure 1, Table 3, & Table 4).

The main façade of the three underground churches in Famagusta is not so inviting from the external view. When it is entered into the yard of Santa Maria de la Cava Church, the entrance of the church is in the opposite direction. All of the case studies have a single doorway after the external stairs which leads us to the underground level, but in St Mary of Bethlehem Church, the stairs are inside the church after the doorway, as its entrance is almost at the level of the adjacent road. Santa Maria de la Cava Church has 20 external stairs before the entrance and four internal stairs after the entrance, while St Mary of Bethlehem Church has eight interior stairs and no exterior stairs. The access to the St Dominic Crypt is after 13 exterior stairs and there is no access to the Unnamed Underground Church in the Walled City of Famagusta. The entrance of Santa Maria de la Cava Church has the shape of a rectangle, but the entrances of St Mary of Bethlehem Church and St Dominic Crypt each have an arc on the rectangular doorway.

St Mary of Bethlehem Church has a small square-shaped window or opening on the right side of the entrance on the main façade and a small circular window on the Eastern side of the church just below the ceiling. On the Eastern wall of St Dominic Crypt, there is a small rectangular-shaped window or opening. Only on the Eastern wall of Santa Maria de la Cava Church, there are pale remaining reddish wall paintings, but the other underground cave churches in this study do not have any interior wall paintings. There is a well in Santa Maria de la Cava Church, which might be used for religious ceremonies, but the other underground churches do not have any wells. Santa Maria de la Cava Church and St Dominic Crypt each have two roof lights that bring light to these dim underground churches. The windows of St Mary of Bethlehem Church and St Dominic Crypt on the Eastern part lighten these churches a little bit. There is a light explosion from the interior of all these churches towards the outside, as the small windows and ceiling lighting are just producing dimmed light into these dark churches (Babazadeh-Asbag, 2023b, pp. 55-56) (See Figure 1, Table 3, Table 4, & Table 5).

The eleven case studies of this research are the churches that are left abandoned without any function in Famagusta and have a proper upper structure. Eight of them are the churches located inside the

Walled City of Famagusta consisting of SS Peter & Paul Church, St Anne Church, Nestorian Church, Armenian Church, Templars' Church, Jacobean Church, Mustafa Pasha Mosque, and Ay Zoni Church. Three of the case studies are the underground churches; Santa Maria de la Cava Underground Church is located just outside the Walled City, St Mary of Bethlehem Underground Church and St Dominic Church/ Crypt are located inside the Walled City of Famagusta. St Dominic Church is ruined almost completely, and the underground part of the church does not have any apse, therefore the underground part of it is considered a crypt (See Figure 1).

The author has published several articles about the churches in the Walled City of Famagusta, North Cyprus which can be studied for more information, and the relevant videos on the YouTube channel of the author can be watched (Babazadeh-Asbagh & Uluca-Tümer, 2018, pp. 418-444; Babazadeh-Asbagh, 2023d, August 2; Babazadeh-Asbagh & Uluca-Tümer, 2019, June, pp. 466-485; Babazadeh-Asbagh, 2023b; Babazadeh-Asbagh & Uluca-Tümer, 2021; Babazadeh-Asbagh, 2023a; Babazadeh-Asbagh, 2023c, May 2; Babazadeh-Asbagh, 2024a; Babazadeh-Asbagh, 2024x, March 8; Babazadeh-Asbagh, 2021c, May 18; Babazadeh-Asbagh, 2024b, January 12; Babazadeh-Asbagh, 2024c, January 13; Babazadeh-Asbagh, 2024d, January 13; Babazadeh-Asbagh, 2024e, January 13; Babazadeh-Asbagh, 2024f, January 14; Babazadeh-Asbagh, 2024g, January 14; Babazadeh-Asbagh, 2024h, January 14; Babazadeh-Asbagh, 2024i, January 15; Babazadeh-Asbagh, 2024j, January 15; Babazadeh-Asbagh, 2024k, January 15; Babazadeh-Asbagh, 2024l, January 15; Babazadeh-Asbagh, 2024m, January 15; Babazadeh-Asbagh, 2024n, January 16; Babazadeh-Asbagh, 2024o, January 16; Babazadeh-Asbagh, 2024p, January 16; Babazadeh-Asbagh, 2024q, January 16; Babazadeh-Asbagh, 2024r, January 17; Babazadeh-Asbagh, 2024s, January 17; Babazadeh-Asbagh, 2024t, January 17; Babazadeh-Asbagh, 2024u, January 17; Babazadeh-Asbagh, 2024v, January 17; Babazadeh-Asbagh, 2024w, January 23).

3.1. Conservation of the Churches in the Walled City of Famagusta

The Walled City of Famagusta was nominated for and placed on the 2008 and 2010 World Monuments Watch. In 2008-2009, Supporting Activities that Value the Environment (SAVE) of the US Agency for International Development (USAID) assessed the conditions of SS Peter & Paul Church. SAVE was established in 2005 for the protection of the natural and cultural heritage of Cyprus. Water penetration, repair of cracks and loose stones, and protection against earthquakes were among the significant structural repairs done by SAVE. Europa Nostra Board visited the Walled City of Famagusta in 2012 and demanded the acceleration of the conservation process there (Mason et al., 2012, pp. 5, 6). The Technical Committee on Cultural Heritage (TTCCH) is playing the most important role in cultural heritage conservation in Famagusta. Since it was established in 2008, TTCCH has played a great role in the conservation of many cultural heritage sites in Famagusta and Cyprus. The agreement of 21 March 2008 reached between Greek and Turkish Cypriots under the auspices of the United Nations (UN), paved the way, to cause the establishment of TTCCH which is dedicated to the recognition, promotion, and protection of the rich and diverse cultural heritage of the island (UNDP, 2015, January, p. 3; UNDP, 2018, October, p. 8).

TTCCH is supported in its work by an advisory board composed of archaeologists, conservation architects, art historians, conservators, and town planners from both communities and all its programmatic decisions are taken in line with the agreed principles and the task attributed by the two leaders (UNDP, 2012, October, p. 1; UNDP, 2015, January, p. 3; UNDP, 2018, October, p. 8). In 2008, the European Parliament requested that the European Commission carry out a study on the condition and the estimated cost of restoring cultural heritage in Cyprus (UNDP, 2018, October, p. 12). In 2009, TTCCH agreed to compile a study of the immovable cultural heritage of Cyprus. This European Union-funded study was finalised in 2010 with the support of the United Nations Development Programme – Partnership for the Future (UNDP-PFF) (UNDP, 2012, October, p. 2; UNDP, 2015, January, p. 6; UNDP, 2018, October, p. 12). The Study conducted in 2010 resulted in the identification of a list of 10 cultural heritage sites

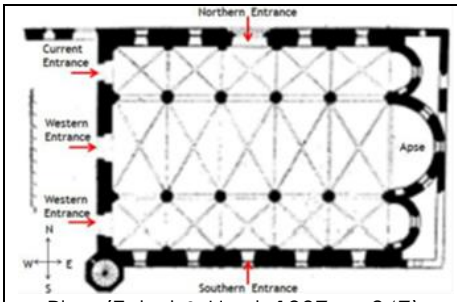
throughout the island in need of emergency measures. Mustafa Pasha Mosque in Famagusta was one of them (UNDP, 2012, October, pp. 2-3). In 2015, An initial list of 40 sites in need of emergency care and conservation was approved by the leaders (UNDP, 2015, January, p. 4).

Until 2015, 18 monuments have been structurally supported and physically protected or restored, Mustafa Pasha Mosque, St Anne Church, and St Mary of Armenian Church were among the completed projects in 2018 (UNDP, 2015, January, p. 7). Since 2010, the United Nations Development Programme (UNDP) has assisted TTCCH in preserving the cultural heritage of Cyprus (UNDP, 2018, October, p. 16). The capacity of TTCCH to define, agree upon, and formulate action priorities and a strategy for the future has been strongly supported by the European Commission since 2012. The strong bicommunal and multicultural ethos and demonstrated commitment of TTCCH to cooperation have led to the development of partnerships with various heritage-related institutions, most notably the Church of Cyprus and EVKAF (Kıbrıs Vakıflar İdaresi or The Islamic Trust of Cyprus), extending also to local and other competent authorities, expert groups, the UNDP and the Cyprus Settlement Support Unit of the European Commission in Nicosia (UNDP, 2018, October, p. 9). EVKAF Cyprus was founded in 1571 and its main office is currently located in Nicosia while there are two other branches, one in Kyrenia and another one in Famagusta. Although some churches in the Walled City of Famagusta have been conserved recently, the relevant information is not available on-site or even online for visitors and researchers to have access to the process of their conservation. See Table 6 for conservation interventions of the churches in the Walled City of Famagusta.

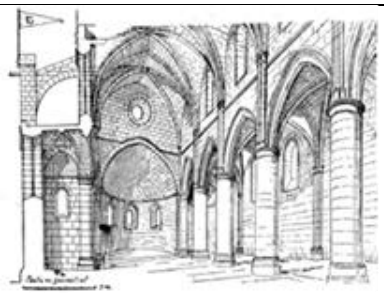
3.2. Current Problems of the Churches in the Walled City of Famagusta

Currently, some of the churches with the proper upper structure are in good structural condition and they have a function, but unfortunately, the others are abandoned. As they have not been used for a very long time, the maintenance problems, lack of security, lack of lighting, and vandalism altogether with natural and weather problems cause the decay of these churches faster and easier. The underground and ruined churches have the same problems and because of inadequate security, they face vandalism much more easily. Furthermore, the absence of a roof on the ruined churches exposes them to adverse weather problems causing more decay to the interior wall paintings and decorations of these churches. The inadequate way-finding to the underground and ruined churches led to their neglect. Lack of function and maintenance increase the speed of deterioration which causes them to be forgotten (Babazadeh-Asbagh, 2023b, pp. 56-57).

Even though some of the churches in Famagusta have been conserved and Theophilus Amin Halil Mogabgab has documented all the conservation works that he has done between the 1930s and 1950s, lack of documentation of the conservation process during different periods inside or beside the building is the common problems of almost all of the churches in the Walled City of Famagusta. Some of the churches that already have a function are closed almost all the time and open for a few events. Lack of documentation and conservation, being ruined and abandoned for a very long time, lighting problems at night, moisture, lack of access ramps for differently-abled, disabled, and elderly people, ageing, neglect and ignorance, natural and weather conditions like water erosion and wind erosion, lack of security, and unwanted plants growing inside, around, and on the walls are the main problems of the ruined churches in the Walled City of Famagusta. All of the underground churches in Famagusta have been left abandoned and vacant without any function for a very long time. Lack of documentation and conservation, lighting problems, moisture, lack of access ramps for differently-abled, disabled, and elderly people, ageing, neglect and ignorance, lack of security, and unwanted plants growing on the stairs and around these churches are the main problems of the underground churches in Famagusta (Babazadeh-Asbagh, 2023b, pp. 59-60). See Table 7 for the current problems of the churches in the Walled City of Famagusta.



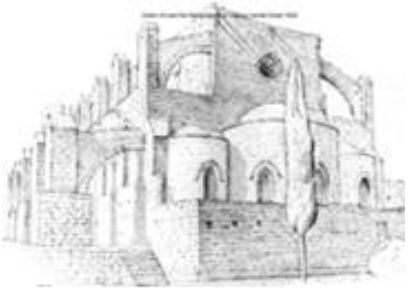
Plan (Enlart & Hunt, 1987, p. 247)



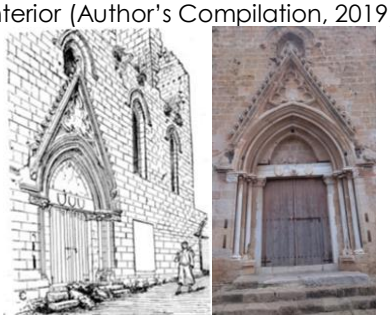
Section (Enlart & Hunt, 1987, p. 247)

Interior (Author's Compilation, 2019)

Interior (Author's Compilation, 2019)

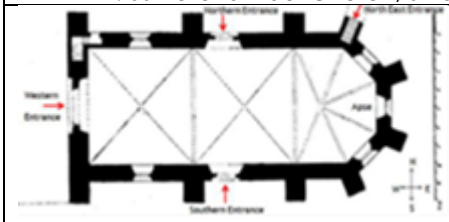


South-East View (Enlart & Hunt, 1987, pp. 578-579)

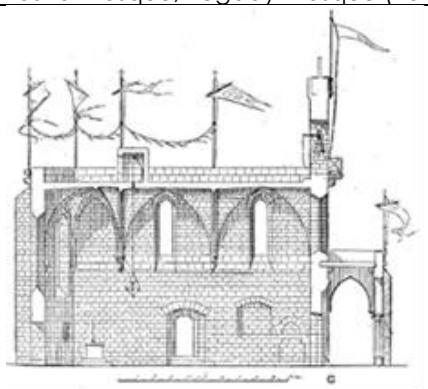


North Façade (Left: Enlart & Hunt, 1987, p. 250; Right: Author's Compilation, 2019)

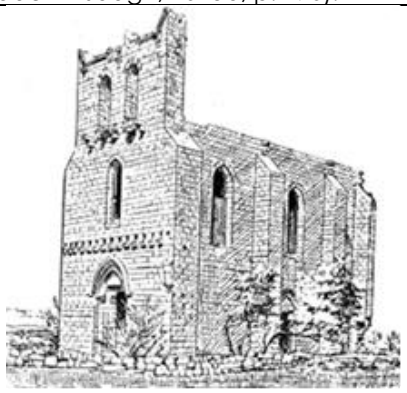
A. SS Peter & Paul Church, Sinan Pasha Mosque, Buğday Mosque (Babazadeh-Asbagh, 2023b, p. 170).



Plan (Enlart & Hunt, 1987, p. 278)

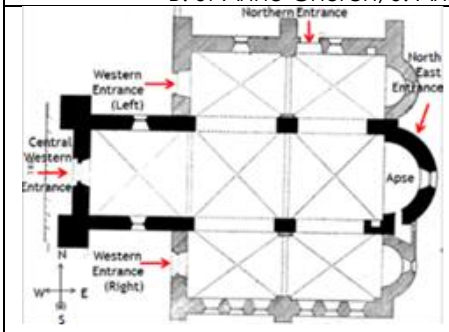


Section (Enlart & Hunt, 1987, p. 275)



South-West View (Enlart & Hunt, 1987, p. 277)

B. St Anne Church, S. Anna Church, Maronite Church (Babazadeh-Asbagh, 2023b, p. 194).

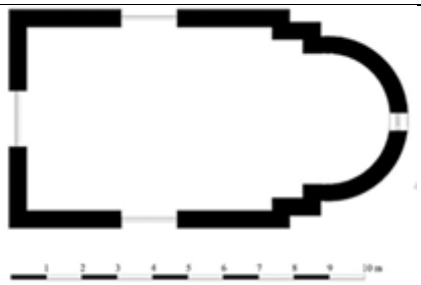


Plan (Enlart & Hunt, 1987, p. 281)

North Façade (Enlart & Hunt, 1987, p. 282)

North-East Façade (Author's Compilation, 2019)

C. The Nestorian Church, Ayios Yeorghios Xorinos Church, Church of Agios Georgios Exorinos, St George the Exiler Church (Babazadeh-Asbagh, 2023b, p. 198).

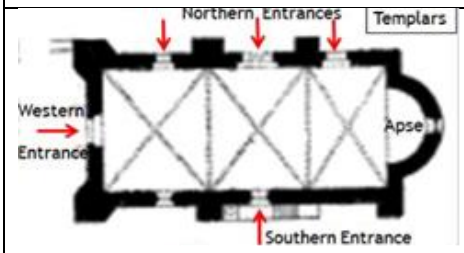


Plan (Author's Compilation, 2019)

South-West View (Enlart & Hunt, 1987, p. 286)

West Façade (Author's Compilation, 2019)

D. St Mary of Armenian Church, Saint Marie Church, St Mary's of the Armenians, Tabakhane (Tannery) (Babazadeh-Asbagh, 2023b, p. 202).

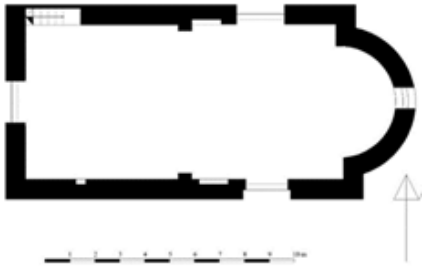


Plan (Enlart & Hunt, 1987, p. 291)

West Façade (Author's Compilation, 2019)

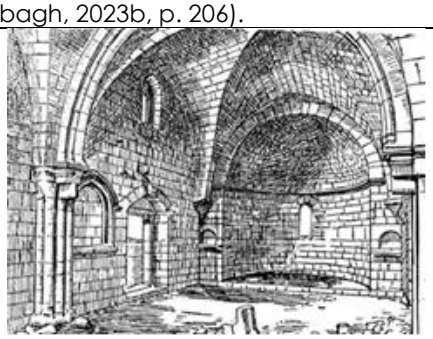
North Façade (Author's Compilation, 2019)

E. Templars' Church, one of the Twin Churches (Babazadeh-Asbagh, 2023b, p. 206).



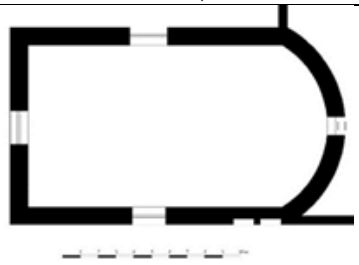
Plan (Author's Compilation, 2019)

South-West View (Enlart & Hunt, 1987, p. 299)



Interior (Enlart & Hunt, 1987, p. 301)

F. Jacobean Church, Tabakhane Mosque, Tanners' Mosque, Jacobite Church (Babazadeh-Asbagh, 2023b, p. 214).



Plan (Author's Compilation, 2019)

North-West View (Enlart & Hunt, 1987, p. 302)

North Façade (Author's Compilation, 2019)

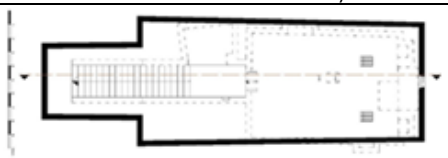
G. Mustafa Pasha Mosque, Stavros Church (Babazadeh-Asbagh, 2023b, p. 218).


West Façade (Author's Compilation, 2019)


East Façade (Author's Compilation, 2019)


North Façade (Author's Compilation, 2019)

H. Ay Zoni Church, Ayia Zone (Babazadeh-Asbagh, 2023b, p. 226).


Site Plan (Author's Compilation, 2019)


Plan (Author's Compilation, 2019)

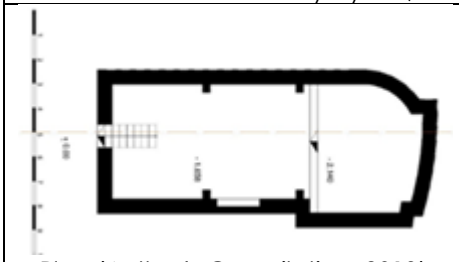

External View of the Main Façade (Author's Compilation, 2019)

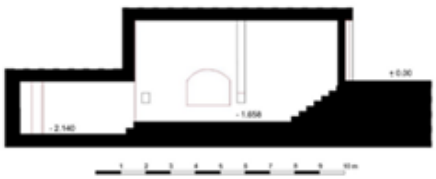

(left:) External View of the Entrance, (right:) Internal View of the Entrance


Interior View (Author's Compilation, 2019)


Wall Paintings (Author's Compilation, 2019)

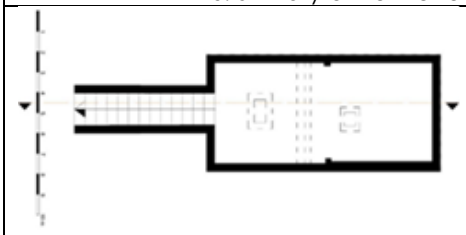
I. Santa Maria de la Cava Church, St Cava Underground Church, Madonna Della Cava (Our Lady of the Cave), St Mary-Hydria, Cana, Cava, de Cena (Babazadeh-Asbagh, 2023b, p. 230).

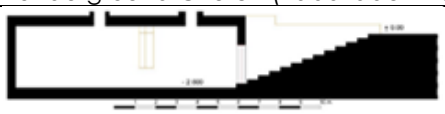

Plan (Author's Compilation, 2019)


Section (Author's Compilation, 2019)


West Façade (Author's Compilation, 2019)

J. St Mary of Bethlehem Underground Church (Babazadeh-Asbagh, 2023b, p. 234).


Plan (Author's Compilation, 2019)


Section (Author's Compilation, 2019)


West Façade (Author's Compilation, 2019)

K. St Dominic Church/ Crypt, Ayia Photou, St Clare, Haia Fotou (Babazadeh-Asbagh, 2023b, p. 238).

Figure 1. Plans, Sections, Façades, and Pictures of the Churches in the Walled City of Famagusta.

Table 3. Evaluation of Plan of the Churches in Famagusta (Babazadeh-Asbagh, 2023b, pp. 139-141).

Name of Church	Total Length (m)	Internal Length (m)	Total Width (m)	Internal Width (m)	Total Area (m^2)	Internal Area (m^2)	Nave/Aisle Number	Bay Number	Apse Number	Entrance Number	Main Entrance	Flying Buttress	Dome	Plan Type	Building Material
SS Peter & Paul Church	29	26	20	17	590	407	1 Nave 2 Aisles	5	3	5	North Façade	√		Three-aisled (Basilica form)	Hewn Sandstone
St Anne Church	18	16	10	6	190	93	1 Nave	2	1	3 (+1 door on East)	West Façade			Single-naved	Hewn Sandstone
Nestorian Church	27	24	22	18	431	294	1 Nave 2 Aisles	3 (at nave) 2 (at aisles)	3	4 (+1 door on East)	West Façade			Single-naved (originally)	Hewn Sandstone
Armenian Church	11	10	6	5	70	47	1 Nave	1	1	3	West Façade			Single-naved	Hewn Sandstone
Templars' Church	20	17	10	7	196	108	1 Nave	3	1	5	North Façade			Single-naved	Hewn Sandstone
Jacobean Church	16	15	8	6	129	86	1 Nave	2	1	3	West Façade			Single-naved	Hewn Sandstone
Mustafa Pasha Mosque	19	18	11	10	209	170	1 Nave	2	1	3	West Façade			Single-naved	Hewn Sandstone
Ay Zoni Church							1 Nave	1	1	1	South Façade		√	Single-naved	Hewn Sandstone
Santa Maria de la Cava		12		7		87	1 Nave	1	3	1	West Façade			Single-naved	Carved Stone
St Mary of Bethlehem underground		13		5		60	1 Nave	3	1	1	West Façade			Single-naved	Carved Stone
St Dominic Crypt		11		5		52	1 Nave	2		1	West Façade			Single-naved	Hewn Sandstone

Table 4. Evaluation of Architectural Characteristics of the Churches in Famagusta (Babazadeh-Asbagh, 2023b, pp. 142-144 drawn from Enlart & Hunt, 1987, pp. 213, 215, 246-253, 274-288, 290-294, 299-303, 578-579; Uluca-Tümer, 2017, pp. 208, 214-216, 218-219, 221, 223-224).

Names of Church	**Location in Famagusta**	**Built Date**	**Architectural Style/ Church Type**	**Structural System**	**External/ Internal Structures**	**Upper Structure**	**Ornamental Elements**
SS Peter & Paul Church, Sinan Pasha Mosque, Buğday Mosque	Sinan Pasha Street	Between 1300-1310	Originally a Latin Church (especially Northern Entrance), Nestorian Church (later)	Good	Good	Good	Good
St Anne Church, S. Anna Church, Maronite Church	Server Somuncuoğlu Street	14th century	Latin Catholic Church	Good	Good	Good	Faded wall paintings
Nestorian Church, Ayios Yeorghios Xorinos Church, St George the Exiler Church, Agios Georgios Exorinos Church	Necip Tözün Street	In 1360	Syrian-Rite Church	Good	Good	Good	Good wall paintings
St Mary of Armenian Church, Saint Marie Church, St Mary's of the Armenians, Tabakhane (Tannery)	Server Somuncuoğlu Street	After the middle of the 14th century	Armenian Church	Good	Good	Good	Faded wall paintings
Templars Church, one of the Twin Churches (The big one on the North side)	Kıshla Street	At the end of the 13th century	Templars Church	Good	Good	Good	Good
Jacobean Church, Tabakhane Mosque, Tanners' Mosque, Jacobite Church	Server Somuncuoğlu Street	During the 15th century	A mix of French, Aragonese Gothic & Byzantine architecture	Good	Good	Good	Good
Mustafa Pasha Mosque, Stavros Church	Lala Mustafa Pasha Street	During the 15th century	Half-Gothic Church	Good	Good	Good	Good
Ay Zoni Church, Ayia Zone	Altın Tabya Street	During the Latin period	Greek Orthodox Church	Good	Good	Good	Good
Santa Maria de la Cava Church, St Cava Church, Madonna Della Cava (Our Lady of the Cave), St Mary-Hydria, Cana, Cava, de Cena	Serbest Liman Yolu	1300	A Hellenistic tomb & burial space turned into a Christian cult place in the Lusignan period	Good	Good	Good	Faded wall paintings
St Mary of Bethlehem Under-ground Church	Kıshla Street	-	Underground Church	Good	Good	Good	Poor
St Dominic Crypt (located under-ground of the ruined church)	Server Somuncuoğlu Street	Latin Period	It is a Crypt, not an Underground Church as it does not have any apses.	Good	Good	Good	Poor

Table 5. Functions of the Churches in Famagusta in Different Periods (Babazadeh-Asbagh, 2023b, pp. 146-147 drawn from Enlart & Hunt, 1987, pp. 213, 215, 246-253, 274-288, 290-294, 299-303, 578-579; Uluca-Tümer, 2017, pp. 208, 214-216, 218-219, 221, 223-224).

Name of Church	Latin Period	Ottoman Period	English Period	After 1960	Current Function	Suggested Function
SS Peter & Paul Church	Church	Mosque, store	Granary, potato storage	Cultural centre, wedding ceremony hall, library, mosque, empty	Closed almost all the time, used for EMU events rarely	Interpretation Centre or Tourist Information Centre
St Anne Church	Church	Not known	Not known	Not known	No Function	Library & Bookstore
Nestorian Church	Church	Camel stable	Orthodox Church (at the beginning of the 20th century), vacant (after 1963)	Hospital (during the siege of the 1974s), cultural centre (since 1989)	No Function	Church
Armenian Church	Church	Tannery	Armenian church (1945)	No Function (after 1974)	No Function	Souvenir Shop
Templars' Church	Church	Mosque	Mosque, Masonic lodge	Refuge, library, association & community study hall	No Function	Exhibition Hall & Art Studio
Jacobean Church	Church	Mosque	No Function	No Function	No Function	Library & Reading Room
Mustafa Pasha Mosque	Church	Mosque	No Function	Mosque (since the middle of the 1990s)	Closed almost all the time	Mosque
Ay Zoni Church	Church	Not known	Not known	Not known	Store	Souvenir Shop
Santa Maria de la Cava Church	Church	Not known	Not known	Not known	No Function	Museum for Peace
St Mary of Bethlehem Church	Church	Not known	Not known	Not known	No Function	Architectural Office
St Dominic Crypt	Church	No Function	No Function	No Function	No Function	Souvenir Shop

Table 6. Conservation Interventions of the Churches in Famagusta (Babazadeh-Asbagh, 2023b; Mogabgab, 1941; Mogabgab, 1951; Piana, 2008, Uluca-Tümer, 2017; UNDP, 2012; UNDP, 2015; UNDP, 2018; Walsh, Edbury, & Coureas, 2016).

Name of Church	Conservation Interventions
SS Peter & Paul Church	Flying buttresses were added after the earthquakes of 1546 and 1568. Small repairs after the earthquake of 1735. Between 1937 and 1945, consolidation, finishing, cleaning, excavation, rehabilitation, strengthening, and renovation of structural elements was done by the Antiquities Department.
St Anne Church	The paintings on the walls were restored in 1937. In the report of UNDP (2018, October), it was listed among the completed projects.
Nestorian Church	At the beginning of the 1900s, the South façade was cleaned by the Greek Church Committee. Between 1937 and 1939, clearance, excavation, lowering of the path, and covering the road with asphalt were done. Some repairs were done for using the building until 1947.
Armenian Church	It underwent some repairs between 1937 and 1939. The south and north façades have improved with roof insulation, doors, and joinery installed. Some medieval foundations were found in the work on the frescoes in 1937. In the report of UNDP (2018, October), it was listed among the completed projects. A ceremony was held for the completion of the conservation works on 26 May 2018 funded by the European Union.
Templars' Church	During the restorations between 1938 and 1950, excavation, lowering of the ground and the road ahead, demolition of the adjoining residences on the East side, preparing against flooding, the building of the perimeter wall, and the structural and architectural elements were completed.
Jacobean Church	During the restoration works between 1937 and 1939, some of the ruined parts were built again. In the report of UNDP (2018, October), it was listed among the completed projects.
Mustafa Pasha Mosque	In 1990, during the restoration works, the concrete coating was poured over the vault. In the report of UNDP (2015, January), it was listed among the projects completed by UNDP-PFF.
Santa Maria de la Cava Church	After the excavations, the neighbouring land was expropriated and a boundary wall was built around it.
St Dominic Church/ Crypt	During the 1938-1939 excavation and repair works, different parts of the building were revealed, and then consolidation was done.

Table 7. Current Problems of the Churches in Famagusta (Babazadeh-Asbagh, 2023b, p. 150).

Name of the church	Lack of documentation near/inside the church	Lack of signs near/inside the church	Lack of access to the interior of the church	Lack of access ramps for disabled & elderly	Lighting problems	Neglect & Ignorance	Lack of maintenance	Moisture	Weather conditions: Water & wind erosion	Lack of security	Growing unwanted plants	Left abandoned	Vandalism	Ageing
SS Peter & Paul Church	√		√	√	√	√	√			√	√			√
St Anne Church	√	√	√	√	√	√				√		√	√	√
Nestorian Church	√		√	√	√	√	√			√	√	√	√	√
Armenian Church			√		√					√		√	√	√
Templars' Church	√		√	√	√	√	√	√	√	√	√	√	√	√
Jacobean Church	√	√	√	√	√	√		√	√	√		√	√	√
Mustafa Pasha Mosque	√		√	√	√	√				√	√	√	√	√
Ay Zoni Church	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Santa Maria de la Cava	√			√	√	√	√	√	√	√	√	√	√	√
St Mary of Bethlehem	√			√	√	√	√	√	√	√	√	√	√	√
St Dominic Church	√	√		√	√	√	√	√	√	√	√	√	√	√

4. Adaptive Reuse of the Churches in Famagusta

SS Peter & Paul Church has a good structural system, good external and internal structures, a good upper structure, and good ornamental elements (See Table 4) with an internal area of approximately 407 square metres (See Figure 1A & Table 3). It was a Latin church passed on to the Syrians in a later period. It was used as a granary, store, stable, and storage of potatoes sometimes. It was supposed to be converted into a museum. It was used as a cultural centre and wedding ceremony hall in the 1960s. It was used as a library in 1974. It was used as a mosque in the 1990s (See Table 5). Currently, it is closed almost all the time and open for a few events of EMU. It can be reused as an interpretation centre or tourist information centre opened every day for informing and guiding international tourists, students, and even the locals as it is needed in the Walled City of Famagusta (Babazadeh-Asbagh, 2023b, p. 83) (See Figure 1A).

St Anne Church has a good structural system, good external and internal structures, a good upper structure, and faded wall paintings (See Table 4) with an internal area of about 93 square metres (See Figure 1B & Table 3). It was used as a church during the Latin period. Its function during the Ottoman and English periods and after the 1960s is unknown. Currently, it is closed almost all the time (See Table 5). The proposed functions of this church based on the public opinions of tourists and locals are an art studio, dance studio, or library, while an exhibition hall, nursery, and residential functions are not considered appropriate (Peyravi, 2010, pp. 42, 66-72, 77, 95, 97). It can be reused as a library and bookstore as it has been already conserved and consolidated by the United Nations Development Programme (UNDP) in 2018 (See Table 6) and the interior spaces are appropriate for bookshelves. The location of the church is very quiet and suitable for a reading room or a library. To respect the authenticity of the interior wall paintings, transparent furniture and reversible interventions like movable bookshelves can be used for the proposed library function to reduce the interferences as minimal as possible (Babazadeh-Asbagh, 2011; Babazadeh-Asbagh, 2021a; Babazadeh-Asbagh, 2021b, May 14; Babazadeh-Asbagh, 2023b, p. 83-84) (See Figure 1B).

Nestorian Church has a good structural system, good external and internal structures, a good upper structure, and good wall paintings (See Table 4) with an internal area of around 294 square metres (See Figure 1C & Table 3). It was used as a church during the Latin period and as a camel stable in the Ottoman period. During the English period, at the beginning of the 20th century, it was an Orthodox Greek Church. It was left vacant after 1963. Between 1963 and 1964, it was used by refugees. During the siege in the 1974s, it was used as a hospital. Since 1989, it has been used as a cultural centre of EMU (See Table 5). Currently, it is closed but it can be reopened as a church because it still has the interior wall paintings and interior spaces similar to a church consisting of an altar and rows of benches for the pilgrims to sit and pray which can be reused for religious ceremonies of Christian students and tourists as most of the participants especially the international tourists are willing to attend religious ceremonies held inside these churches (Babazadeh-Asbagh, 2023b, p. 84) (See Figure 1C).

The Armenian Church has a good structural system, good external and internal structures, a good upper structure, and faded wall paintings (See Table 4) with an internal area of roughly 47 square metres (See Figure 1D & Table 3). It was used as a church during the Latin period and as a tannery in the Ottoman period. During the English period, it was an Armenian church (1945). It was left abandoned without any function after the 1960s (See Table 5). Currently, it is closed almost all the time. The proposed functions of this church based on the public opinions of tourists and locals are a tourist information centre, or library, while residential functions are not considered appropriate (Peyravi, 2010, pp. 42, 87-93, 95, 98). Due to its small size and location and also because of the lack of signs and wayfinding problems, it can not be reused as an information centre or library. As it has been already conserved and consolidated by UNDP in 2018 (See Table 6), it can be reused as a souvenir shop due to its limited interior space and transparent furniture can be used inside the church to respect the authenticity of the interior wall paintings (Babazadeh-Asbagh, 2011; Babazadeh-Asbagh, 2021a; Babazadeh-Asbagh, 2021b, May 14; Babazadeh-Asbagh, 2023b, p. 84-85) (See Figure 1D).

Templars' Church has a good structural system, good external and internal structures, a good upper structure, and good ornamental elements (See Table 4) with an internal area of almost 108 square metres (See Figure 1E & Table 3). It was used as a church during the Latin period and as a mosque in the Ottoman and English periods. It might have been used as a Masonic Lodge in the English period. After the 1960s, it was used as a refuge, a library, and an association and community study hall (See Table 5). Currently, it is closed almost all the time and just open for a few events. The proposed functions of this church based on the public opinions of tourists and locals are an exhibition hall, art studio, dance studio, or library, while a museum, nursery, tourist information centre, and residential functions are not considered appropriate (Peyravi, 2010, pp. 42, 58-65, 94, 95, 97). Due to its location and small size, it can be reused as an exhibition hall, and an art studio, as it was used before, opened every day for tourists and locals to visit the interior (Babazadeh-Asbagh, 2023b, p. 85) (See Figure 1E).

Jacobean Church has a good structural system, good external and internal structures, a good upper structure, and good ornamental elements (See Table 4) with an internal area of nearly 86 square metres (See Figure 1F & Table 3). It was used as a church during the Latin period and as a mosque during the Ottoman period. It was empty without any function during the English period and after the 1960s (See Table 5). Currently, it has no function. The proposed functions of this church based on the public opinions of tourists and locals are a café, souvenir shop, tourist information centre, or architectural office, while an exhibition hall, nursery, and residential functions are not considered appropriate for it (Peyravi, 2010, pp. 42, 73-79, 95, 97). As it has been already conserved and consolidated by UNDP in 2018 (See Table 6), it can be reused as a library and reading room due to its location and quite large interior space which is very suitable for a quiet reading room. Furthermore, reversible interventions like movable furniture can be used for the proposed library function to reduce the interferences as minimal as possible (Babazadeh-Asbagh, 2011; Babazadeh-Asbagh, 2021a; Babazadeh-Asbagh, 2021b, May 14; Babazadeh-Asbagh, 2023b, p. 85-86) (See Figure 1F).

Mustafa Pasha Mosque has a good structural system, good external and internal structures, a good upper structure, and good ornamental elements (See Table 4) with an internal area of approximately 170 square metres (See Figure 1G & Table 3). It was used as a church during the Latin period and as a mosque during the Ottoman period. It was empty without any function during the English period and after the 1960s. It was once used as a coffee-roasting establishment (See Table 5). It has been already conserved by UNDP-PFF in 2015 (See Table 6). It used to be open and a local Muslim Imam was teaching the Holy Quran to children, but currently, it is closed almost all the time and has no present function. The proposed functions of this church based on the public opinions of tourists and locals are a tourist information centre, souvenir shop, nursery, library, or dance studio, while residential functions are not considered appropriate for its reuse (Peyravi, 2010, pp. 42, 80-86, 95, 98). As it has been used as a mosque before, it can be reopened every day and reused as a mosque again for Muslims to say prayers (Babazadeh-Asbagh, 2023b, p. 86) (See Figure 1G).

Ay Zoni Church has a good structural system, good external and internal structures, a good upper structure, and good ornamental elements (See Table 4). It was used as a church during the Latin period. Its function during the Ottoman and English periods and after the 1960s is unknown (See Table 5). Currently, it is used as a store of unused commodities. Due to its small size and location near the gate, it can be reused as a souvenir shop (Babazadeh-Asbagh, 2023b, p. 86-87) (See Figure 1H).

Santa Maria de la Cava Underground Church has a good structural system, good external and internal structures, a good upper structure, and faded wall paintings (See Table 4) with an internal area of about 87 square metres located just outside the Walled City of Famagusta (See Figure 1I & Table 3). A Hellenistic tomb turned into a Christian cult place in the Lusignan period. It was an important burial space that appeared as early as 1300 under the name of Cava. It must have been used as a church during the Latin period, but its function is not known after that. It has been abandoned and left empty without any function for a very long time (See Table 5). It can be reused as a museum for peace in

North Cyprus after the renovation and restoration of the church (Babazadeh-Asbagh, 2023b, p. 87) (See Figure 1I).

St Mary of Bethlehem Underground Church has a good structural system, good external and internal structures, and a good upper structure (See Table 4) with an internal area of around 60 square metres (See Figure 1J & Table 3). Camille Enlart did not mention this underground church in his book (1987), nor did he indicate its location on his map. It must have been used as a church during the Latin period, but its function is not known after that. It has been abandoned and left empty without any function for a very long time (See Table 5). It can be reused as an architectural office after the renovation and restoration of the church (Babazadeh-Asbagh, 2023b, p. 87) (See Figure 1J).

St Dominic Crypt has a good structural system, good external and internal structures, and a good upper structure (See Table 4) with an internal area of roughly 52 square metres (See Figure 1K & Table 3). It was used as a church during the Latin period. Its function during the Ottoman and English periods and after the 1960s is unknown (See Table 5). Currently, it is empty, but it can be reused as a souvenir shop due to its small size and location near the North-East entrance gate to the Walled City of Famagusta (See Figure 1K) (Babazadeh-Asbagh, 2023b, p. 87).

5. Conclusion

When conflicts occur among different communities, religious buildings are the main target of ignorance, abandonment, or even conscious vandalism. As the historic buildings and sites belong to all human beings, no matter what their nationality or religion is, not even to the currently living people, not just for their builders in the past time, but also for future generations, everybody must do whatever they can for the protection and conservation of the valuable heritage worldwide. Interpretation and its different tools can be one of the methods for prolonging the life of historic buildings and especially abandoned cultural heritage like religious buildings. Adaptive reuse can be another solution for abandoned historic buildings when their original function is not the first choice for people with different religious beliefs in various communities.

In the case of the Walled City of Famagusta, St Nicholas Cathedral is the most famous historic building amongst the others, not just because of the elaborate west façade and is one of the Gothic masterpieces, but because it is the only church in Famagusta which has had a function since the establishment time. It suffered the bombardment and earthquakes just like the other churches, but as it was converted into a mosque and used continuously and experienced conservation, restoration, and constant maintenance, it became the icon of the Walled City of Famagusta. Similarly, if the abandoned historic buildings are given a function and are used with a proper management plan and being cared for with periodic repair and maintenance, this could prolong their life which is the ultimate goal of conservation. Adaptive reuse and changing the original function of abandoned religious buildings in different countries can benefit the historic buildings to live longer and even help with the financial issues for their maintenance and repair. Moreover, informing the people no matter if they are the locals who live in the same city and neighbourhood of the historic buildings, the tourists who might have seen them just once, or the international university students who have lived in that city or country for a short time of their life during their academic years or even the youngest students of the schools who are curious about the history of their city and country can help to raise the knowledge about the values of the cultural heritage as reducing the ignorance and vandalism (Babazadeh-Asbagh & Uluca-Tümer, 2021, pp. 96-97; Babazadeh-Asbagh, 2023b, pp. 110-111).

When the communities are changed during the time and their religious buildings are left abandoned and become vacant, due to the lack of function, poor maintenance policies, and lack of security, vandalism can be a serious problem for their cultural heritage buildings. Having a function can prevent vandalism due to the security and regular maintenance of cultural heritage buildings. Although the best function for a church is to be used as a worship centre, when the communities are not present

anymore, adaptive reuse can be suggested for a different function proposed for the abandoned church building. Adaptive reuse is one of the conservation methods that can have positive effects like financial benefits of the income for maintenance of the abandoned church buildings which is necessary for the sustainability of the cultural heritage buildings. Architectural characteristics, structural situation, size, and the location of the church buildings are important factors in choosing a new function for their adaptive reuse.

Adaptive reuse functions for a church building can be commercial like a café, bar, coffee shop, restaurant, or shopping centre, or community functions like a library, bookstore, or cultural heritage centre. Office functions like an architectural office or art studio, cultural functions like a theatre, museum, or concert hall, and residential functions like a house for a single-family residence, hostels, or even hotels, are the other reuse functions that can be used for the church buildings. Some of these functions are proposed for the adaptive reuse of the abandoned churches in the Walled City of Famagusta with proper upper structure and no function. The other churches which are ruined especially in their upper structure can be visited by tourists after the restoration and consolidation projects making sure that their physical structures are safe. There are some vacant places near some of these ruined churches in the Walled City of Famagusta which can be reused as a public park with sitting benches, public toilets, children's playgrounds, and sports facilities open to all visitors, tourists, students, and locals as there is a need for designing more green and public spaces (Babazadeh-Asbagh, 2023b, pp. 111-112).

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

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Building Collaborative Innovation Platforms for Engineering Education: Government University Industry Nexus

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ABSTRACT

The paper discusses the challenges of co-creating a 21st-century engineering, architecture, and urbanism curriculum in Egypt, emphasising the need for collaboration between the government, industry, and higher education providers. The paper aims to overcome barriers in the Government-University-Industry (GUI) nexus to align and enhance the engineering sector's contribution to Egypt's economic prosperity. The study identifies cultural, educational, and structural factors influencing innovation in Egypt and addresses gaps at the national, university, and program levels. The paper highlights the similarities of innovation landscape with the UK. The authors identified, poor communication and alignment between national goals, industrial strategy, and academic research that hinder engineering innovation in Egypt. The research highlights the inflexibility and lack of clarity in the current engineering curriculum, contrasting the evolving demands and advancements in engineering technology. The paper also refers to the UK Apprenticeship Education Programme as a possible model for improving industrial collaboration and discusses its relevance to Egypt's technical education initiatives.

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1. Introduction

Co-creating Engineering Curriculum for the 21st Century is not a simple task. It requires genuine and deep-rooted collaboration between the government, the industry, and higher education providers. The efforts to improve the engineering curriculum in Egypt also rely on pulling together a number of organisations and integrating disparate and fragmented innovation structures. This has been a key driver behind the CRUISE research project, a collaborative effort between UK and Egyptian partners. The Project identified the similarities and differences between the two countries' innovation landscapes. The project also explored the UK apprenticeship Education Programme as a possible model for co-creating an exemplary cadetship Engineering curriculum featuring industry-driven educational content. Throughout the project,

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several challenges facing the Government-University-Industry (GUI) collaboration in Egypt have been identified.

This paper explains the challenges facing GUI (Government- University- Industry) and identifies the innovation ecosystem to deliver further improvement to the engineering industries that are core to the economic prosperity in Egypt.

Dating back to 1816, Engineering education in Egypt has equipped graduates with key engineering skills across the Middle East and Africa. Over the last 50 years, Egyptian engineers have pushed the boundaries of knowledge, science, and technology. At the same time, the number of engineering graduates has continued to increase, reaching more than 35,000 graduates, with an increase of approximately 300% since the turn of the century. (Elsafty 2020)

It would be possible, sensing the recent rise and improvement in the ranking of a number of Egyptian Universities, to opt for a quiet life basking in previous successes, shrugging off the current challenges, and shirking the need for reform. It would be, however, detrimental to delay the urgent need for transformation as the engineering industry is already changing faster than it has ever done before, and the pace of change will continue to accelerate. Egyptian universities are key to the country's ability to effectively manage change without becoming enmeshed in it. Future success is dependent on better mobilizing the knowledge, imagination, creativity, skills, and abilities of our whole engineering workforce to contribute to national economic prosperity.

The Co-Create Government University Industry Engineering Curriculum for the 21st Century (CRUISE) project, presented in this article, stands as a collaborative endeavour between academic institutions and industry, aiming to develop engineering education in Egypt. The project focuses on narrowing the knowledge gap between academia and industry by jointly crafting a cadetship curriculum tailored to meet industry demands. Throughout the project journey, several pivotal milestones were reached. These include the comprehensive mapping of Egypt's research and innovation landscape, critical comparison between Egyptian and UK innovation landscape, capacity-strengthening workshops, and the development of industry-driven educational content. Central to the project's success was active stakeholder engagement, with workshops and seminars serving as platforms for dialogue among academics, industry stakeholders, and government representatives, addressing crucial aspects such as curriculum development, industry integration, and research innovation. Significant highlights emerged from stakeholder workshops which delved into topics like the UK apprenticeship programmes, fostering industry-university partnerships, and adapting curricula to align with industry standards. Notably, the project emphasised practical experiences and industry engagement, resulting in the adaptation of modules across partner universities to involve industry in the modules' delivery.

2. Literature Review

The transition from higher education to the workplace represents a critical phase for new graduates, where they must navigate the socialisation process within organisations to integrate effectively into their roles. Korte (2008) emphasized the significance of this socialisation process in shaping newcomers' experiences and perceptions of work and the organisation. He suggests that these early experiences not only impact job satisfaction and learning but also have potential long-term effects on turnover and commitment. This underscores the importance of understanding and facilitating the transition for new professionals. In response to the evolving demands of the job market, higher educational institutions are reevaluating their teaching methods to equip students with the necessary skills for lifelong learning and adaptability. Khodeir and Nessim (2020) highlight the challenges posed by '21st Century Competencies' and the imperative for educational institutions to address them. This shift reflects a recognition of the dynamic nature of industries and the need for graduates to possess versatile skills to succeed in their careers. Zeidan and Bishnoi (2020) delve into the gap between academia and industry readiness, particularly in the context of Industry 4.0. Their study investigates the skills and competencies required by

the industry, revealing discrepancies between graduates' abilities and industry expectations. This misalignment underscores the need for collaboration between academia and industry to bridge the gap and ensure graduates are adequately prepared for the workforce.

Achieving successful collaboration between universities and industries presents its own set of challenges. Chen, Lu, and Wang (2020) highlight the complexities involved in university-industry collaboration, including questions regarding timing, contributions from both parties, and achieving mutual benefits. This indicates the necessity for clear frameworks and strategies to facilitate effective collaboration and maximize outcomes for all stakeholders. Furthermore, the implementation of standards-based reform in education requires leadership that can navigate both technical and adaptive challenges. Pak, Polikoff, and Desimone (2020) emphasize the importance of technical and adaptive leadership in aligning curriculum with standards. Without addressing both aspects, they argue, challenges in implementation will persist, hindering the effectiveness of educational reforms.

The literature on academy-industry relations demonstrates a broad spectrum of activities, structures, and concepts facilitating the exchange of resources, ideas, and influence between universities and for-profit entities (Anderson, 2001). Factors influencing university-industry interaction include networking, legal support, facilitating agents, and management practices (B€urger & Fi, 2021). University programs aim to equip students with skills and knowledge for employment, fostering critical thinking and empowerment. However, there is a growing emphasis on aligning programmes with industry needs to enhance graduates' employability (Al Asefer, 2021). Higher education faces the dual mission of preparing graduates for the workforce and fostering well-rounded individuals with qualities of citizenship, responsibility, and professional expertise (Suleman, 2021). Employability skills have been extensively studied, while attributes related to holistic education receive less attention, despite their societal relevance (Suleman, 2021). In the context of Egypt, its higher education system has shown promise, particularly in the establishment of a national accreditation body (Saeed, 2021). Meanwhile, in China, challenges persist in promoting industry-education integration, necessitating comprehensive policies, involvement of enterprises, and a robust evaluation system (Xu, Su, & Hong, 2021). Innovation ecosystems play a crucial role in enhancing university-industry interactions, with factors such as networking, legal support, and management practices influencing the relationship (B€urger & Fi, 2021). Moreover, the importance of hard and soft skills in employability is emphasized, with soft skills increasingly recognized as vital assets in the labour market (Kraja & Begani, 2021).

The implication and significance of industry-education integration have been a subject of growing interest and scrutiny in recent years. Xu, Su, and Hong (2022) examined this discourse and emphasized the importance of constructing a comprehensive system of policies and regulations, coupled with a robust evaluation mechanism. Their study underscores the pivotal role of enterprises in this integration process, suggesting that harnessing the full potential of industry partnerships is crucial for its success. This assertion resonates with the broader consensus in academia, advocating for a symbiotic relationship between educational institutions and industries to address the evolving demands of the workforce. Bae, Polmear, and Simmons (2022) contribute to this discourse by shedding light on the development of employability among civil engineering students. Their findings highlight the multifaceted nature of career preparation, emphasizing the significance of intrinsic motivation, extracurricular engagement, and the role of educators. The study underscores the imperative for academic institutions and management to bridge the gap between theoretical knowledge and practical skills demanded by the industry. Such efforts are deemed essential for enhancing students' readiness for the workforce and ensuring their long-term success in their careers. Bermejo, Eynian, Malmskold, and Scotti (2022) introduce a cooperative model, grounded in the Plan–Do–Study–Act cycle, as a viable framework for industry-academia collaboration in the context of Manufacturing Engineering education. Through a detailed examination of its application in curriculum design, the authors demonstrate the efficacy of this model in aligning educational objectives with industrial requirements. The study advocates for the broader adoption of

such methodologies across various fields of education, emphasizing its potential to bridge the gap between academia and industry effectively.

Wilson, Dyer, and Cantore (2023) provide insights into the evolving landscape of stakeholders in the education sector. Their investigation identifies strategic shifts in stakeholder dynamics, attributing these changes to factors such as the emergence of concepts like the third mission and corporate social responsibility. The study underscores the need for educational institutions to adapt to these evolving stakeholder dynamics, recognizing the shifting influence and salience of various stakeholders. Such adaptability is crucial for fostering sustainable partnerships and ensuring the relevance of educational initiatives in a rapidly changing societal context. Collectively, these studies underscore the multifaceted nature of industry-education integration and the evolving dynamics within the educational landscape. They emphasize the importance of collaborative efforts between academia, industry, and other stakeholders in addressing the challenges posed by the changing demands of the workforce. Moreover, they advocate for innovative approaches and frameworks to facilitate effective collaboration and ensure the continued relevance and success of educational initiatives.

Several efforts have been made to foster the co-creation of engineering curriculum in the United Kingdom. For example, *Connected Curricula* developed by Siemens and adopted in a number of Engineering courses in the UK, are based on round education where academic and industry partners work together to develop the modules. While Siemens is developing and updating the lecture content and adding practical projects around the subject of industrial automation to fit seamlessly into the existing university syllabus, the academics are responsible for delivering this content to students. Siemens also gives technical help and engages with the students in project meetings. Siemens never gets involved in the assessment; students are assessed by university academics. In addition. connected curriculum modules allow students to access Siemens simulation software, NX Mechatronics Concept Design, Tecnomatix Plant Simulation, and PLCSIM Advanced and TIA Portal. Students will also get the chance to learn and apply the digitalisation techniques such as MindSphere and Digital Twins (Salford University, 2019). Table 1 shows the SWOT analysis for possible application of the Connected Curriculum in an Egyptian context.

Table 1: SWOT analysis of the Connected Curriculum. (Source: Authors)

Strength	**Weaknesses**
• Diverse and interactive learning approaches • Upskilling students' capabilities in new technologies • Equipping students with Industry 4.0 skills • High-skilled students' attributes • Fulfil industry needs • Saving budget for buying equipment	• Complexity and difficulty of the software and the hardware • The time constraint • The limitation to specific modules • The non-involvement of the industry in assessment methods
Opportunities	**Threats**
• Academic collaboration with the industry (industry networking) • Universities' competitive value and be aligned with the national Industrial Strategy • Improving reputation • Incorporating blended learning approaches in future curriculum development	• Diminished teacher/student relationship • Less care for the students in the theoretical content • Possible lack of coordination • Ethical challenges • The possible bureaucratic procedures and decision making

3. Gap Analysis Methodology

In Egypt, higher education is offered through different typologies, there are 199 High or technical Institutes containing 454 faculties/ institutes; 27 private universities (209); 10 Technological universities (16); 4 community universities (10); 4 public universities (41 Domain); 12 public universities emanating from governmental universities (122); 4 branches for European universities (14); 2 universities of special nature; 8 Universities, academies and institutes with international and framework agreements; 7 newly approved universities; 4 governmental Academies and institutes; in addition to 199 High or technical Institutes (MOHESR). The total number of enrolled students in all HE institutes in Egypt is about 3.495 million during the academic year 2021-2022 (CAPMAS, 2022).

Engineering education is highly connected to the health and structure of the innovation landscape. The CRUISE project conducted a thorough literature review to gather existing knowledge and insights, related to curriculum mapping, research, and innovation landscape in Egypt. The project has therefore, mapped the Egyptian research and innovation ecosystem. This helped in understanding the current state of engineering education in Egypt at different national, university, and module levels. The project has identified relevant frameworks and best practices. The gap analysis aimed to identify discrepancies between the existing curriculum and industry requirements in Egypt. This involved comparing the skills and knowledge provided by the current curriculum with the skills and knowledge demanded by the industry, using both qualitative and quantitative data sources. CRUISE project employed a comprehensive research methodology and data collection approach as shown in Figure 1. These combine qualitative and quantitative methods to gather diverse perspectives and evidence for informing curriculum development, research landscape mapping, gap analysis, and module development.

3.1. Stakeholder workshops were organised to gather qualitative data and insights from various stakeholders, including academics, industry partners, government officials, and students. These workshops facilitated discussions on curriculum mapping, industry needs, and the research landscape, providing valuable qualitative data for analysis and decision-making.

3.2. Pilot Testing: New modules developed as part of the project were pilot-tested in real-world settings to gather feedback from students, instructors, and industry partners. This iterative approach allowed for continuous refinement and improvement of the modules based on actual implementation experiences.

3.3. Surveys and questionnaires were utilised to gather quantitative data on specific aspects of the project. For example, primary questionnaires were administered to students to gather their opinions and feedback on their experience with the newly developed modules that integrated the industry into the content delivery and evaluation process.

3.4. Expert Consultations: Expert consultations were conducted with academic experts, industry professionals, and policymakers to gather specialised knowledge and insights on curriculum development, industry trends, and research innovation. These consultations helped in refining project strategies and recommendations.

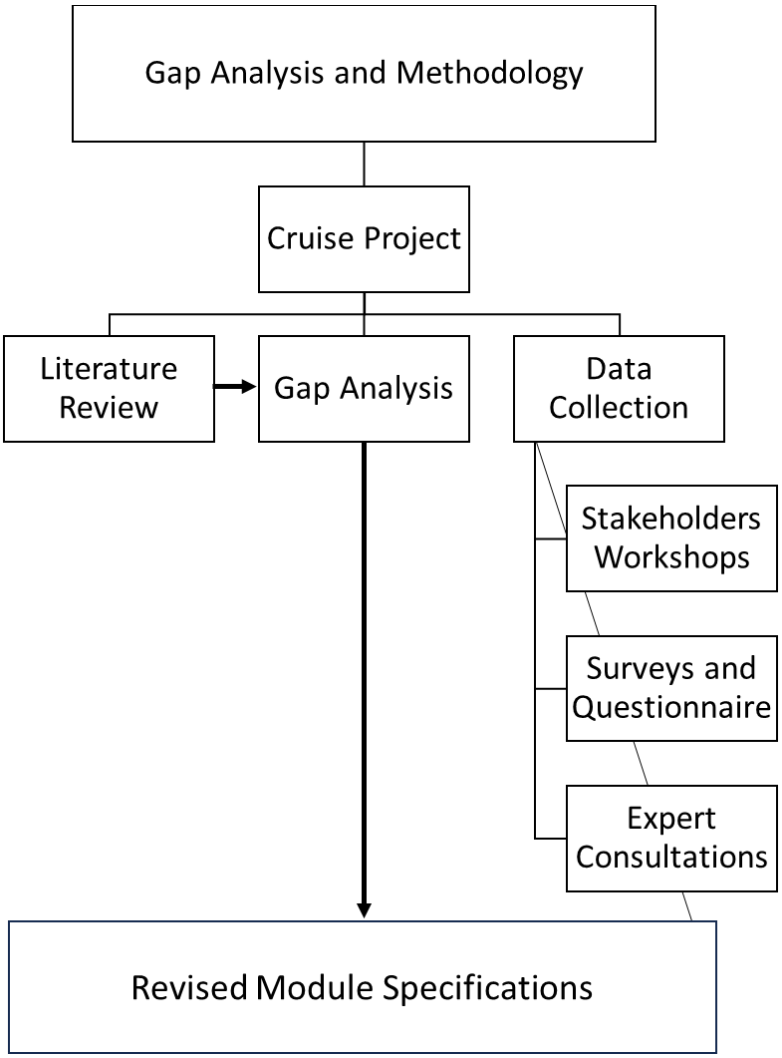

Figure 1. Theoretical framework and methodological process of the study (Source: Authors)

4. Results

Innovation in any country relies on several cultural, educational, and structural factors. Co-creating a new contemporary engineering curriculum could not and should not be separated from those factors. Mapping the innovation landscape in Egypt in this project has revealed several opportunities and exposed a number of gaps, especially when comparing it with its equivalent in the UK as seen in Table 2. The CRUISE project team has tackled those gaps on three different levels; the strategic national level, the universities' missions and structures related to industry engagement, and the engineering programmes level.

Despite the similarities in the innovation landscape in the UK and Egypt shown in Figure 2 and 3, fragmentation, and lack of overall coordination, heightened by poor communication between departments on all levels, seems to halt the acceleration of innovation in Egypt. The project found discrepancies between the objectives of the Egyptian national industrial strategy and research priorities in higher education. The engineering curriculum has neither the flexibility nor the clarity to meet those national goals. Egyptian academics were largely either not aware of the national goals set in the industrial strategy, or under the impression that it is the role of the industry rather than academia to achieve those

goals. Universities' research strategies do not seem to be in sequence with the national strategic cycles. Therefore, research strategies and plans do not reflect the urgency to adapt to the Egyptian national industrial goals.

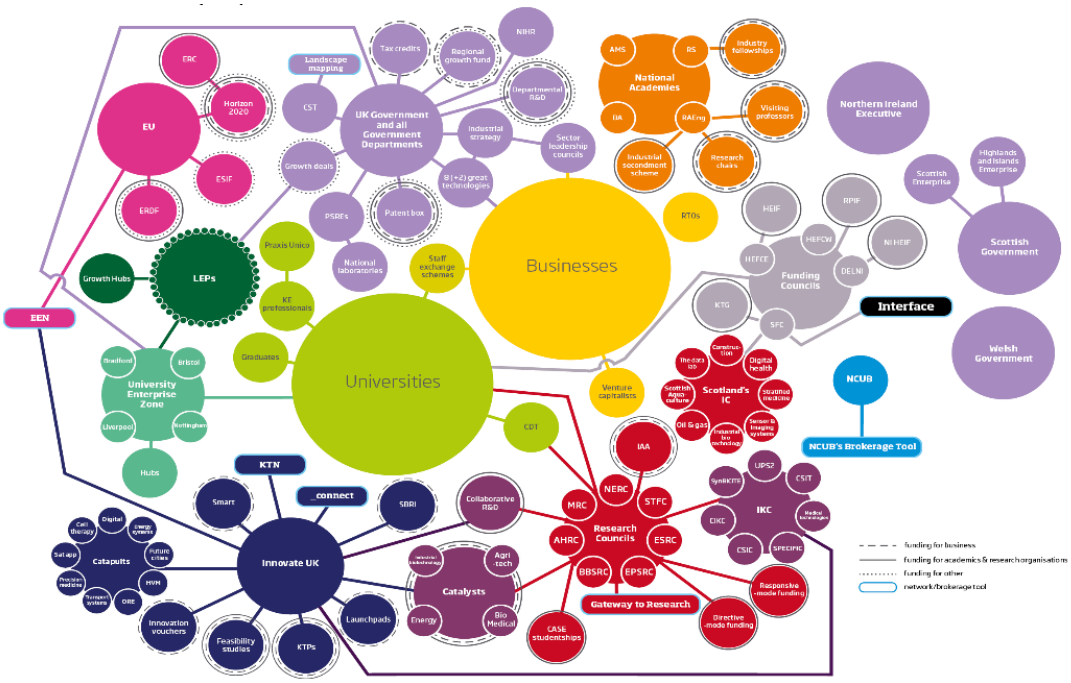

Figure 2. UK innovation landscape (Source: BEIS, 2015)

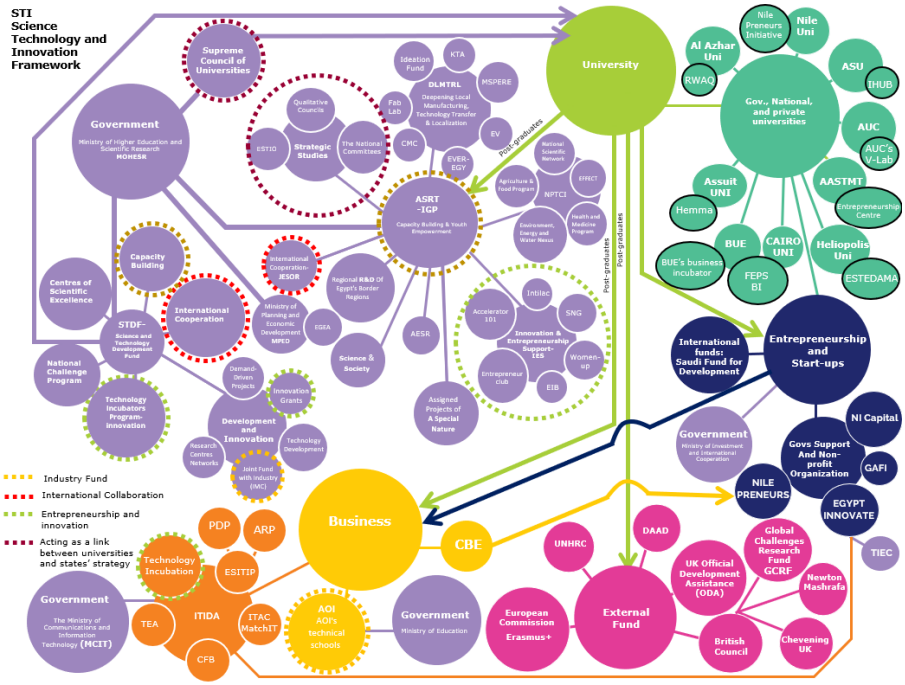

Figure 3. Egypt innovation landscape (Source: Authors)

Egyptian universities are keen to build bridges with the engineering industry. There have been a number of shining examples of successful joint projects. Success has been however limited and heavily relies on personal individual interests and contacts. CRUISE project has provided UK good practices of how to manage and nurture industrial engagement in a more holistic view. Different levels of key accounts need to be identified with clarity of management structure that includes levels of responsibilities and accountability to ensure the sustainability of any industrial collaboration schemes. This would also ensure different levels of engagement that would benefit both universities and the industry including offering opportunities for co-development of course materials and staff development. CRUISE has also made some recommendations on ways to motivate academic staff to prioritise industrial links and collaboration.

Table 2. Comparison between innovation structures in UK and Egypt. (Source: Authors)

Aspect	UK	Egypt
Innovation landscape	Connected and effectiv	Fragmented and less effective
Funding	Funding available	Funding limitations
Visibility	Visible and noticeable	Lack visibility
Organizational Connectivity	Connected	Dotted with broken connections
University Awareness	Fully aware	Aware
Industrial partnerships	Structured and organized	Personal ad-hoc basis
Sustainability	Sustainable	At risk
Incentives	Explicit framework	No explicit framework
Modes of delivery	Flexible	Little flexibility
Curriculum	Sound developed	Well developed
Assessment	Flexible	More effort required

The structure, delivery mechanism, and assessment of engineering curriculum in Egypt have not generally been changed for decades. There have been some welcomed efforts to liberalise modules structures such as the introduction of credit hour framework in several universities. The core of engineering education has however remained unchanged despite the vast technological advances, changes in demands, students' profiles, and nature of contemporary learning methods. CRUISE carefully examined samples of engineering programmes, their structure, contents, delivery mechanism, and assessment methods. The research team investigated, in particular, elements in the examined curriculum related to industrial engagement, knowledge and required industrial skills. While there have been numerous references to industrial input and industrial knowledge, most of these objectives remain theoretical and are limited to efforts to attract guest lectures from the industry and/or limited placement agreements. Almost all the identified, industrial-relevant, intended learning outcomes (ILOs) are not assessed. CRUISE project team has made several recommendations to overcome those challenges.

At the national level, there are numerous efforts to link the university (education and scientific research) and the industry. This is to promote the employability of both fresh graduates and entrepreneurs. Although these efforts may have succeeded in achieving the goals set, these efforts seem like isolated islands. A national-level, comprehensive and integrated regulatory framework that organises these efforts is missing. The absence of this framework might lead to the mismatch of these efforts with the development priorities according to the state's vision, as well as to a lack of clarity in the responsibilities of all the parties involved.

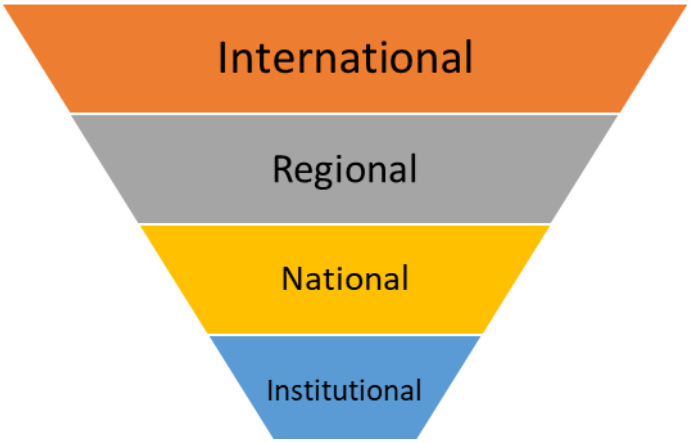

Figure 4. Levels of Government Initiatives Supporting University-Industry Links (Source: Author)

5. Discussion and Conclusions

Egypt boasts considerable potential for fostering research and innovation across various sectors. However, the current research and innovation landscape is fragmented and lacks comprehensive awareness among many staff members. Despite the country's rich pool of talent and resources, there is a need for greater understanding and coordination to harness Egypt's research and innovation capabilities fully. Efforts to consolidate and disseminate knowledge about existing research initiatives and innovation opportunities can significantly enhance collaboration and drive transformative change in the Egyptian research and innovation ecosystem.

5.1. Improved Curriculum Integration: Through stakeholder engagement and collaboration, the project successfully integrated industry-driven content into the curriculum of partner universities. This resulted in modules that better align with industry needs and equip students with practical skills for the workforce, enhancing their employability.

5.2. Enhanced Industry-Academia Collaboration: The project facilitated stronger partnerships between academia and industry, fostering collaboration in curriculum development, research projects, and experiential learning opportunities. This collaboration has the potential to drive innovation and economic growth in Egypt's engineering sector.

5.3. Identification of Skills Gaps: The project identified key skills gaps in the current engineering education system through gap analysis and stakeholder consultations. This insight informed curriculum revisions and provided valuable information for future educational initiatives.

5.4. Positive Student Feedback: These collected during the project indicated a positive reception to the revised curriculum and increased industry engagement. Students reported feeling better prepared for their future careers and appreciated the practical learning experiences provided by the project.

Recommendations for Future Initiatives: Based on the project findings, recommendations were made for ongoing efforts to enhance engineering education in Egypt. These recommendations include continued industry collaboration, ongoing curriculum review, and promoting experiential learning opportunities for students.

The CRUISE project has made substantial strides in enhancing engineering education in Egypt, fostering collaboration between academia and industry, and aligning curricula with industry requirements. Looking ahead, the project's outcomes are poised to continue shaping the future of engineering education,

catalysing innovation, and driving economic growth in Egypt. There are two areas, in our engineering education, that must improve.

First, the expansion of engineering education to respond to the immediate and future needs of the industry in Egypt, the Middle East and North Africa. This would require a genuine closer collaboration to co-create an updated contemporary curriculum with the industry.

Second, we must make better progress in harnessing industrial knowledge as well as the use of cutting-edge digital technology for a step change in the delivery mechanism of the engineering curriculum. We must involve the industry in a more contemporary delivery mechanism that would use digital platforms, reduce reliance solely on university resources, blend working and learning environments, and support our future talented and well-equipped Egyptian engineers.

In conclusion, the CRUISE project successfully improved curriculum integration enhanced industry-academia collaboration, identified skill gaps, received positive student feedback, and provided valuable recommendations for future educational initiatives. The project has laid a foundation for continued progress in engineering education and industry engagement in Egypt.

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

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Morphological Analysis of Public Spaces and Their Contribution to Urban Resilience in Guelma, Algeria

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ABSTRACT

Modern Algerian cities are facing various uncertainties, both natural and human-made. To address these risks, urban areas need to be more adaptable and responsive. The increasing impact of climate change and the recent pandemic have emphasized the importance of outdoor spaces. As people spend a significant amount of time in these areas, public spaces have become essential for urban life. This study conducts a comparative analysis of public spaces, using a grid-based methodology to identify similarities and differences between two resilient public spaces and the square of Guelma. The analysis is preceded by a literature review that establishes key conceptual frameworks. The main objective is to develop recommendations for resilient public spaces and their contribution to a city's environmental resilience, particularly its capacity to withstand climate change. By understanding how these spaces can mitigate the effects of climate change, this research aims to guide the design and management of urban environments.

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1. Introduction

Cities, like living organisms, exhibit dynamic and complex characteristics, undergoing continuous adaptation in terms of scale, social organization, political systems, and technological infrastructure (Sharifi & Yamagata, 2014; Holling, 1985). Although possessing unique urban morphologies, cultural fabric, historical trajectories, and identities, cities globally are confronted with a shared set of challenges, namely rapid urbanization, population growth, and climate change. The resilience concept's wide appeal stems from its adaptability. It can be applied to diverse urban challenges, both climate-driven and not. Deepening our understanding of resilience and how to measure it will be crucial for developing transformative approaches.

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These approaches are essential for cities to contribute to climate stabilization and achieve Sustainable Development Goals, Social cohesion, economic stability, environmental sustainability, infrastructure robustness, and effective governance are all crucial aspects of urban resilience, and each face unique challenges as documented in various studies, the recent surge in interest extends beyond resilience itself, focusing on developing assessment tools. These tools aim to capture the multifaceted nature of resilience and translate it into a clear and actionable framework for both the public and policymakers (Cutter, 2015; Fox-Lent, Bates, & Linkov, 2015). The relationship between resilience and sustainability is a topic of debate. Some argue they share a significant overlap, focusing on the same social, economic, ecological, and spatial dimensions. Others, however, see them as distinct concepts (Zhang & Li, 2018).

Social resilience is the capacity of individuals and social groups to withstand and adapt to stresses and disruptions caused by social, political, and environmental changes (Adger, 2000). More concise and impactful: Economic resilience is the ability of an economy to absorb and bounce back from economic shocks, both internal and external while maintaining its capacity for efficient resource allocation in the long term (Siavash, 2016). Ecological resilience refers to the ability of an ecosystem to adapt and recover from disturbances, even by transitioning to a new and potentially improved stable state (Folke et al., 2004). Emerging as a key concept, spatial resilience focuses on the dynamic interplay between the physical layout and various components of a system, contributing to its overall resilience (Cumming, 2011).

Examining these definitions of resilience highlights its crucial role in cities. Social, economic, built, and natural environments all contribute to urban resilience. Therefore, deepening planners' understanding of resilience and its terminology is essential. This will allow them to use resilience principles into urban conceptions, particularly through the design of resilient public spaces. This definition aligns well with the concept of systems regaining stability after a disruption, mirroring how resilience has been applied in physics. Psychology and psychiatry have adopted this same principle, using it to describe individual resilience (Chelleri & Olazabal, 2012). Philosopher Hannah Arendt viewed public space as the cornerstone of democratic citizenship.

She argued that public spaces serve as a vital sphere for citizens to come together and engage in collective action (Goodsell, 2003; Hansen, 2013). Public spaces and streets are often considered the signature features of a city. Just think of iconic landmarks like Times Square in New York or Piccadilly Circus in London – these spaces instantly conjure up the image of the city they inhabit (Public Spaces for All, UN-Habitat website, 2020). Public spaces, from grand squares and bustling boulevards to peaceful gardens and vibrant playgrounds, are the building blocks of a city's image.

Streets and public spaces form a crucial framework of a city, connecting various areas together. While they may seem like spaces between buildings, they play a vital role in social interaction, commerce, and transportation (Gehl, 2001, as cited in Rupa, 2015). Public spaces are not just amenities; they are essential assets that contribute significantly to a city's economic prosperity, environmental quality, safety, public health, social integration, and connectivity. As a result, residents' quality of life is closely tied to the quantity and quality of these spaces.

A study of the physical features of public spaces can shed light on how they can help cities become more resistant to climate change and other risks. This research is important because it focuses on Guelma, Algeria, a region that is often ignored in academic research. By looking at how the design of public spaces is related to a city's ability to endure challenges, we hope to increase our understanding of this important issue.

2. State of the art

2.1. Risilient urban space

A study by Degros, Knierbein, and Madanipour (2014) highlights the challenges many cities face in managing open spaces as they undergo structural transformations. These challenges are further

amplified by external pressures, whether a slow decline due to factors like demographic shifts or rapid shocks caused by climate change, Public open spaces are confirmed as key contributors to urban resilience, encompassing economic, social, environmental, and spatial aspects. Research by Ruchinskaya (2018) emphasizes that resilient public spaces are crucial for strengthening existing communities and fostering social cohesion, especially during and after crises. These spaces become even more vital in both everyday life and emergencies (Allan & Bryant, 2010, cited in Ruchinskaya, 2018).

Resilient public spaces effectively combine the characteristics of urban resilience with the essential features of well-designed public spaces. Urban spatial resilience focuses on the interconnectedness of a city's natural and built environments, with a emphasis on how activities and spatial arrangements contribute to its overall resilience. As a result, the indicators used the spatial organization of the urban system is a critical factor in assessing urban spatial resilience (Fariba Gharai et al., 2018). Public spaces, through inclusive practices and collective creativity, enhance urban resilience comprehensively (Ruchinskaya, 2018).

Resilient public spaces have gained increasing significance in the transformation of cities. They are no longer considered as leftover spaces, but rather as key focuses in urban development and regeneration. The design and use of public spaces have evolved due to changes in society and the economy, resulting in the need for a new theory and architectural tactics for creating successful temporary public spaces. Public spaces are recognized as essential components of urban environments, promoting social interaction and sustainable development. However, concerns remain regarding the impact of globalization, consumerism, and gentrification on public spaces. The introduction of new technologies has created a duality in public spaces, with digital aspects shaping borders and social interactions. Using digital technologies in urban spaces can transform boundaries and promote new types of social interaction. Traditional public spaces were downgraded in the past, but there is now a growing recognition of their importance in creating healthier and more vibrant cities.

2.2. Urban Morphology: A Foundation for Spatial Resilience

By examining urban morphology, researchers can identify and analyse changes in urban spatial structure and form over time. This necessitates comprehensive, multi-temporal datasets covering entire urban areas. Fortunately, advancements in geospatial technologies have made high-resolution remote sensing data widely available and affordable. To inform urban planning and disaster preparedness, researchers investigating urban recovery from traumatic events (Vale, 2005; Prasad et al., 2009; Clark, 2010) have focused on identifying urban system vulnerabilities. The effects of change can manifest at various spatial scales, ranging from the neighbourhood to the global level (Müller, 2010). Although concentrated at specific scales, these impacts frequently reverberate across multiple levels due to intricate interdependencies.

Müller (2010) emphasizes the difficulty of identifying resilience qualities specific to different scales because of the complex and interconnected nature of urban and regional systems. It is crucial to develop reliable methods for analysing resilience across varying scales. In a related work (2007), Müller highlights four key dimensions of urban life and function. By examining the concept of a resilient urban form and the role of governance, this study seeks to understand how the built environment can be designed and managed to adapt to changing circumstances.

Urban morphology describes the form and development of human settlements, influenced by a combination of factors including urban fabric, natural and human structures, street networks, architectural complexity, building materials, and human behaviour (Sharifah et al., 2013). Urban morphology plays a crucial role in urban resilience. As cities deal with rapid population growth and development pressures, it is vital to focus on sustainable urban growth. Unplanned urban expansion can

result in significant environmental degradation, as seen in the case of Granada. Despite these challenges, the importance of urban morphology in planning is often overlooked (Whitehand, 2004).

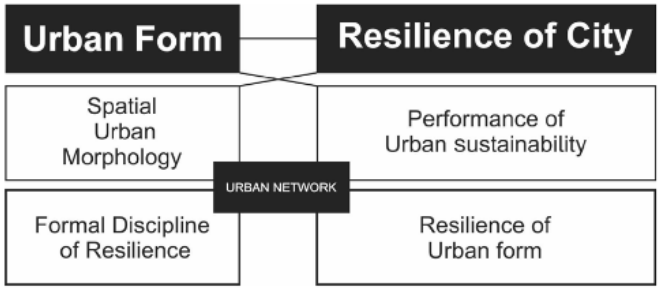

Figure 1. Structure of the study.

3. Methodology

Public spaces' morphology is crucial in enhancing urban environmental resilience. Analysing the structure and design of public spaces within cities aims to understand how these spaces can contribute to mitigating the impacts of climate change and improving overall urban resilience. The importance of urban morphology in shaping cities that are adaptable, sustainable, and capable of responding effectively to environmental challenges. Through methodologies that integrate spatial analysis (Djouad, 2021), urban morphology, and environmental considerations (Djouad, 2021), experts seek to create frameworks that guide the development of public spaces to enhance environmental resilience and reduce the vulnerability of urban areas to various threats (Mretto,2023).

The methodology of this research is based on a comparative approach between a resilient public space and the case of studying that aims to study the morphological effect of public spaces on urban environmental resilience:

A. Morphological Analysis (UM): This involves a detailed study of the physical form and layout of the urban fabric, plot systems, and how they've evolved.
B. Pedestrian Movement Flow Analysis (PMF): This analyzes pedestrian movement patterns within the urban space, considering factors like physical layout.

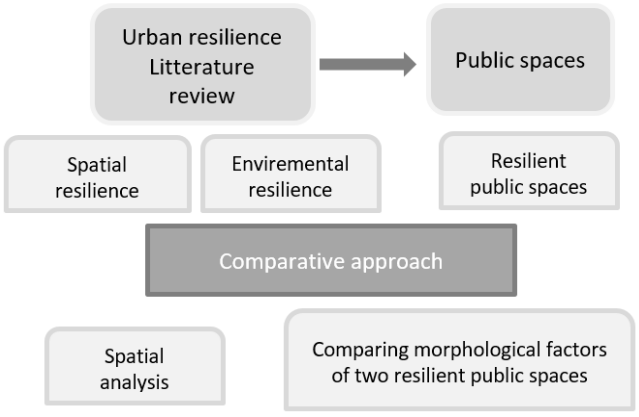

Figure 2. Structure of the study

C. Case of studying:

The square, named the open place of Martyrs "Saint Augustin," is served by four lanes and features a mineral pavement and a kiosk in the centre (fig 02). Over time, it has undergone various changes,

including the addition of a fountain, extension, and a stele. Its prime location in the heart of the colonial centre adds to its significance.

Figure 3. Case of studying open space in Guelma city (Source: Google Earth).

4. Analysis:

The analysis revealed that the resilient public space exhibited distinct morphological characteristics that contributed significantly to its resilience. These characteristics included:

a) Spatial diversity: This means a mix of open green spaces, pedestrian areas, and civic infrastructure, which enhanced the space's adaptability to various activities and user needs.

b) Connectivity: The space was integrated with the surrounding urban fabric through a network of paths and connections, promoting accessibility and facilitating social interaction.

c) Flexibility: The space's design allowed for multiple uses and adaptations over time, ensuring its continued relevance.

d) Resilient materials: Durable and sustainable materials were used to enhance the space's resistance to environmental stressors and reduce maintenance requirements.

5. Results:

Urban morphology delves into the essence of a city by analysing its urban fabric. This fabric, a unique tapestry woven from buildings, streets, and open spaces, reflects the conscious and unconscious design choices that have shaped the physical city, while urban morphology emerged in the 1950s to understand the challenges of modern cities, it's now evident that its true strength lies in its integration with other disciplines and tools. This collaborative approach equips us to better address the evolving needs of society and its citizens.

Table 1. Comparing morphological characteristics. Source: author, 2024.

Studycase/ comparative cases	**Square of martyrs**	**Resilient P S (A)**	**Resilient P S (B)**
			
Shape	Regular	Nearly a regular	Nearly a regular
Urban fabric	Colonial	Ancient	ancient
orientation	North-eastern	Due north	Due north
Surface (m²)	190	225	210
Compactness	slightly compact	Extremely compact	Extremely compact
buildings closeness	slightly	Highly	Highly
Openness /fermeture	slightly	Highly	Highly
Buildings elevation	slightly	slightly	slightly
Buildings height	Colonial	Ancient	Ancient
Existence of nature	Green elements	Bleu elements	Bleu elements
Historical value	slightly	Highly	Highly

Characteristics of a resilient design of a public space encompass various elements that contribute to its ability to withstand challenges and promote sustainability. These characteristics, as indicated in the provided sources, include considerations such as spatial distribution, environmental features, safety measures, inclusivity, and adaptability to community needs. Resilient public spaces are designed to foster community well-being, enhance safety perceptions, and integrate green infrastructure to mitigate environmental risks. Additionally, features like lighting, accessibility, landscape design (Djouad, Spiga, 2010), and maintenance play a crucial role in creating public spaces that are inclusive, safe, and capable of supporting sustainable urban development. The design of resilient public spaces is guided by principles that aim to address the diverse needs of urban communities while promoting environmental resilience and social cohesion.

Table 2. Pedestrian Movement Flow Analysis. Source: author, 2024.

Case of studying/comparative cases	Square of martyrs	Resilient P S (A)	Resilient P S (B)
			

The square of martyrs experiences a distinct pattern of pedestrian movement throughout the day. A dominant flow (A1) enters the public area from the west side in the morning and heads towards the centre. Another significant flow (A2) reaches the northern edge of Guelma's urban fabric.

6. Discussion:

The concept of a "resilient morphology" applied to a square specifically might not be a perfect fit. Resilience is typically used for a system or an entity that can adapt and recover from disturbances. A square itself, being a geometric form, would not inherently possess the characteristics of resilience.

However, we can discuss how the design of a square or plaza can contribute to the overall resilience of an urban area. Here are some ways a square can be designed with resilience in mind:

a) Multifunctionality: The Square can be designed to accommodate a variety of activities, such as markets, gatherings, or even temporary shelters during emergencies. This allows the space to adapt to different needs over time.

b) Connectivity: The Square can be a key element in the pedestrian network, connecting different parts of the city and encouraging walking and cycling. This can be important during emergencies when car traffic might be disrupted.

c) Environmental design: The Square can be designed to reduce the impact of climate change, such as incorporating green spaces for shade and rainwater management or using materials that reflect heat.

d) Social cohesion: The Square can be designed to be a welcoming and inclusive space that fosters a sense of community. This can be important for social support and recovery after disasters.

Pedestrian flows can significantly affect a city's environmental resilience in several ways:

a) Mitigating Urban Heat Island Effect: Higher pedestrian traffic can encourage the creation of shade through street trees and awnings. Shade reduces heat absorption by pavement and buildings, lowering overall ambient temperatures. Increased pedestrian activity can lead to a reduction in car traffic, thereby decreasing heat generated by vehicle emissions.

b) Promoting Sustainable Transportation: Dense pedestrian networks encourage walking and cycling, reducing reliance on private vehicles and their associated greenhouse gas emissions. Improved pedestrian infrastructure like dedicated lanes and safe crossings incentivize walking and cycling, contributing to cleaner air.

c) Enhancing Urban Microclimates: Pedestrian activity can generate a slight cooling effect through body heat dissipation, although this impact is minimal compared to other factors. Well-designed pedestrian zones often incorporate water features, green spaces, and permeable surfaces. These elements can help regulate temperature, manage stormwater runoff, and improve air quality.

d) Social Resilience and Community Building: Vibrant pedestrian areas foster a sense of community and ownership. This can lead to increased social interaction and collective action on environmental issues. Active public spaces encourage residents to spend time outdoors and connect with their surroundings, fostering a sense of stewardship for the environment. Here are some additional points to consider:

e) Pedestrian flow density: While a certain level of pedestrian activity is beneficial, excessively crowded spaces can negate some of the environmental advantages. Striking a balance is crucial. Mixed-use development: Integrating residential, commercial, and recreational areas within walking distance promotes pedestrian activity and reduces reliance on cars.

f) Walkability and connectivity: A well-connected pedestrian network with safe and accessible routes encourage walking and cycling.

7. Limit of research:

The availability of comprehensive data on public space characteristics, usage patterns, and climate-related impacts was limited, which could affect the depth of analysis. The accuracy and reliability of data sources, particularly historical data, could potentially influence the research outcomes. Comparing only two resilient public spaces might not provide a sufficiently broad range of case studies to draw robust conclusions. This approach might overlook certain qualitative aspects of public space morphology that could be relevant to resilience. The study primarily focuses on environmental resilience, potentially neglecting other dimensions of urban resilience such as social, economic, and institutional resilience.

8. Conclusion

This research underscores the critical role of public space morphology in enhancing urban resilience, particularly in the face of climate change. By conducting a comparative analysis of public spaces, this study has demonstrated that specific morphological characteristics, such as spatial diversity, connectivity, flexibility, and the use of resilient materials, are essential for creating resilient urban environments.

The findings highlight the need for a reorientation of public space design and planning practices to prioritize resilience. By incorporating these morphological principles, cities can significantly improve their capacity to adapt to and recover from various shocks and stresses.

However, it is essential to acknowledge the limitations of this study, including its geographical focus and potential data constraints. Further research is needed to explore the generalizability of these findings to different urban contexts and to delve deeper into the complex interplay between public space morphology and other dimensions of urban resilience.

Ultimately, this research contributes to a growing body of knowledge on the importance of public spaces in building resilient cities. By understanding the critical role of morphology, policymakers and urban planners can develop strategies to create more sustainable, equitable, and resilient urban environments for future generations.

As an environmental infrastructure, it allows solving the problems of wastewater and nitrified water through ecological systems, covering small peri-urban sectors, where low density makes the

implementation of traditional sanitation networks very expensive. On the other hand, the incorporation of solutions based on nature allows the creation of lagoons for water treatment with less impact on historical agricultural landscapes. Future research should analyse the validity of the model in other agricultural settings subject to environmental impacts.

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Hermeneutic Cartography for the Restitution of a Lost Antique Seaport: Case of Muslubium Horrea of Bejaia, Algeria

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ABSTRACT

This article deals with the reconstruction of an ancient seaport in the town of Bejaia, known as Muslubium Horrea. This settlement, ignored by the official historiography, would nevertheless have played an important role in wheat exports and trade with the Roman port of Ostia. Moreover, of all the ancient ports known to date, the Algerian coast has only two port warehouses, and Muslubium Horrea is the only granary belonging to the Roman province of Mauretania Sitifensis (400AD). The methodology adopted to locate and reconstruct the topography and the settlement's structures is based on the concept of cartographic hermeneutics. The compilation of existing historical accounts and the interpretation derived from the superimposition of ancient geographical maps and 19th century archaeological and geological maps identified all the natural resources necessary for its construction, in particular the abundance of water sources and deposits of geomaterials for construction (clay, stone, gypse, marble, etc.). These data were confirmed by field and photogrammetric surveys, resulting in a map showing the archaeological context of the Muslubium Horrea port and the remains of structures still visible today. The approach adopted allowed to delineate the size of the port site and scale the structures that make it up, as well as identify the water supply source and its primitive topography prior to its establishment.

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1. Introduction

Nearly 6,000 ancient coastal settlements have been identified worldwide to date (De Graauw, 2022). The archaeology of Mediterranean ports has changed significantly over the last thirty years, since the discovery of several archaeological excavations (Morhange, 2014:12), including the antique ports of Narbonne, Marseille and Egypt. However, the exact location of some abandoned ports often remains unknown, due to the complete transformation of the environment caused by the large deposits of ancient alluvium and/or the erection of buildings on the sites. However, a great deal of scientific work is still being carried out to date on the location of former ports that have disappeared.

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A number of authors have attempted to define criteria for locating antique ports (Mauro, 2019). Some authors have applied geomorphological criteria (topography, sediments, bays and coastline). This is the case, for example, of the underwater discoveries and the location of the port of Missua (Sidi Daoud) in Tunisia, which was carried out through geo-archaeological and paleo-environmental research, (Trabelsi, 2019: 2). The combined studies of coring, high-resolution sedimentary studies as well as archaeological prospecting have identified several port basins comprising the port of Missua. Research into the identification of the ancient topography of Narbonne's ports, through which the geomorphological conditions and layout of the ancient settlement were determined using geotechnical drilling, archaeological documents and underwater excavations (Ambert, 2000: 295). Nautical aspects, in particular navigation, ships and the flow of goods, have received little attention in the literature (De Graauw, 2022). With the exception of a cartography locating the antique ports used as relays for the various commercial exchanges in the Mediterranean, based on the analysis of historical documents through which the itineraries as well as the speed of the routes, the flows and the navigation seasons were reconstructed (Arnaud, 2005).

This article relates to the rediscovery of an ancient port in the town of Bejaia in Algeria. This port settlement mentioned as Muslubio Horrea or Muslubium in ancient maps and located on 19th-century archaeological maps. This port was considered a granary that played an important role in trade with the port of Ostia (Rome) during antiquity and was very active during the Severan era (Gallico, 2020:100). The port of Muslubium dates back to a period yet to be defined (antique or earlier).

The rediscovery of this site in 2022 is the fortuitous and fortunate result of research devoted to the reconstruction of Bejaia's port landscapes. An exploration of the entire northern zone of the Babors (study area from Aokas to Melbou) led to the identification of archaeological ruins and the discovery of artefacts on the Andriach plateau (French name). This site is presumed to be the site of the Muslubium settlement, which had not been found since it was published by A. Poulle during his exploration of the area in 1858.

The aim of the research work undergone is to geolocate the port and all its structures, to reconstruct its primitive topography, and also to estimate its approximate size by incorporating evidence of daily life, in particular the artefacts found on site.

A number of hypotheses have been put forward concerning the Muslubium settlement, including that it was made up of several entities (such as the port, the granaries, a village and ceramic manufacturing workshops), and equipped with important hydraulic systems for supplying water to the entire settlement and for irrigating the surrounding land. The potential of the topographical site, in terms of its geographical location, geological nature, and the existence of mineral and plant resources within a radius of less than 10 km, suggest that these vital potentialities contributed to the choice of the Muslubium Horrea facility.

To locate Muslubium and recreate its topography, urban layout and architecture, geo-referenced locators and modern surveying methods (drone) were exploited, in conjunction with in situ archaeological excavations, exhumation of the remains of structures and their constituent materials and artifacts. The results were then analyzed and hermeneutically validated.

1.1. The lost antique seaport of Muslubium Horrea

The site, buried under ancient deposits of alluvium and sand, on which a few modern buildings have been erected, and of which very few structures remain visible today, is unfortunately unknown in the historiography of the town of Bejaia. As a statement, this site is not part of any conservation operation. It is true that for more than 1,500 years, apart from the antique maps showing the granaries of Muslubio (Musluvium, Muslubium Horrea), no document mentioned this site, either in writing or on maps. It was not until the 18th and 19th centuries that archaeologists were able to identify its existence on maps.

However, the site was not covered by the extensive archaeological exploration work carried out as part of the 1911 Archaeological Atlas of Algeria (Stéphane Gsell, 1911). Various results of scientific investigations relating to a few rare sources and revealing the approximate location of the port as well as the identification on a map of its existing structures were published during the French colonial period.

It is important to point out that exploration of this area was very superficial and that no topographical representations or archaeological excavations were undertaken during the French colonial period (De Mannert 1849. Poulle, 1858). To date, this immense port settlement covering more than 800 hectares unfortunately remains Terra incognita and deserves to be rescued from oblivion.

2. Study area and methodology

The study area corresponds to the site of the port establishment from the plateau known as Andriach or Sidi Rehane, and its entire extent as far south as the Kefrida pass, covering an area of 800 ha. The area is located in the commune of Aokas, 25 km east of the capital of the wilaya (department) of Bejaia. The aim of this research is to study all the discoveries made in this area in terms of structures, materials, fragments, etc. The methodology adopted in this research consists of an on-site investigation based on the study of archaeological remains still visible or discovered by exhumation and their photogrammetric recording. This in situ investigation is combined with a hermeneutical approach to support the results obtained by interpreting the contents of ancient maps and accounts. In order to locate and reconstruct the remaining visible architectural structures of the port, as well as to restore its initial topography, two studies were carried out and their results cross-referenced. The first study involved exhuming and surveying the site using aerial photogrammetry (using a drone) (Figure 1).

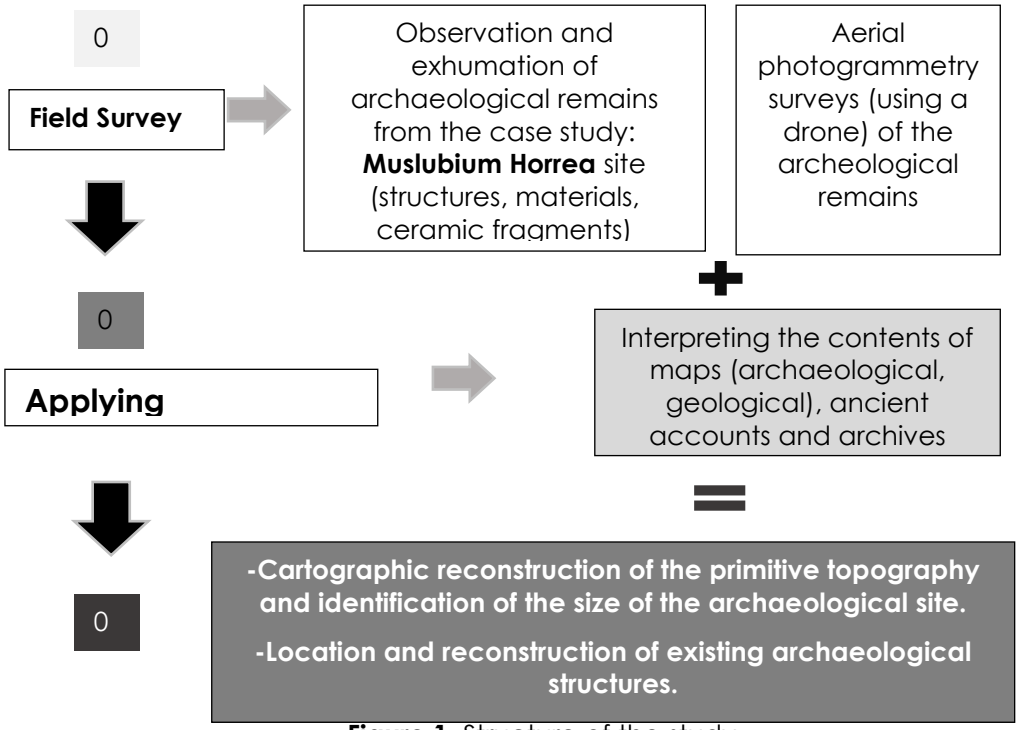

Figure 1. Structure of the study

Photogrammetry is a sophisticated means of safeguarding and transmitting the real and material values of sites of historical importance. It is the art and science of deriving highly accurate metric and descriptive information about three-dimensional objects from a number of analogue and digital images (AL-Ruzouq, 2012: 97).

The aerial photogrammetry was developed from various shots taken in 1960 by a French aircraft equipped with an RMK 30 reference camera at a scale of 1:25,000 (acquisition of ortho-photos by INCT, 2023). More recent images were captured by a drone overflown in May 2024 at two different heights, 64 m and -24 m (measured from my own position, towards the bottom of the pass of Kefrida ravine, giving a level of 667m above sea level.), in full HD 1080/1920. The both old and recent images were employed to analyze the current topography and compare it with the old images, as well as to measure the visible archaeological structures. This method was applied to provide precise metric information for mapping and locating all the archaeological finds.

Verification of the Muslubium's location and determination of the original topography of the natural landscape is achieved by hermeneutics. As a reminder, hermeneutics is the science concerned with the correct explanation of texts, firstly the Bible, then other texts and works of art (Palavestra 2011). It would be the method of understanding the contents of ancient documents such as texts and images and giving them the possibility of speaking and revealing the meanings that would interpret invisible experiences. For Heidegger, this possibility of speaking is given only to the person who advances to meet them, in search not of the thought they contain but of the vital experience they make possibl' (Zarader 1990: 23), in other words to the interpreter who undertakes to apply them. Hermeneutics is an approach used to understand the different layers that make up historical landscapes that are bound to evolve, by interpreting the tangible elements visible through time (Redzinska et al., 2022). The desire to understand the different layers of a historic landscape therefore means understanding the imaginary of that landscape, which is already 'discursible' (Corboz, 2009: 74). Interpretation in archaeology is always hermeneutic; in archaeological interpretation, what people thought in the past from the present is assumed to be the appropriate context (Johnsen et al., 1992: 432).

This understanding can be apprehended through three dimensions, which are architectural, scriptural or pictorial [...]. To these three dimensions is added an abstract part, a signifier of sorts (Morisset, 2011: 45), which is what was applied here in the hermeneutic analysis through the interpretation of architectural remains, texts and maps.

Hermeneutics was applied by targeting literary and cartographic sources, as well as French archives whose contents would reveal information of a descriptive or typological nature, with regard to the location of the structures of the Muslubium Horrea settlement, and the topography of the site, which would provide verification in support of the two sources retained in this research, in particular the works of Stephane Gsell (1919) and Jean Pierre Laporte (2017).

It should be noted that, in addition to the two main sources selected for this research, this approach was also based on an exhaustive literary compilation of all the sources relevant to the research problem, and a targeted cartography. A literary corpus was compiled, consisting of nine memoirs and collections by scientific explorers dating from the period between the 18th and 19th centuries. For the cartographic corpus, three antique maps (Table de Peutinger, Anonymous map of Ravenna and antique maps from Samuel Butler's Atlas 1902), a dozen maps drawn up by French explorers, an archaeological map by S. Gsell's archaeological map of Bougie (1919) (Sheet No. 07) at 1:200,000, the geological map of Ziama No. 48 of 1925 at 1:50,000, the fieldwork for which was carried out by Dussert and Brives of Algeria's geology department. And the acquisition of aerial photographs of the Aokas area dating from 1960 from the Institut National de Cartographie et de Télédétection (INCT) of Algiers.

3. Results

3.1. Geographical data

3.1.1. The settlement of Muslubium Horrea on maps

On the Peutinger Table (Tabula Peutingeriana), a 13th-century copy of a Roman map of the entire Roman Empire, Muslubio Horreta (Figure 2) is shown to the right of the colony of Saldae (or Saldas Colonia, the antique name given to Bejaia). On the map of northern Roman Africa in Samuel Butler's 1902 atlas, Muslubium (Horrea) is geographically positioned at latitude 36 50 N and longitude 4 30 E (Butler, 1902), (Figure 3). Between Choba Municipium (now Ziama Mansouria) and Saldae, the ancients also mentioned a station that Antonin's Itinerary calls Muslubio Horreis (Henri Fournel, 1850). The Peutinger Table describes it as Horreta, but it should have read Horrea, a word designating a grain shop, and there was no information on this place (Duesberg, 1842). The location of Andrianch (Muslubium Horrea) in relation to Bejaia (formerly Bougie) is at most 30 kilometres and there are 13 or 14 kilometres from the latter point to Ziama (i.e. approximately 44 kilometres from the first of these localities to the last, which represents 29 or 30 miles, i.e. about half the distance marked by the roads) (Poulle, 1858).

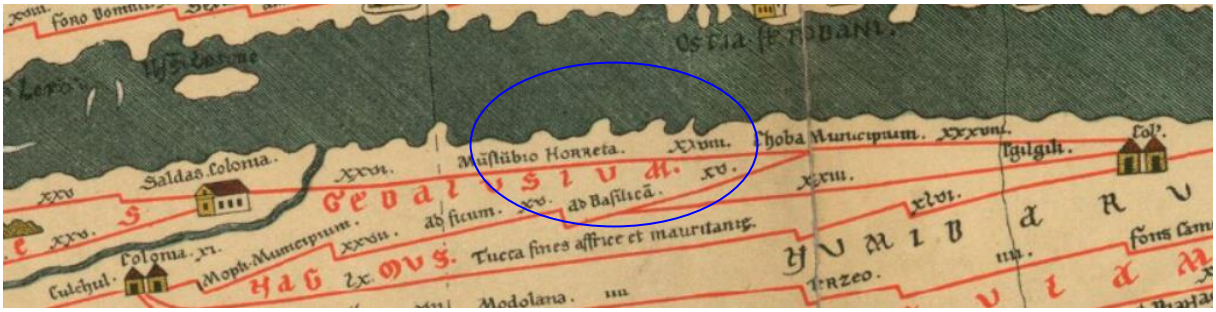

Figure 2. Muslubio Horreta next to Saldas Colonia, inscription on the Peutinger table. Konrad Miller's 1887 facsimile (Otto Maier (Ravensburg, 1888) available online at Gallica: http://catalogue.bnf.fr/ark:/12148/cb4

In a geographical, administrative, postal, statistical and archaeological dictionary published in 1869, the authors place the considerable ruins of Antonin's Muslubium 4 km from Mansouria (J. Adolphe et al., 1869). On the map of the cartographer Guillaume De Lisle in 1726, the Anonymous of Ravenna places Muslubium and Horrea between Choba (Ziama) and Saldae (Bejaia). He places the granary and port of the Roman village Muslubium, which was a Municipium on the same level as Choba, at an equal distance from Choba to Horrea and from Horrea to Muslubium (Figure 4).

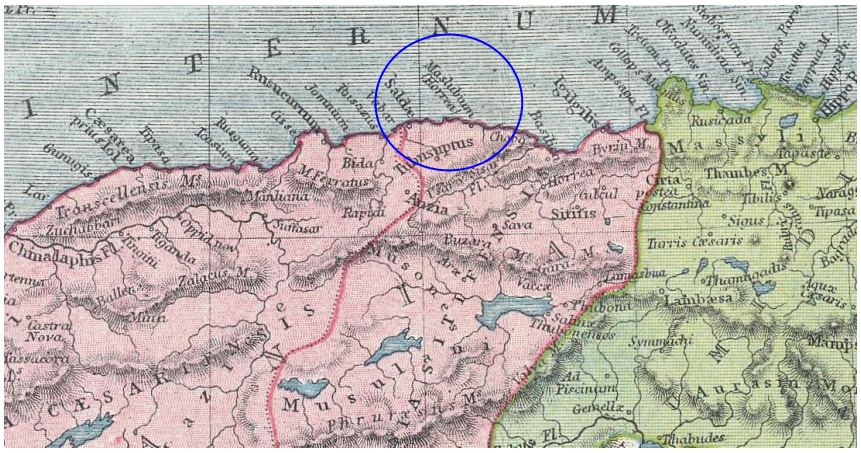

Figure 3. Muslubium Horrea on the map of northern Roman Africa in Samuel Butler's 1908 atlas. Available online at Gallica: http://catalogue.bnf.fr/ark:/12148

The main source for locating Muslubium Horrea is the map on sheet 07 of the archaeological atlas by Stéphane Gsell (1911), a French archaeologist and historian specializing in Roman Africa. He explored the entire area and produced a 1:200,000 map (Figure 5) on which numbers indicate antique ruins all along the northern slopes of the Babors near Cap Aokas. The map shows that from number 57 to 63 lies the entire length of the antique port of Muslubium, from the port to the water source tapped by the founders and known as 'Aqua Frigida'. On his map, Gsell indicates the position of Muslubium in an uncertain manner, since it is accompanied by a question mark.

Figure 4. Muslubion Horrea or (Musluviom Orea) on the anonymous map of Ravenna reproduced by cartographer Guillaume De Lisle in 1726. Available online at Gallica: https://gallica.bnf.fr/ark:/12148/btv1b52519327v/f17.

In the work of Jean Pierre La Porte in 2017, Muslubium is located 25 km west of Bejaia (Bougie), and 3 km south-east of Cap Aokas. This location supports S. Gsell's hypothesis, as well as the superimposition of the three names given to the site in antiquity, during the colonial era and today: Musluvium, Andriach and Sidi Rehane. The port is thought to have been silted up by alluvial deposits carried by the Agrioune (to the east) and Oued Soummam (to the west) rivers on either side of the site (La Porte, 2017: 25), which have been deposited since ancient times, detaching the promontory from the sea in a tongue of sand 600 m wide and more than 10 km long (Khelifa, 2006: 418).

In Stone's (2014) location of the various ports with man-made harbour structures in North Africa, Muslubium is in 'C' (Figure 6). According to S. Trabelsi, Muslubium could be classified in the group of

medium-sized ports, which does not correspond to the merchant ports Stone (2014) and S. Trabelsi (2019). However, the export function attributed to Muslubium, with reference to the mosaic in Ostia's Piazza di Corporazione, classifies the port of Muslubium as one of the large merchant ports.

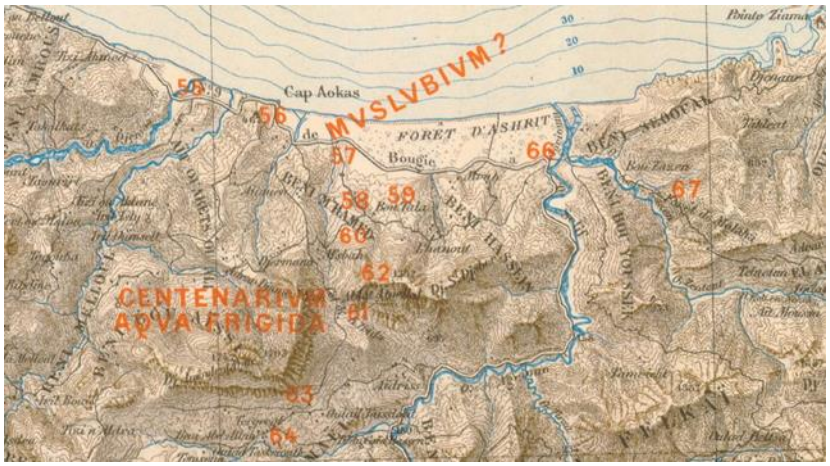

Figure 5. Uncertain location of the Muslubium on S. Gsell's archaeological map (Sheet no. 07. The Archaeological Atlas of Algeria, 1911).

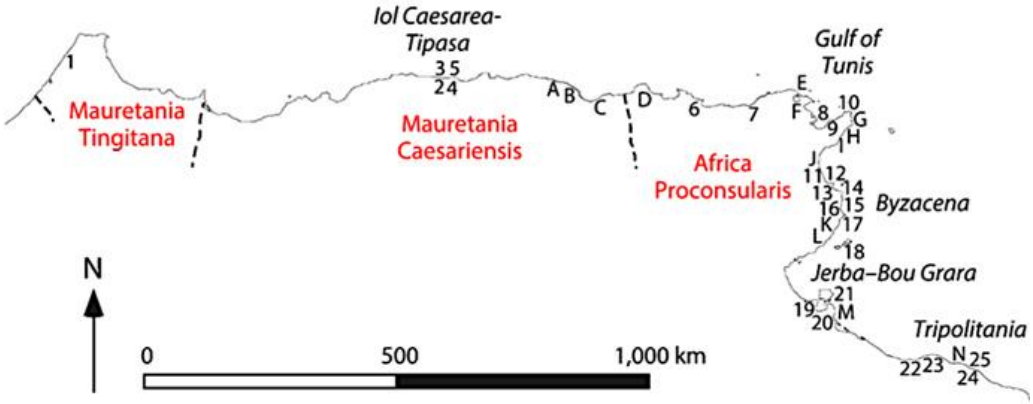

Figure 6. Muslubium from the location of different ports with artificial harbour structures in North Africa (C). (Stone, 2014: 573)

3.1.2. Communication with the port of Ostia

The term Horrea refers to a storehouse or granary for storing wheat, and the port, which was very active in antiquity, had to export goods (wheat, wine, oil) from the inland plains, particularly Ain Roua, hence the name 'Horrea' (La Porte, 2017: 26). Some of the foodstuffs brought into the country's granaries and shops in this way was intended for the upkeep of the troops of the occupying corps; another part was distributed to civil servants as remuneration and for the upkeep of their staff in proportion to their rank, and finally the largest part was sent to Rome, to Ostia in particular (Marcus, 1842).

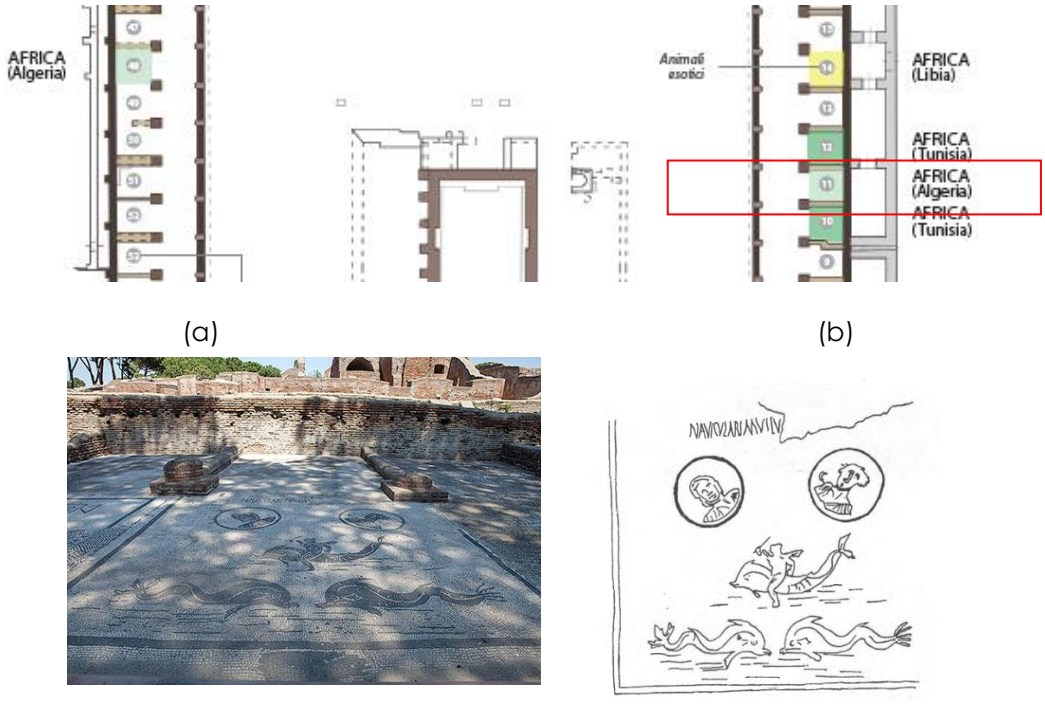

Figure 7. Guild square in the port of Ostia (a), station no. 11 for Muslubium. Mosaic of station no. 11 (c). and drawing by J. P. La Porte (2017) (d) Source: Roman ports, 2016. https://www.romanports.org/fr/les-ports/298-musluvium-algeria.html

According to the geographical database of ancient ports compiled by De Graauw in 2014, there are no fewer than 74 ancient ports in northern Algeria, including those modern or identified from a nautical point of view mentioned in ancient writings (De Graauw et al., 2014). Muslubium is identified on the aforementioned database under the number 4219 with geographical coordinates 36.62985° N and 5.26162°E. However, as a warehouse port, there are only two on the Algerian coast, namely Musluvium and M[auretania] C[aesariensis] (Gallico, 2020:100).

In terms of its commercial function, Muslubium was considered as being a real merchant port and a facility with a significant Mediterranean influence compared with other ports, since exports were made to Ostia. In fact, in Ostia, nine out of thirty-one agencies in the guild square were African (Romanelli 1960), and two were Algerian. This is evidenced by a mosaic laid in the Piazza dei Corporatori at no. 11 around 200 AD, the presumed office of the Muslubium shippers in Ostia, on which Muslubium naviculars were depicted, adorned with two medallions, each with a bust of a lover riding a dolphin, and two other dolphins (La Porte, 2017: 26) (Figure 7).

3.1.3. Communication roads

Despite the location of Saldae (Bejaia), the Romans, in accordance with their traditions, endeavoured to open up the site as much as possible by tracing routes to Roman cities (Comolli, 1997: 98). During the colonial period, five communication routes were recorded linking Saldae to inland and coastal towns in Setifian and Caesarian Mauritania. However, the two main routes linking the port of Saldae to two other ports Tubusuptu (river port: Laporte, 2017) and Muslubium (maritime port), both located at a distance of 25 km (Figure 8), Tubusuptu to the south and Muslubium to the east, will be retained.

Figure 8. Commercial route from Muslubium (Andriach, Sidi Rehane) to ad Horrea (Ain Roua, Setif) during Antiquity. On a map of Roman roads ; (Dépôt de la guerre. Function undetermined (France) 1843. Essay on Algeria during the Roman Domination.

These two stations were linked to inland towns for the supply of merchant goods from the starting point called Horrea (Ain Roua) located on the high plateau of present-day Setif and renowned for the quality of its seeds and a fish-based sauce (La Porte, 2017), including:

- Coastal route to the east: linking Saldae and Igilgili (Jijel) via Muslubium,
- Route to the south - east Sitifis (Sétif): Muslubium is linked to the Roman cities to the east by the route that passes through: Centenarium Aqua Frigida- Ad Olivam - Ad Lesbi and Ad horrea (Ain Roua). All these routes were dotted with military posts, which were judiciously placed (Comolli, 1997).

From Muslubium onwards, five posts were recorded on the road to Horrea, stretching as far as the Kefrida pass. Four posts at intervals of 1,000 m but at different altitudes in 58, 60, 61, 62.S. (Gsell, 1919). In addition to these four posts, the 1:50,000 map (Figure 9) identifies an R.R. (Roman Ruins) between 58 and 60 at a distance of 1,000 m from the two points. In terms of altitude, the five points are located at the following altitudes: pt. 58 on120m, pt. R.R on 230 m, pt. 60 on 500 m, pt.61 on 787 m, and pt. 62 on 1364 m.

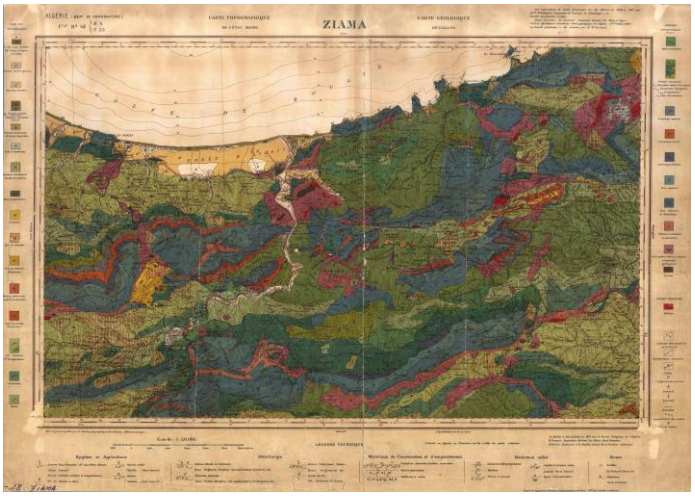

Figure 9. Detailed geological map of Ziama No. 48 of 1925 (1:50,000). Fieldwork carried out by Dussert and Brives of Algeria's geology department. Map acquired from the Bejaia hydraulic services, 2023.

3.2. Ancient geomorphology and topographic reconstruction

The ancient configuration of the coastline is characterised by a crescent-shaped cove facing east and southeast and a high, prominent promontory providing a relatively well-sheltered anchorage from the prevailing northerly winds. As the seawater beat against the rocks at the foot of the promontory, the cove was shallow, less than 7 m deep according to the contour line. On the 1:50000 geological map of 1925, the legend indicates recent alluvial deposits. The mention R.R (Roman ruins) on this map and the mention 59 on the Gsell map indicate a port infrastructure 800 m east north east of Bou Tala, which today indicates the position of 36.622707° N and 5.265324° E, on a height of 6 m above sea level. This structure, described as an antique castle on the plain, represents a port infrastructure given its position. Nearby, there is a 150m long and 70m wide hill reservoir (the result of digging by farmers, who now use the water for watering and irrigation). This reservoir could refer to the existence of a Roman pond or fishpond. Could this antique castle on the quayside be the lighthouse of the port of Muslubium?

According to the 1:50 000 geological map, the Andriach plateau is made up of Valanginian Hauterivian in the north and east, marine deposits in the west and ancient deposits in the south. This spur rises to a height of 50 m in the north, before widening and rising towards the south to an altitude of 57 m above sea level. The rocky spur, which is made up of a single layer of Cretaceous limestone, can be used for construction purposes, according to the data on the 1:50,000 geological map, which is made up of siliceous schist and marl-limestone that are very hard and break up into large slabs, slabs and platelets. Data collected in the field revealed that at the foot of the plateau, evidence of stone extraction, grooves and blocks squared off in tiers are now visible on the northern part of the rock (Table 1).

Table 1. Data collection.

Topography	*Ancient geomorphological description as described in texts*	*Field illustration*
The Andriach plateau (Sidi Rehane, Muslubium)	1-The rocky spur widens as it rises, forming a small plateau known as Andriach. 2-A knoll that forms the last ring of foothills descending from the Babors range. 3- A clump of centuries-old aspen trees at the foot of the mound. 4- At the foot of a high cape on the edge of the sea (1869 by J Adolphe). 5- In Antiquity, the sea beat against the foot of the mountain.	 Evidence of stone quarrying on the northern part of the rocky spur.
Port plain	-The bay was covered by the prevailing winds -The waters of the sea beat against the foot of the mountain.	 Freshwater reservoir to the east of the rocky outcrop

Apart from the rocky, ancient part, the ancient marine deposits are thought to be fill brought in by the founders of Muslubium to raise the level of the rock so that they could build on it. for this reason, a remainder of this article, the term retaining wall is used, alternating schistose boulders, instead of enclosure wall. The composition of the wall blocks confirms this hypothesis. The morphology of the

plateau was transformed at the time of the first settlement by the raising of the southern part by around 7 m of marine sand fill (see profile in Figure 10).

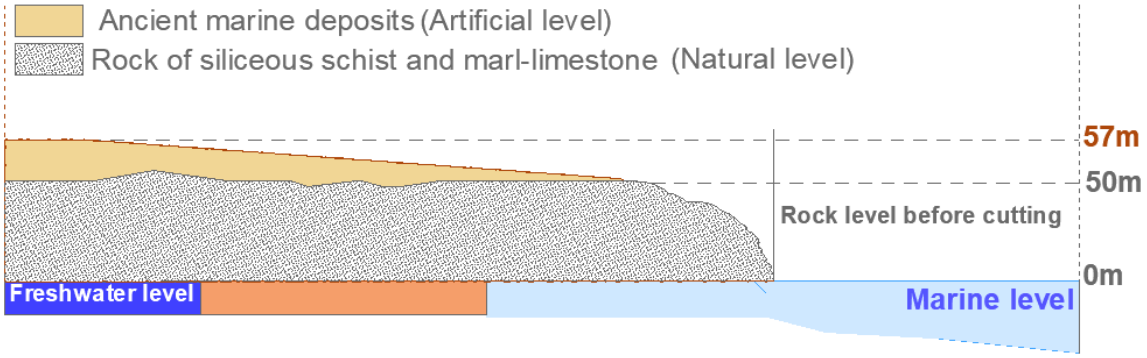

Figure 10. Restitution of the original topography before the Muslubium was built.

3.3. Graphic restitution of the urban extent of the Muslubium port settlement

Given the vast extent of the port settlement, the site has been divided into two areas according to the proximity of the visible structures found on site:

Site 01: this area includes the Andriach plateau, where surviving retaining walls, the ashlar field and fragments of solid brick retaining walls were found. The area is strewn with ceramic debris, amphorae, crockery, tiles, bricks and mosaic shards.

Site 02: checkpoints, aqueducts, Aqua Frigida spring and the Centenarium. This area represents the water supply site from the Aqua Frigida spring, as well as the checkpoints (forts and posts) for the roads leading to Horrea and Sitifis. As well as the aqueduct served to supply Muslubium. Figure 11 shows the profile of the two sites 01 and 02, covering an area of 800ha, with their altitudes.

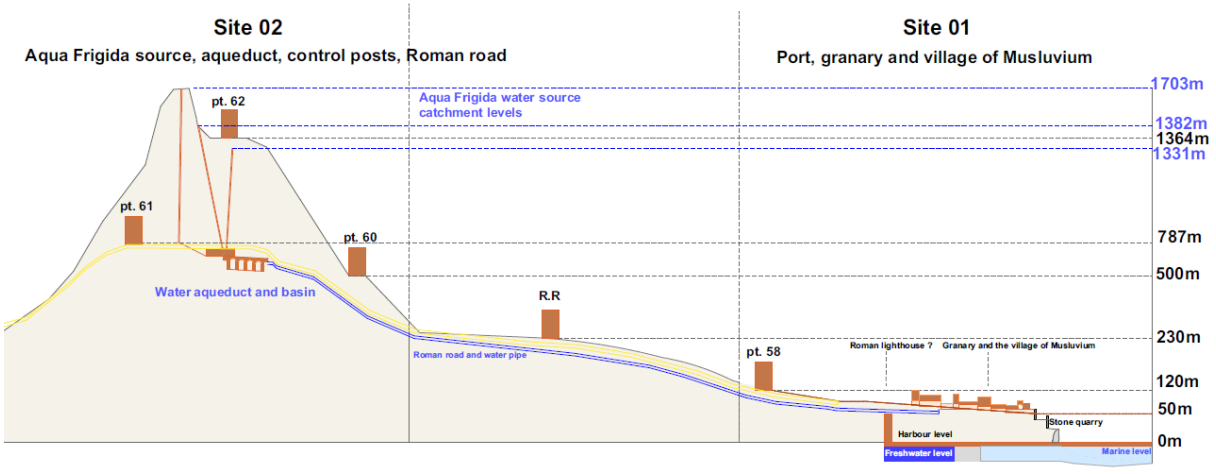

Figure 11. Extent of sites 01 and 02 on longitudinal profile with elevations

3.3.1. Site 01: Infrastructure, land use and activities

From all the texts analysed, the landscape structures making up the port settlement of Muslubium could be identified by recording the different names that could be given to each infrastructure, their function

and their geographical location. The map above shows the extent of the settlement as described in the texts and on the archaeological maps. Figure 12 shows a bird's-eye view of the extent of Site 01.

On a recent nautical map produced by SASPlanet (Geospatial Tool version 2019), a Russian program designed to view and download high-resolution satellite images (downloadable free of charge from the internet), this map shows an underwater bathymetric survey, and in the area of site 01 a submerged structure extending from the port can be seen. Could this be one of the artificial quays in the port of Muslubium?

Figure 12. Site 01, partial view of the Sidi Rehane (Andriach) site (taken from the northeast by drone at an altitude of 100 m).

Table 2 summarises the descriptions of all the architectural and urban structures found on site, as well as their hypothetical functions according to the texts of various authors (Fournel, 1850), (Poulle, 1858), (Bugnot, 1867), (Adolphe, 1869), (Gsell, 1919), (La Porte, 2017).

Table 2. Collected descriptions in texts

Infrastructure	*Land use*	*Activity*
-The ruins of an antique population center -The most important antique center between Choba and Saldae -Station - Large enough for a small village and the Administration's granaries -Roman village No. 57 on the map by S. Gsell.	Plateau of Andriach.	Village and attic (living and storage)
Port No. 58 on the S. Gsell map	On the plain below.	Sea transport of wheat to Ostia in Italy.
-Rampart	The perimeter of the	Supporting the

-Enclosure No. 57 on the map by S. Gsell	Andriach plateau follows the sinuosities of the plateau.	embankments of the rocky outcrop.
Antique castles in ruins. N° 58, 59, 60 on the map by S. Gsell	On the eastern plain and in the Kefrida mountains: one on Ablat Amelal at an altitude of 1,364 m, the other below on Mesbah at an altitude of 787 m.	-A lighthouse? Protection posts on the Kefrida pass road.
Horrea, *ksar* or granary, old fort N° 57 on the map by S. Gsell	High up on the set	Granary for storage
Roman road From 57 to 61 on the map by S. Gsell	From here, an ancient Roman road leads to Setif, which runs along the right bank of the Oued Sidi-Réhane and climbs straight up to the south with this stream, which it crosses at its source at the Col de Kefrida.	Muslubium communicates with Ain Roua (Horrea) and Setif (Sitifis).

As a first result, a map was produced by combining field data with hermeneutic data, showing the position of all the structures identified and their functions on site 01 (Figure 13).

3.3.2. Nature of the ramparts

In the texts compiled, the authors speak of ramparts that follow the sinuosities of the plateau (Figure 14). Surprised by the state of preservation of a large part of the ramparts in 1858 (Fournel, 1850 and Poulle, 1858), they give a brief typological description of the wall, in particular: 'built of blockwork alternating with ashlar chains. Surveys carried out on site 01 in 2023 and 2024 uncovered fragments of walls made of alternating ashlar blockwork that were still homogeneous on the northern slope. This technique, known as Opus Africanum, is made up of vertical or horizontal chains of large blocks joined to the rubble filling, which may have been laid with live joints or clay mortar, (Adam, 1995). This process evolved over the centuries, with the use of lime mortar in the 2nd century BC, and the shape of the rubble stones joined with lime mortar was simplified (Adam, 1995: 130-131).

The drone surveys carried out on May 2024 and the superimposition of 27 old and recent aerial photographs (from 1960 to 2024) revealed the alternating and parallel succession of the same wall at two different heights (see profile, Figure 15). In other words, the hill (the plateau) is made up of three terraces supported by the opus africanum retaining wall, and each terrace has a platform that cannot be detected visually (Ouaret Ladjouze, et al. 2024). Some of the blocks are parallelepipedic (80 x 50 cm) or cubic (50 x 50 cm). Towards the north-west (Figure 16), a fragment of wall still has a brick bond above which a glazed floor tile measuring 25x25cm.

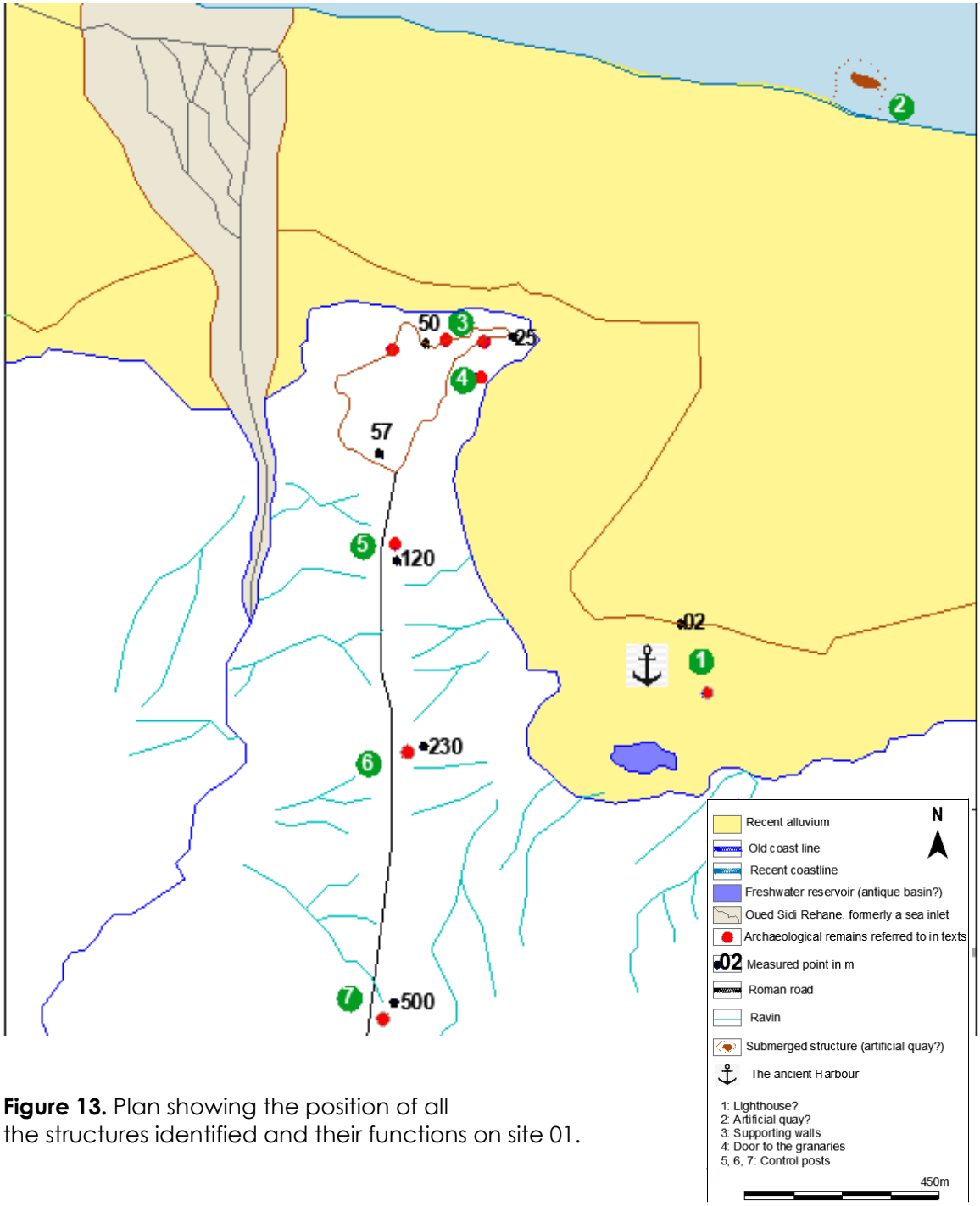

Figure 13. Plan showing the position of all the structures identified and their functions on site 01.

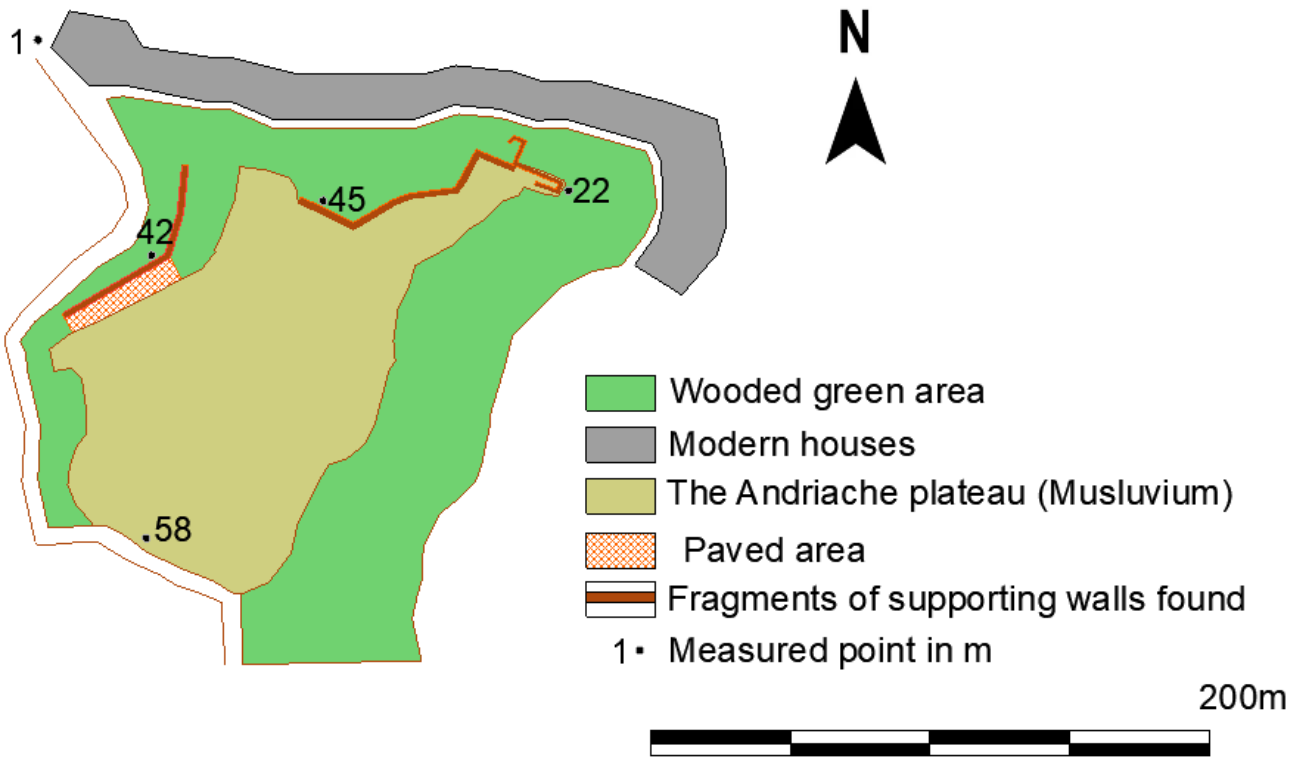

Figure 14. Plan view of the retaining walls visible today

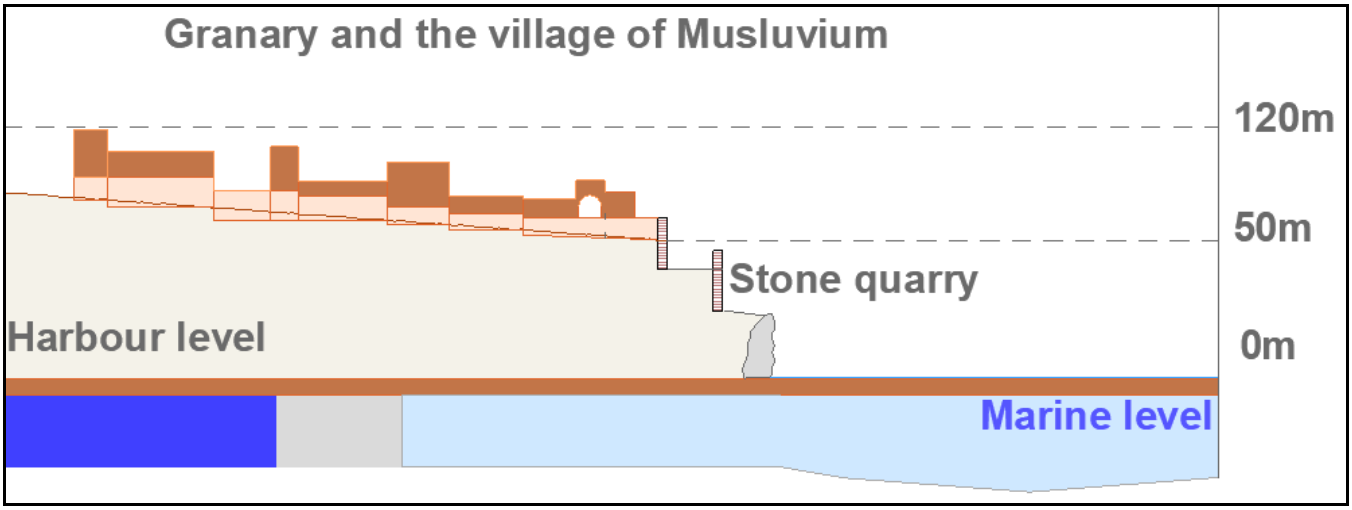

Figure 15. Longitudinal topographic profile and location of retaining walls

Figure 16. Fragments of retaining walls still standing (a). Wall materials scattered over site 01 (cut stone, bricks, floor tiles) (b).

3.3.3. Water source and catchment in site 02

The Kefrida Pass depression, which reaches 900m, is located on the eastern flank of Mount Adrar N'fad (1,756m), part of the Babors massif. This massif has often been described as the most fertile (Ficheur, 1890: 35), watered (around 1m) and forested region of Algeria (Explanatory note to the 1920 1:50,000 geological map). According to nineteenth-century texts (Table 3) and the testimony of the water authorities, there is a spring about 300 meters south-west of the pass, known as Tala Aïzraren, which serve nowadays to supply water to the villages of Aokas.

Table 3. Collected text data.

Infrastructure	Land use	Fonction
- Old aqueduct with a basin below	West-facing slope at the Kefrida pass	Water supply from source to port
-Porte de l'est or two forts or two control posts, Fort or Centenarium de Kefrida or two towers, or a large ruin called Kherbetel- Ksar, close to a small one called Rherbet- Merdj-el-Anasser. Military station.N° 61 on the map by S. Gsell.	On either side of the Kefrida pass and lapidary inscription commemorating the restoration of the Centenarium under Diocletian.	- Controlling the Roman road to Ain Roua (Horrea). - A fortified construction for a garrison of one hundred men.
-Kefrida spring. -Acufida, Aqua Frigida.	-300 S . W of the kefrida pass -Antique catchment at 1703m, 1382m, 1331m in the Triassic sandstone on the Adrar Nfad peaks.	Water supply.
- Necropolis (a sarcophagus at the foot of the slope at the Col de Kefrida).	- Slope (east or west?) of the Kefrida pass.	Old cemetery.

The discovery of the spring was a key factor in the foundation of Muslubium in this location, as it provided an abundant supply of water and was close to the port. Poulle cited a beautiful spring framed by ashlars and known as Tala Aïzraren during his exploration in 1857, around 300 meters south-west of the pass. On one of these stones there is an inscription of which Mr. Faure, an engineer with the Cie des Mines du Djebel Anini, had sent 'an incomplete copy, but sufficient to give an idea of the value of the original'. The lapidary inscription bears witness to the reconstruction of the Centenarium Aqua Frigida by the Cesars in 292-293 AD (Poulle, 1858).

This is ultimately the result of the drop-in altitude of the true source of Kefrida (hence the ancient name Aqua Frigida: fresh water) due to the subsidence resulting from the fault that ran parallel beneath the three true sources of Kefrida in ancient times. These springs were identified by Marcel Billiard (1934), as well as by geologists M. Dussert and M. Brives (1925) on the 1:50,000 geological map. The three source points of Kefrida are located exactly in the lias of Mount Adrar N'Fad on these three summits at 1703m, 1382m and 1331m. According to the work of Marcel Billiard, subsidence due to the fault caused erosion of the slopes, resulting in more abundant water flowing lower down and at an increased rate. Today, the subsidence has revealed the existence of three drains coming from the summits of the mountain, two of which no longer function. The other is connected to the Tala Aizraren spring.

The discovery made in September 2023 of the remains of a stone aqueduct (Figure 17) confirms the information found in the texts about the existence of an aqueduct and a basin beneath it. This aqueduct is now located below the current Tala Aizraren spring, 24 m above the road and just above the spring, which has the following geographical coordinates: 36.5919851-N 5.2535539 E. The subsidence that occurred in 1874 resulted in a 2 m drop in the road and the aqueduct to break in two (as reported in the deliberations minutes of the general council of the Constantine department in 1874), leaving a stone stream visible on the aerial photograph taken in 1960.

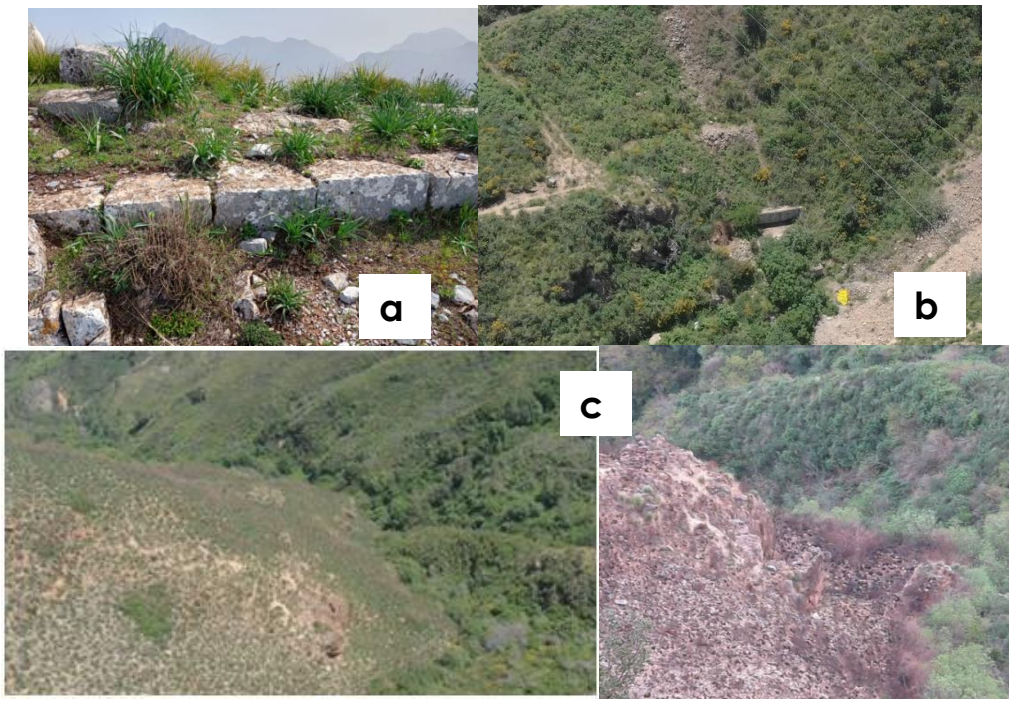

Figure 17. Visible remains of the antique fort located at an altitude of 1364m on the Ablat Amellal ridge (a) photo by Mr. Zidani, president of the Aokas hikers' association (2024). Drone view of the Kefrida spring basin (b). And a left-hand section of the aqueduct, right-hand section of the aqueduct taken by the drone at an altitude of (- 24 m) from road level and towards the bottom of the pass of Kefrida ravine (altitude 476 m) (c).

3.4. Ceramic artefacts found at Site 01

The various surveys also led to the discovery of countless ceramic artefacts (amphorae, crockery, bricks, floor tiles, tesserae) (Figure 18), dotted around the wheat field and its boundaries (Andriach plateau). The timely discovery of amphora bases and handles leads us to believe that this was indeed a granary or warehouse, given the abundance of fragments. After collection and cleaning, a comparison was made with the listed collections of African amphorae. A number of projects were carried out to classify and list the various amphorae of African origin, their contents and their place of manufacture. Classifying the amphora artefacts found at Site 01 is not the subject of this article, but at this stage it is more a question of drawing on the results of previous work in an attempt to find similarities in characteristics. The bases of cone-shaped African amphorae were used as containers for preserving fish-based sauces (Lemaître et al., 2017), while others listed by La Porte belong to Caesarian or Setifian Mauritania and could contain wheat, wine or olive oil (La Porte, 1980).

A strange shallow circular incision (not yet filled in) was found on two amphora fragments (Figure 19). This feature, which was also noted at Fréjus, has been identified as very old, and is in fact a pre-perforation device designed to facilitate the emptying of the contents. These have been identified as 'African amphorae of the Ostia XXIII type' (Excoffon et al., 2015: 156). When this device is not recorked for a second use, it is considered to be of recent manufacture. We could therefore assume that this amphora was made in situ and that there could have been amphora-making workshops at Muslubium. This hypothesis could be further confirmed by the fact that several deposits of clay for making tiles, bricks and pottery have been recorded on the 1:50,000 geological map of 1925, at Beni Ismail, located at the southern end of the Kefrida Pass behind Mount Adrar Nfad.

Figure 18. Some fragments of amphorae found on site 01.

However, the absence of any other explicit evidence calls for caution and circumspection, and the archaeomagnetic studies planned as a continuation of this research will certainly shed new light on the precise dating of the ceramics found on site, as well as on the date of the foundation of Muslubium (Ouaret Ladjouze et al. 2025).

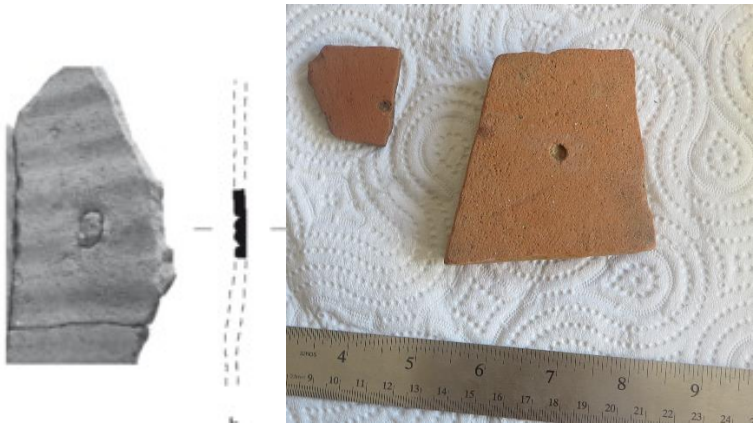

Figure 19. Similarity in the ancient perforation device on ancient amphorae of African origin found at Fréjus of the Ostia XXIII type (P. Excoffon et al. 2015: 159), in comparison with the remains of amphorae found on site (the perforations have not yet been filled in).

4. Discussion

From the foregoing, it is clear that the interpretation resulting from the superimposition of ancient geographical maps and 19th-century archaeological and geological maps has enabled to identify the extent of marine deposits and recent and ancient alluvial deposits that may have modified the ancient levels, burying the port settlement over a 2000-year period. These maps also enabled to record all the natural resources required to build the settlement, in particular the abundance of fresh and salt water springs, deposits of building and paving materials (sand, stone, brick and tile clay, gypsum and marble) and the identification of the various structures that made up the settlement, such as the Roman village, granary, aqueduct, drinking water pipeline, fortifications and checkpoints.

The archaeological discovery of Muslubium was methodologically verified by the interpretation of its preserved past, which still survives in the few texts and maps studied. The geolocalised cartographic restitution of the archaeological structures found, then verified by the interpretation made by hermeneutics, has enabled to highlight a number of new results, notwithstanding a number of hypotheses:

- The Sidi Rehane or Andriach plateau, on which the granary and the village of Muslubium were built, is artificial and of a geological nature that favoured construction, offering the port safe shelter from the northerly winds.
- Today, almost 600 meters wide of alluvial deposits and sand separate the coast from the foot of the Sidi Rehane plateau. This environmental transformation, which took place over more than 2,000 years, buried all the port structures, revealing linear underwater structures visible to the north of the plateau in recent bathymetric surveys. Could these port facilities have been used for mooring?
- A freshwater reservoir on the plain, near a ruin believed to have once been a fortified castle, suggests the existence of ancient basins used as fish ponds. The ruins of an ancient castle, as cited in the texts, suggest the existence of a lighthouse near the freshwater basins.
- The presence and proximity of food resources such as the Kefrida spring, which is abundant and located 4,000 m from the port, an aqueduct and a dock, are fundamental arguments in favour of the founding of the Muslubium settlement. The same applies to the proximity of identified quarries for the extraction of building materials (gypsum (lime), clay, iron, copper, etc.).

It is important to note, however, that both hermeneutics and geoarchology are rather limited in their ability to give a precise date for the founding of Muslubium Horrea, or even to identify the reasons for its disappearance.

Subsequently and as a research perspective, this results needs to be extended by carrying out excavations to establish the link between the granary and the village located on the plateau and the port located below on the plain, to specify the stages in the construction of the village, the layout of the Roman road, as well as the restitution of the structures of the hydraulic network from the Kefrida water source to the aqueduct leading to the port of Muslubium, as well as the possibility of the existence of ceramic manufacturing workshops on the site by dating. Indeed, the exact date of its foundation remains unknown in historical documents. The investigations require future dating studies, which are planned as part of the continuation of this research (Ouaret Ladjouze et al., 2025).

5. Conclusion

The aim of this study was to reconstruct the initial topography prior to the establishment of the Muslubium settlement, and also to pinpoint the precise location of the port, for which there is little archaeological evidence. This was achieved by combining hermeneutics and geoarchaeology applied at different scales from territory to architecture and from architecture to artefact. These investigations brought out the following salient points:

- The settlement has been duly located and its extent clarified,
- The dismantled parts of the site (ramparts, structures, etc.) were identified and objectively located.
- The conditions under which it was founded as a major commercial port have been identified.

The results of this study constitute a significant contribution to current scientific research and the first milestones in the identification of lost ancient Mediterranean ports, and even provide a global understanding of the relationships between different Mediterranean ports in the past. These results obtained need to be backed up by investigations and excavations, as well as laboratory dating tests and other hermeneutical research.

Conflict of Interests

The author declares no conflict of interest.

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Spatial Negative Influence of Cairo Mega Movement corridors on adjacent Local Areas Land Uses and Movement: Ain Shams Corridor Case Study

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ABSTRACT

The research is focused on discussing the importance of transportation in metropolitan areas and analyzing the positive and negative spatial impacts of the major movement corridors in Greater Cairo on the surrounding local areas. It aims to highlight the regional benefits of these corridors while also addressing the spatial challenges faced by the local areas. The study emphasizes the significance of movement circulation for pedestrians and vehicles in the urban functionality of local movement, serving as a connection between land uses and daily activities. While the mega movement corridors have significantly improved access between Greater Cairo's main districts, they have also introduced challenges at the local level. The research examines the impact of the Ain Shams corridor as an example of a new movement corridor introduced by the government in the last 5 years, in two major areas, and additionally, identifies the resulting challenges in land uses and movement circulation in these areas. The findings underscore the importance of segregating movement circulation between the regional and local levels to enhance accessibility for pedestrians and vehicles in local areas. Furthermore, the study reinforces the importance of comprehensive measures to enhance the efficiency of the corridor. Implementing solutions such as dedicated service roads, improved parking infrastructure, and optimized traffic management strategies can play a pivotal role in mitigating congestion and addressing the specific needs of local traffic. By addressing these challenges, the corridor can achieve improved functionality, accommodate the diverse traffic demands, and enhance the overall transportation experience for commuters and urban activities.

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1. Introduction

The development of transportation systems has had a profound impact on the layout and character of cities. The popularity of automobiles in the early 20th century, particularly in urban areas, contributed to rapid urban growth. Cars allowed people to travel to areas further from city centers, leading to the

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emergence of new suburbs and communities. The expansion of suburbs aimed to accommodate increasing populations and reduce crowding in older urban areas, often facilitated by the introduction of affordable public transportation options. However, this outward growth presented new challenges related to transportation, land utilization, and the environment. Problems such as traffic jams, air pollution caused by vehicle emissions, lengthy commutes, noise pollution, lack of parking space, limited room for walking and biking, and concerns about public safety became more common.

Prior to the emergence of the concept of sustainable development, urban planners made attempts to address the imbalances between motor vehicles and human activities. However, since the late 1970s, there has been a noticeable increase in policies aimed at addressing these issues in three major aspects. The first aspect involves promoting alternative modes of travel, emphasizing mobility through walking and public transport. The second aspect focuses on altering land use and urban design policies to facilitate alternative modes of travel and reduce trip distances, as shown in the case of compact city planning. Lastly, there has been a push to reform transportation prices and taxes by factoring in the full socio-environmental costs of driving into the price of fuel, road use, and parking, as demonstrated in the central London business area through increased taxes for access after 6:00 am (Wheeler, 2004).

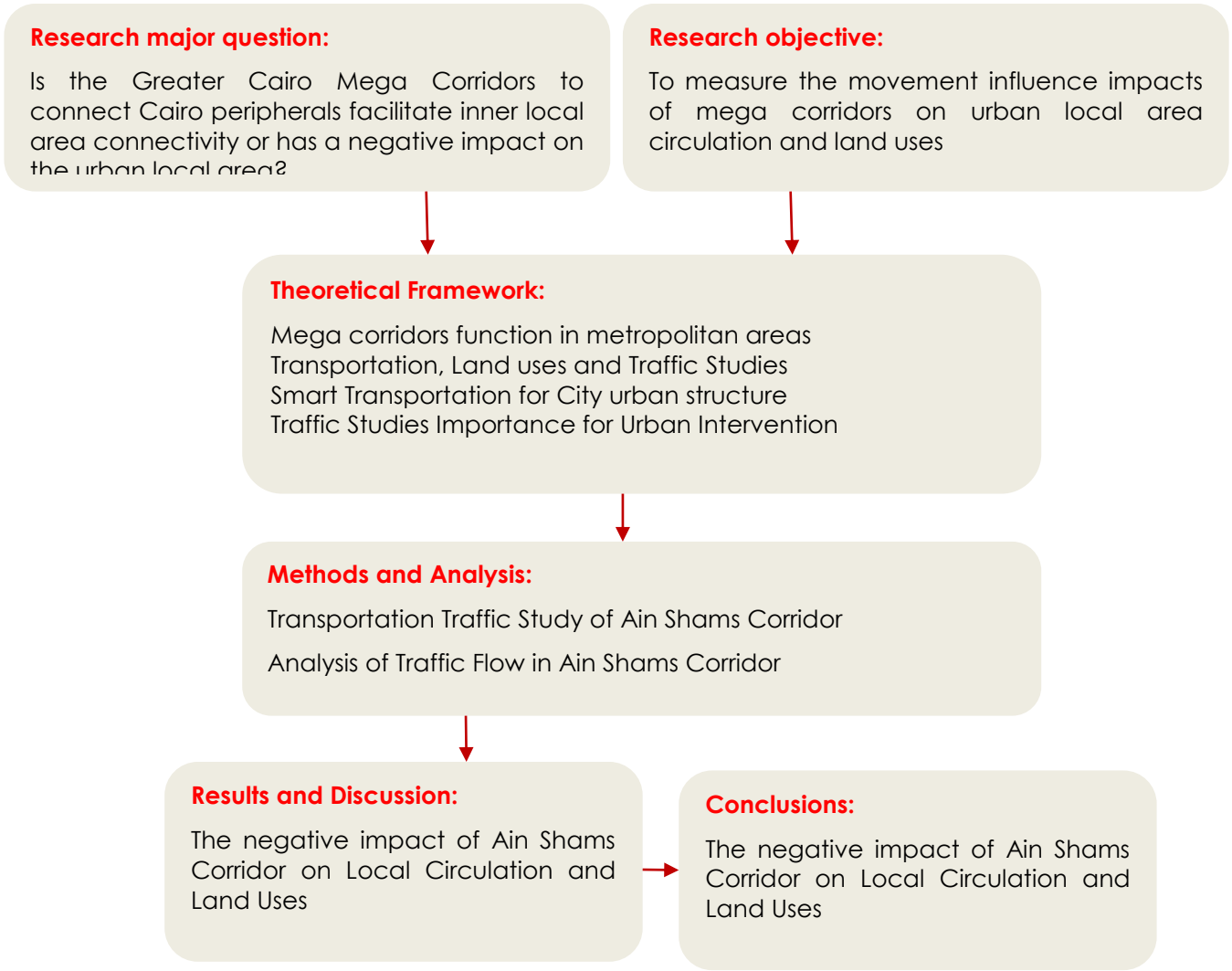


Figure 1: Research Methodology

Over the past five years, the Egyptian authorities have implemented an ambitious plan to upgrade specific roads in the Cairo metropolitan area with the aim of improving traffic flow from east to west and north to south. This initiative connects new cities such as the 6th of October, the new Cairo, and the new capital city on the outskirts of old Cairo. However, these corridors have negatively impacted the surrounding areas, resulting in traffic congestion and insufficient parking facilities, limiting local transport accessibility. Figure 1 presents the research methodology used to assess these negative impacts and determine the effectiveness of these corridors in addressing transportation delays in the Cairo metropolitan peripheries, while also exploring alternative solutions.

2. Transportation, Land uses and traffic study

2.1. Land uses and transportation

traffic is influenced by land use, and changes in land use can lead to different types of traffic movements. Similarly, London's Blunden notes that traffic serves as the link between the transport system and land use. Both elements are responsible for generating traffic, as changes in land use can create specific traffic patterns, while transport infrastructure developments can also generate traffic to specific areas. This, in turn, can lead to the emergence of new uses and activities in the area, such as the establishment of factories or tourist attractions (Breheny, 1992). Research in urban transport planning has emphasized the crucial role of transportation in people's daily lives, providing mobility within and outside the city. The economic structure of a community relies on transportation and mobility infrastructure, encompassing various modes of transport. Given the close relationship between urban land use and traffic, comprehensive data on traffic conditions, public transport, land use, population, economic activities, social dynamics, and urban services is essential for effective planning and development of urban areas, particularly in relation to highway schemes (Breheny and Rookwood 1993)

Traffic jams are a pressing problem in many urban areas. Recent advancements in traffic management methods have proven effective in addressing this issue by enhancing urban transportation efficiency and reducing congestion. Assessing traffic patterns in urban road networks is crucial for effective traffic control. It enables authorities to accurately determine the status of network traffic operation and provide relevant information about congested roads. Evaluating the situation of traffic congestion with appropriate measures is essential. Cities typically experience high congestion during peak commuting hours, especially on highways. Over the last three years, the congestion problem has exacerbated due to insufficient road infrastructure and poor management in urban areas. It is essential to identify the primary causes of traffic congestion, particularly how the existing infrastructure fails to meet the demands of city traffic. In Saudi Arabian cities, traffic congestion arises from factors such as low usage of public transportation, inadequate street networks, high vehicle ownership, urbanization, and population growth.

2.2. What is a traffic study?

The traffic study involves estimating the volume and movement of various types of vehicles, including those wishing to move through the study area. The study assesses car ownership, development needs, and future projects in the study area, as well as the services required from commercial, cultural, recreational, and emergency vehicles. Conducting a traffic survey to determine the current traffic volumes on the road network in the study area. Predicting the volume of trips to and from the region. Analyzing the service levels of streets within the study area before and after planning and reconstruction efforts. Evaluating the demand for waiting areas, both indoor and outdoor, within the study area. Proposing alternative traffic routes in the event of congestion and developing traffic regulation proposals within the framework of the Urban Plan or for industrial works (Chavhan, S., & Venkataram, P. 2020).

2.3. Importance of traffic study

The main objectives of traffic studies are to Assess the current traffic situation and identifying bottlenecks and traffic problems. Predicting future traffic levels based on expected physical and population developments. identifying appropriate solutions to improve traffic flow and reduce congestion, and ensuring the safety of all road users, including drivers, pedestrians, and cyclists. The traffic study receives its importance through helping to achieve smooth and efficient traffic flow, saving time and costs, enhance traffic safety and reduce road accidents, improve the quality of life of the population by reducing environmental pollution and noise resulting from traffic congestion, and support economic growth and sustainable urban development by providing effective traffic infrastructure (Almatar, M., 2023).

2.4. Traffic Study Methodology

Field data on traffic volume is collected in various regions and roads and analyzed to understand current patterns and trends. Projections of future traffic levels are also made based on different factors such as population growth and urban development. Current and projected traffic analysis mainly follows the major methodology of traffic planning study which includes these elements to form traffic study (Shirazian& Eskandari, 2021)

1. Road and intersection traffic capacity study:
   The ability of roads and intersections to absorb current and projected traffic volume was assessed, identifying choke points and potential problems.
2. Assessment of service levels and traffic congestion:
   Traffic service levels are analyzed to measure the quality of traffic flow and the driving experience. Traffic congestion levels and their impact on traffic network efficiency are also assessed.
3. Study of entrances, exits, and traffic flow:
   Traffic flow is analyzed at key entrance and exit points for projects and urban areas, and the best solutions are identified to design them to ensure smooth traffic.
4. The importance of studying entrances and exits in projects:
   Studying and designing entrances and exits play a vital role in ensuring smooth and safe traffic flow in urban and suburban projects. Their importance lies in:
5. Ensure smooth traffic and avoid congestion at key points:
   Well-designed entrances and exits help to efficiently distribute traffic and avoid stacking cars at key entry and exit points, reducing congestion, delays, and improving users' experience.
6. Determine the best locations for entrances and exits based on traffic flow:
   Traffic studies help understand traffic patterns and identify locations best suited to create entrances and exits. These sites are selected to correspond to the main traffic flow, facilitating seamless access and exit.
7. Design of entrances and exits according to engineering standards and legal requirements:
   Entrances and exits are designed according to specific geometric standards, such as passage width, navigation vision, rotation angles, etc. The applicable legal requirements and traffic regulations are also observed to ensure safety and compliance with regulations (Almatar, 2023).

2.5. Transportation and metropolitan spatial land use structure international best practice

Metropolitan areas are implementing policies to manage urban growth, such as the compact urban growth strategies seen in Portland, Oregon, and the Greater Vancouver region. Greater Vancouver's approach prioritizes creating a compact metropolitan region by concentrating a significant portion of population growth within the "growth concentration area" in the central part of the region, as depicted in Figure 2.5 showing the Greater Vancouver growth boundaries. The urban growth policy aims to channel future growth around regional centers while also providing mass transit to connect these centers,

promoting accessibility and reducing private automobile dependence (Ewing & Bartholomew 2018) . In a similar vein, Portland, Oregon, has managed urban growth through the adoption of an Urban Growth Boundaries policy (UGB), which helps the local government regulate growth using tools such as urban service limits (Wheeler, 2004). While individual communities contribute to a city's overall structure, the planning of the broader urban region is crucial. Larbi (2022) argues that adopting a polycentric urban structure, where multiple centers are connected by public transit corridors, can accommodate growth while preserving walkable neighborhoods and reducing reliance on cars. Figure 2 illustrates how this approach allows a city to expand while providing efficient public transportation options that decrease car dependency. (Larbi, M., *et al.* 2022).

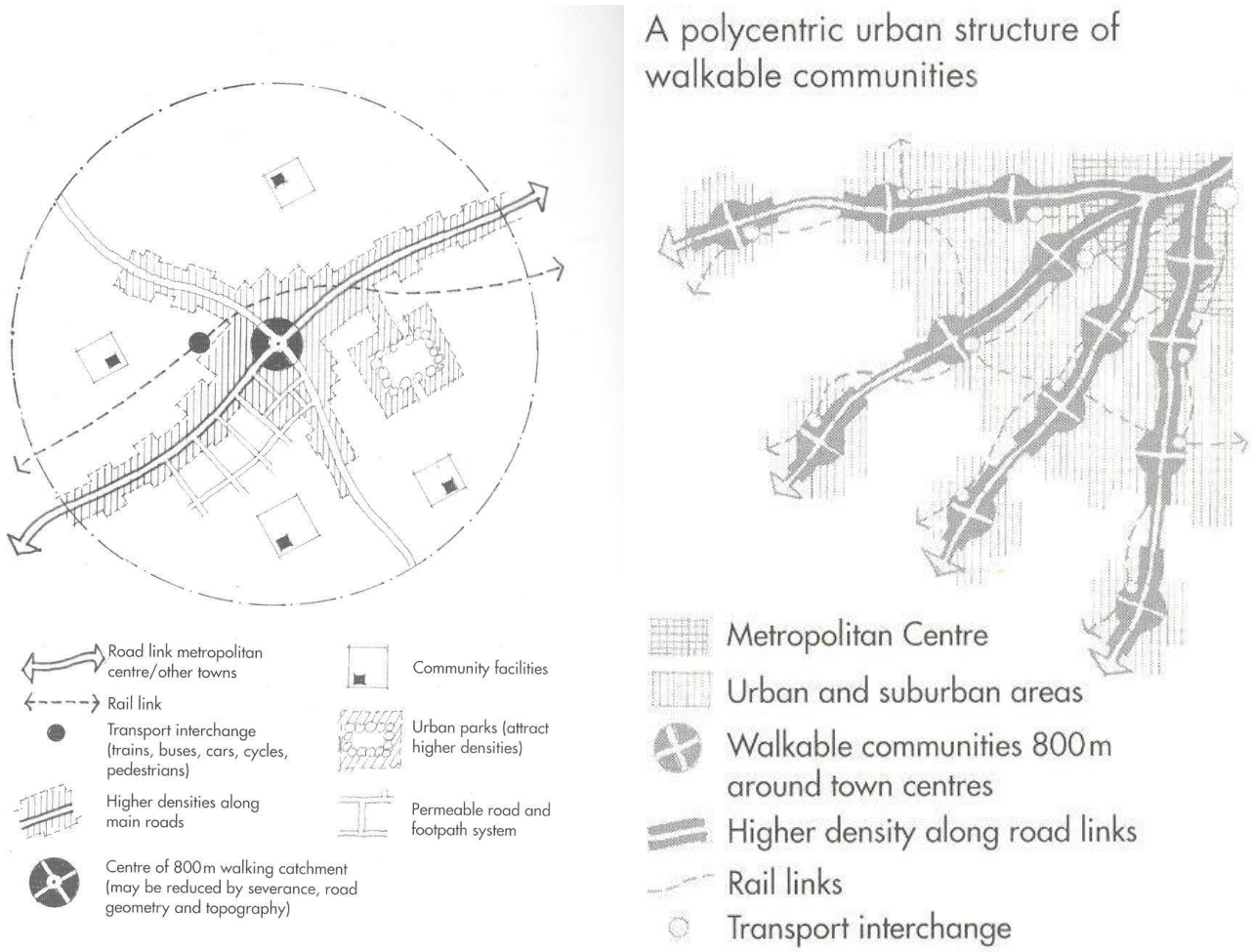


Figure 2. Poly-centric Urban Growth of Greater Cairo Model (Calthorpe, 2000)

The urban structure of a community starts with the urban region. According to Volgmann & Münter, (2022), the idea of a polycentric urban structure supports the expansion of cities while preserving pedestrian-friendly sub-communities through the development of urban transit corridors. As shown in Figure 2, the concept of a polycentric urban structure permits the city to expand while simultaneously establishing transit corridors to lessen reliance on automobiles. The polycentric urban structure is endorsed by Calthorpe in the concept of Transit-Oriented Development. Calthorpe emphasizes the importance of pedestrians as "the catalyst that gives meaning to the essential qualities of communities"

(2004, p. 76). He argues that the spatial layout should be influenced by transit accessibility and environmental considerations and proposes the establishment of urban growth boundaries that support polycentric growth (2004, p. 80). The effectiveness of transportation in facilitating polycentric urban growth hinges on the provision of a suitable mass transit system that reduces reliance on automobiles.

The example of Curitiba's public transit system shows how effective a well-designed bus network can be. The city prioritized bus transportation by creating dedicated bus lanes and using these routes to guide urban development. This approach resulted in a fast and affordable system that is now being expanded to connect with the surrounding metropolitan area. Figure 3, indicates the concept of using the major Corridor a a mass Transit system. The system's efficiency has encouraged residents to choose public transit over personal cars, even though Curitiba has a high rate of car ownership and a growing population. Remarkably, car traffic has decreased significantly. Today, Curitiba boasts the highest public transit ridership in Brazil, with approximately 2.14 million daily passengers (Larbi, M., *et al.* 2022). Furthermore, the city enjoys some of the country's lowest pollution levels and per capita gas consumption. Curitiba's system also prioritizes affordability and accessibility. A low "social fare" makes transportation accessible to low-income residents living on the city's outskirts. The system uses a flat fare for all trips, meaning shorter rides help subsidize longer ones. This allows a single fare to cover trips up to 70 kilometers (Ewing, 1997).

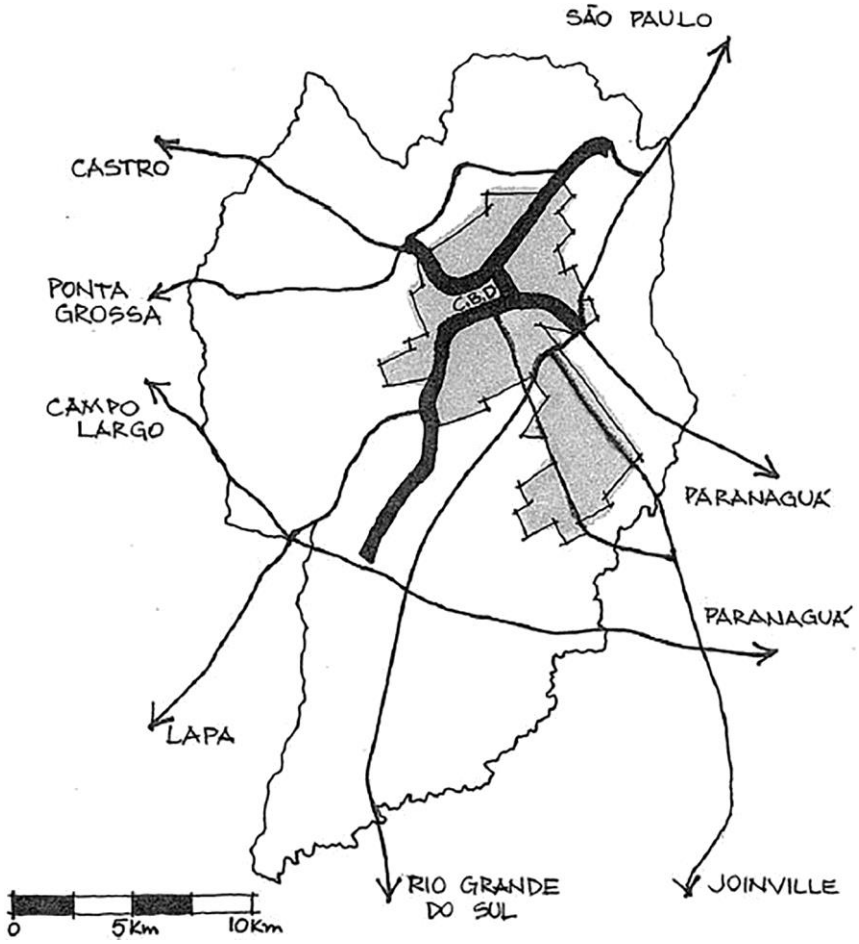


Figure 3: Curitiba, Brazil Mass Transition System and Urban Corridors (Larbi, M. *Et al.* 2022)

3. Greater Cairo Metropolitan Region GCMR transportation issues

3.1. Greater Cairo Metropolitan Region urban characteristics in the last decade

The Greater Cairo Metropolitan Region (GCMR) is home to over 21 million people (CAPMAS, 2017) and ranks among the top twenty largest mega-cities globally. It spans 928 km2 in central Egypt and is situated alongside the Nile River. Within this region lies the Greater Cairo Metropolitan Area (GCMA), encompassing the major cities of Cairo, Giza, and Qaluibia. After undergoing privatization, economic reform, and market liberalization in the 1990s, the region experienced rapid economic growth with real economic expansion averaging around 6.2% annually during the 1994–1997 "boom" period (Rodenbeck, 2000). the last decade between 2013-2023 urbanization took a radical turn with the new regieme that witnessed a vast road netwrok and a series of new towns such as the New Capital city, New Alamain, additionally, a big number of intiatives and urban projects that require a clear urban policy which put a load of pressure in infrasructure and transportation strategy.

The Greater Cairo Metropolitan Region (GCMR) has become increasingly integral to the Egyptian economy, contributing over 45% to the GDP and almost 40% to manufacturing output (CAPMAS, 2017). This growth can be traced back to the late 1980s when the Egyptian government adopted an economic reform strategy in line with the recommendations of the International Monetary Fund and the World Bank (Bush, 2001). The years 1985–1989 witnessed a 52% expansion of Greater Cairo, leading to the emergence of a new industrial hub. However, the lack of effective land management policies has resulted in the scattered placement of factories throughout the GCMR, intertwined with other land uses, making it challenging and costly to provide services. Additionally, the development of housing compounds, recreational facilities, and service infrastructure has further strained the GCMR. For instance, housing developments in the 6th of October satellite town increased by 76% during the 1994–2000 period. The structure of the manufacturing sector exacerbates the lack of planning and services due to the absence of necessary planning regulations, which are crucial for mitigating the adverse impact of factories (Sutton and Fahmi, 2001). The rapid industrial growth, along with other forms of development in the GCMR, additionally, the introduction of a New Capital City in the North in 2017, has intensified long-standing problems such as inadequate infrastructure, extensive environmental degradation, and growing social inequality Ghalib, et al, 2021).

Egypt, despite not being a newly independent country, faces similar challenges that necessitate demonstrating its unity and sovereignty to both national and international audiences. In 2011, a revolution led to the overthrow of President Mubarak and his regime after a 30-year rule. Another wave of protests occurred in 2013, resulting in the removal of President Morsy from his elected position due to his close ties to the Muslim Brotherhood and his attempts to manipulate the constitution in their favor. Following several transitional phases, President El-Sisi came to power, marking a critical need for the restoration of Egypt's economic, political, and social stability. The new capital is set to accommodate five million residents and create 1.75 million permanent job opportunities. The residential areas are designed to include housing options suited for various income levels, prioritizing quality of life. In addition to housing governmental buildings and foreign embassies, the city will feature hotels, shopping centers, an airport, a theme park, and essential services for residents and visitors. With Cairo's agglomeration currently housing nearly 20 million people, the new capital aims to accommodate a population equivalent to 25% of the existing agglomeration.

3.2. The regional ring road as an attraction for urbanization

The completion of the regional ring road in its northern, eastern, and southern sections has significantly impacted land use and population changes around Cairo. The road has spurred development around the 6th October new town, leading to potential further expansion. This has also led to the growth of informal private development, along with social exclusion, impacting new settlements and cities in a manner not anticipated by the master plan or the General Organization for Physical Planning (GOPP). Moreover, to the east of the city, the New Capital City has emerged, with continuous extensions in the

eastern areas However, much of the housing development associated with the regional ring road is private and caters to higher-income groups, rather than being part of the public infrastructure. As a result, growth has proceeded despite the master plan, rather than due to it.

3.3. Cairo urban transportation corridors growth

The official development goals for Cairo, as outlined in the 1970 Master Plan, were designed to accommodate 2 million inhabitants and included plans for the city's urban structure and public facilities. However, due to the substantial increase in Cairo's population, the challenges posed by agglomeration dis-economies and disadvantages have become more pronounced for both the national and city governments (Jenssen et al., 1981). The focus of master planning in Cairo has been on physical development, particularly the road network, water supply, and sewage disposal (MHR, 1970 and 1976), reflecting local political and technocratic attitudes toward urban planning and city management. It remains uncertain whether the plan has successfully achieved its objectives. The urban area covered by the GCMR has expanded by over three times its 1974 size, now encompassing approximately 602 km2. In 2015, plans were unveiled to relocate the capital of Egypt. The new capital, often referred to as the "New Administrative Capital," is slated to be situated no more than 45 km from the current Cairo location. The specific selection of the site was not publicly justified, in contrast to previous proposals to move the Egyptian capital. The chosen location, which is roughly equivalent in size to Cairo's current agglomeration, is situated in Egypt's eastern desert. Some researchers associate this choice with the ongoing development initiatives in the Suez Canal region, viewing it as a means to bolster regional connectivity (SISNAC,2024). Official statements cite the primary reasons for relocating the capital as the challenges faced by the existing city, including the intensifying congestion and insufficient infrastructure to support the growing population in one of the world's most densely populated cities. The designated area for the new capital spans 170 thousand feddans, approximately 700 km2. Importantly, the selected site is devoid of existing settlements (SISNAC,2024).

The transportation corridors experience severe congestion due to intensive use, highlighting the contrast with the relatively underutilized land between them. Additionally, decentralized development has been rapidly expanding. For instance, between 1976 and 1984, 45% of land converted to urban use was located 11-20 km from the urban center. This trend continued from 1984 to 1988, with 45% of converted land located over 30 km from the urban center. These extensive development patterns will lead to higher infrastructure costs and increased energy consumption in the future. As a consequence, in 2016, according to the New Urban Communities Authority NUCA, a series of urban corridors were introduced to solve these congestion problems to facilitate regional transportation from east-west and north-south GCMR peripherals. Consequently, the absence of effective land management institutions and policies before and during recent economic changes led to a predictable outcome: the congestive expansion of urban activities across the region (NUCA, 2019).

3.4. Political influences on urban planning in Egypt

It is worth noting that the Egyptian government can be categorized within the framework of the well-known "new Authoritarian" model. This model has been utilized in Latin America and numerous Arab countries. According to Collier (1979), it does not entail the authoritarianism of an individual or a family dictatorship (as seen with Colonel Nasser in 1952), where the military merely plays a supporting role. Rather, it involves a more complex bureaucratic, authoritarian system where the military, law enforcement, and civil bureaucracy assume prominent roles, not to sustain a dictator in power, but to execute projects that serve political objectives. In Egypt, this takes the form of strong law enforcement to quell the labor force and pave the way for rapid economic growth. In both scenarios, the model is bureaucratic in the sense that it operates through a reinforced executive and a robust central administration. Additionally, it depoliticizes the expression of social interests and extends bureaucratic

control over daily life. Various factors must be considered to address the issue of political influence on urban planning decision-making, including political instability, elitism, and political expediency.

The urban planning policy has been significantly affected by political instability. One notable characteristic of urban development politics is the prevalence of rhetoric without corresponding policy plans, leading to limited policy implementation. This is primarily due to the transient nature of political leadership, resulting in the breakdown of new policy development at an early stage. New leaders often distance themselves from the intentions and plans of their predecessors, striving to establish their own mark on decision-making. They typically appoint their own advisors to key government positions, leading to delays and the loss of valuable knowledge and experience.

Furthermore, top-level instability results in inactivity within the lower tiers of the civil service. The hierarchical nature of the Egyptian administrative system fosters a top-down decision-making approach that discourages administrators from delegating responsibilities. Consequently, they frequently handle day-to-day matters unrelated to the priorities of private citizens or groups. Additionally, lower-ranking civil servants are hesitant to take independent action, as doing so may result in reprimand, transfer, or even dismissal. Consequently, they typically act only with direct approval from superiors.

The second significant political factor influencing urban planning is the impact of the elitist nature of the government. The disparity between the elite and the general populace is evident in the urban space organization proposals. Decision-makers prioritize city beautification and orderly layouts over fundamental urban planning needs. In Egypt, it is common for decisions to be influenced more by political factors than sound technical reasons.

4. Current state of Urban transportation in the GCMR

In the Greater Cairo Metropolitan Region (GCMR), urban transportation has garnered attention from decision makers despite the absence of a sustainable urban policy. This attention primarily focuses on issues related to pollution and traffic management. Urbanization in Egypt experienced significant growth at the beginning of the 20th century, with only around 15% of the population residing in urban areas. By the late 2020s, this figure had tripled to approximately 44%, and it is projected to surpass 50% by the early 2030s (CAPMAS, 2017).

The existing Egyptian cities were not initially designed to accommodate the rising population, resulting in considerable strain on infrastructure and utilities, including transportation, communication, water, sewage, and electricity. Unplanned urban expansion around major cities also gives rise to social problems and adverse environmental consequences.

4.1. Sustainable development and transportation planning: an assessment of progress in the GCMR

Since the 1970s, numerous projects have been approved to expand and improve urban quality. Efforts to enhance infrastructure and expand existing urban areas began in the early 1980s. The most significant progress in transportation and road networks occurred between 2013 and 2023, witnessing several mega projects. Despite this vast progress, a holistic framework is needed to connect these mega projects with the extensive urban growth in GCMR, such as the underground network and the second ring road. Movement corridors intersecting GCMR are essential to facilitate regional movement across the old Capital.

The government's transportation policy aims to connect the different parts of the GCMR. For example, the two ring roads have revitalized the new towns project and provided accessibility for the population to commute to and from the city. Therefore, the transportation project does not theoretically increase the rate of overall urban growth. Additionally, the government does not allow building permits to be issued within a certain range of the two-ring roads. However, the application of the law and its

enforcement at the local government level remains problematic, as pressures from local representatives in the political council to deliver favors for the local population create urban chaos at the local level.

4.2. Impacts of transportation projects on the GCMR urban context

The construction of transportation projects aimed at connecting the inner city with new towns has led to traffic congestion issues at the junctions where these roads intersect with Cairo's local transport network. The transportation department is currently focusing on reorganizing the city's transportation network to address these challenges. Key issues with the existing urban transportation system include the absence of a long-term policy and the lack of coordination between transport projects and urban development in the city.

The long-term impact of policies is sometimes misunderstood by certain government bodies, leading them to view policy-making as simply proposing a new set of projects. Additionally, many policymakers are primarily focused on the day-to-day aspects of transportation services and operations. The importance of establishing reliable information for policy formulation and monitoring is not fully recognized by city officials. For those officials who do recognize its significance, challenges arise in obtaining either nonexistent data or acquiring it with great difficulty. Furthermore, the significance of an adequate information system is often overlooked by top politicians, who tend to prioritize short-term projects that produce immediate results, thereby diverting attention from the formulation of long-term policies.

4.3. Organisational, institutional and financial constraints in transportation planning in the GCMR

In many developing countries, including Egypt, the existing institutional structure often hinders the expected output and achievements. This is often due to the mismatch between qualified personnel and their appointed positions. Additionally, there are issues in the financing system of projects, with major implementation work being prioritized over complementary tasks, often leaving the local government with insufficient resources and technical support. To address these challenges, the government needs to consider restructuring the local government mechanism and decentralizing decision-making over the next decade. This will require a clear agenda and sustained efforts to strengthen decision-making at the local level.

4.4. Traffic Study of Ain Shams Corridor Method

The Ain Shams corridor is of utmost significance for Cairo, serving as a critical thoroughfare that seamlessly connects the western fringes of the city, including 6th of October City, the West Cairo Ring Road, and Giza City, with the eastern fringes, encompassing the New Capital City, Nasr City, and Cairo International Airport. This important corridor not only serves as a link between these areas but also plays a vital role in facilitating transportation and connectivity for the residents and businesses located along its route.

Furthermore, the historical urban fabric of Old Cairo is intricately intertwined with the path of the Ain Shams corridor, as it extends from the northern part of the city, showcasing the corridor's deep-rooted connection to the rich heritage and traditional elements of the region. The visual representation in Figure 4 provides an intricate and detailed depiction of the exact path of the Ain Shams Corridor, highlighting the specific districts and neighborhoods it traverses through, including Mostorod, Matria, Ain Shams, Masr Elgedida, and Almaza Airport.

By effectively interconnecting these diverse areas, the Ain Shams corridor plays a crucial role in promoting economic growth, tourism, and urban development. Its influence extends beyond mere physical connectivity, fostering cultural exchange and bolstering the social and economic ties between different

parts of the city. Additionally, the corridor serves as a lifeline for the efficient movement of goods and services, contributing to the overall vibrancy and functionality of Cairo's urban landscape.

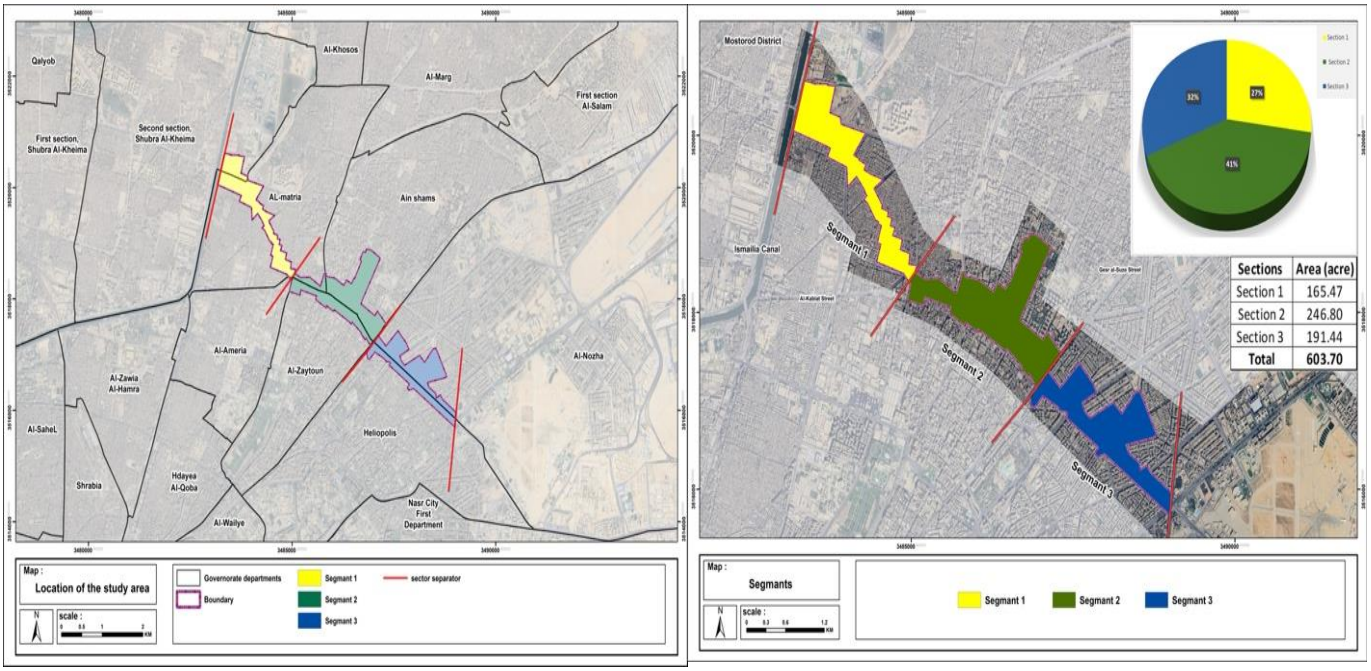


Figure 4: Ain Shams corridor location and Major Trafic Segements (Researcher, 2024)

4.5. Urban Characteristics of Ain Shams Corridor

The Ain Shams corridor, situated in the northern part of GCMR, is a bustling mixed-use area with a high density of various developments spread along the route from the Ring Road to Alamaza Airport as indicated in Figure 5. It's noteworthy that only 13% of the land is designated for residential use, while the remaining area encompasses a diverse range of land uses including commercial retail centers, administrative services, daily use markets, food and beverage establishments, as well as small shops and workshops. This corridor experiences heavy local traffic due to its popularity, and it is well-connected with bus stops and microbus stops to accommodate the densely populated areas. The population density within this region varies from 500 people per acre to as high as 3000 people per acre. Figure 3 provides a detailed spatial distribution of land uses and their corresponding percentages, depicting a significant clustering of both land use types and population densities.

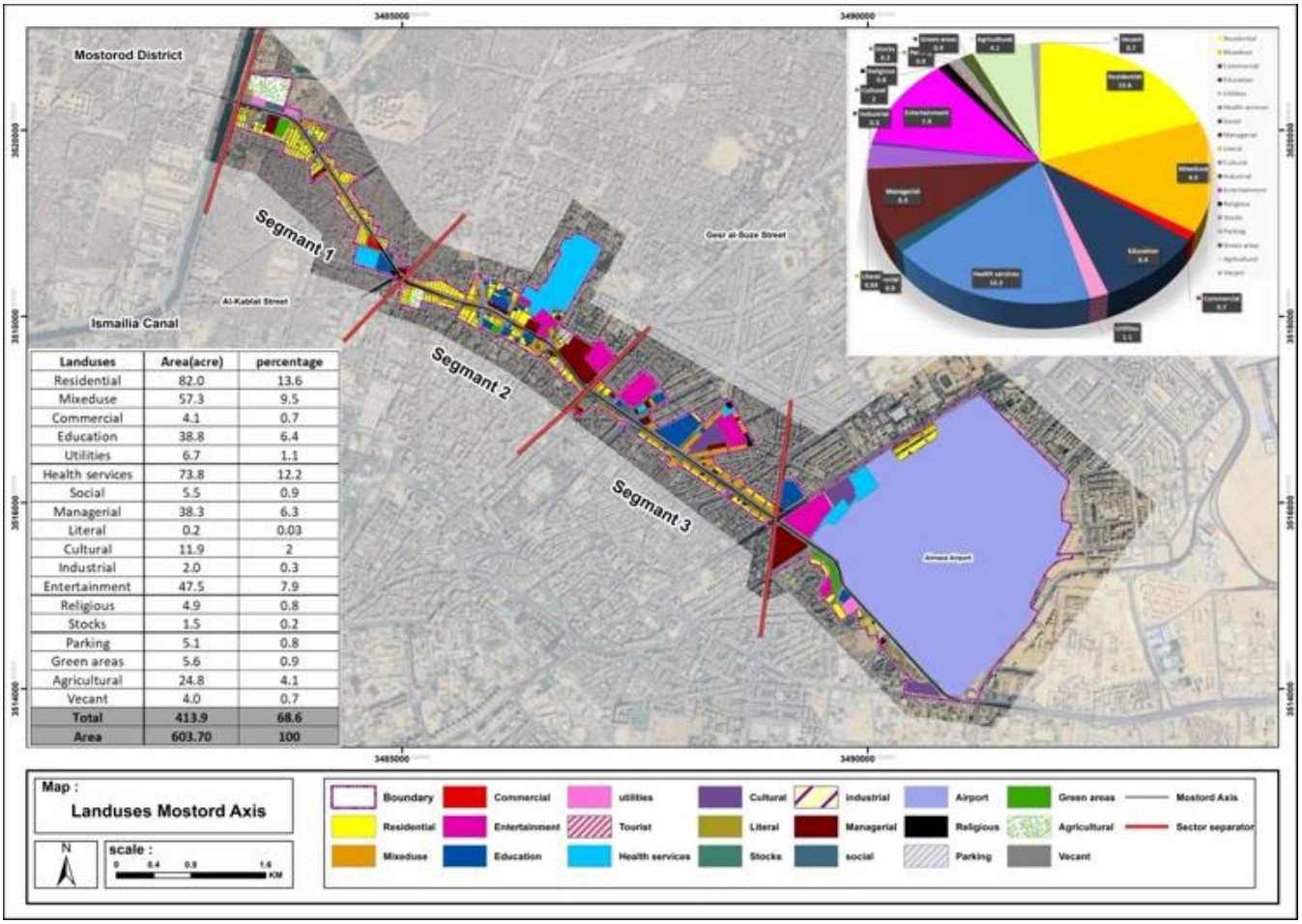
The development in the Ain Shams corridor has been driven by the burgeoning demand for commercial and residential spaces in the area. The carefully planned mix of land uses has contributed to the vibrancy of the corridor, making it a hub of activity and economic exchange. The presence of various businesses and services has not only provided convenience to the residents but has also attracted visitors and workers from other parts of the Greater Cairo Metropolitan Region.

The transportation infrastructure plays a crucial role in facilitating the movement of people within the corridor. The well-connected network of roads, along with the availability of public transit options, ensures that the area remains accessible despite the heavy local traffic. Additionally, the presence of bus stops and microbus stops serves as vital nodes for commuting, catering to the transportation needs of the densely populated region.

Moreover, the spatial distribution of land uses and population densities, as depicted in Figure 5, showcases the intricate interplay between urban planning and demographic patterns. The clustering of

different land use types reflects the deliberate arrangement of commercial, residential, and service-oriented spaces to cater to the diverse needs of the population. Similarly, the varying population densities across different areas within the corridor underscore the dynamic nature of urban settlement and the nuanced distribution of inhabitants across the landscape.

Overall, the Ain Shams corridor stands as a prime example of effective urban planning and development, showcasing a harmonious integration of diverse land uses, robust transportation infrastructure, and responsive spatial organization to meet the needs of a burgeoning population within the Greater Cairo Metropolitan Region.



Landuses	Area(acre)	percentage
Residential	82.0	13.6
Mixeduse	57.3	9.5
Commercial	4.1	0.7
Education	38.8	6.4
Utilities	6.7	1.1
Health services	73.8	12.2
Social	5.5	0.9
Managerial	38.3	6.3
Literal	0.2	0.03
Cultural	11.9	2
Industrial	2.0	0.3
Entertainment	47.5	7.9
Religious	4.9	0.8
Stocks	1.5	0.2
Parking	5.1	0.8
Green areas	5.6	0.9
Agricultural	24.8	4.1
Vecant	4.0	0.7
Total	413.9	68.6
Area	603.70	100

Figure 5. Ain Shams Corridor land uses distribution (Researcher, 2024)

4.6. Traffic Study Methodology

In order to test the research hypothesis, a comprehensive quantitative analysis will be conducted to examine the traffic flow through the Ain Shams corridor. This analysis will specifically focus on distinguishing between local car units and passing-through car units traveling from west to east. The methodology for this analysis is as follows:

Firstly, we will employ Geographic Information System (GIS) technology to thoroughly assess and estimate the land uses on both sides of the corridor. This will allow for a detailed understanding of the spatial distribution of different land uses in the area.

Subsequently, the corridor will be divided into three distinct segments based on the homogeneity of socio-economic aspects and the nature of land uses on both sides. This division will be illustrated in a designated figure for clarity.

Furthermore, specific count points will be identified at the beginning and end of each segment, particularly at the bridge locations over cross junctions. These count points will enable us to effectively separate local circulation from passing-through traffic and obtain accurate traffic flow data for analysis and comparison figure 6 and 7.

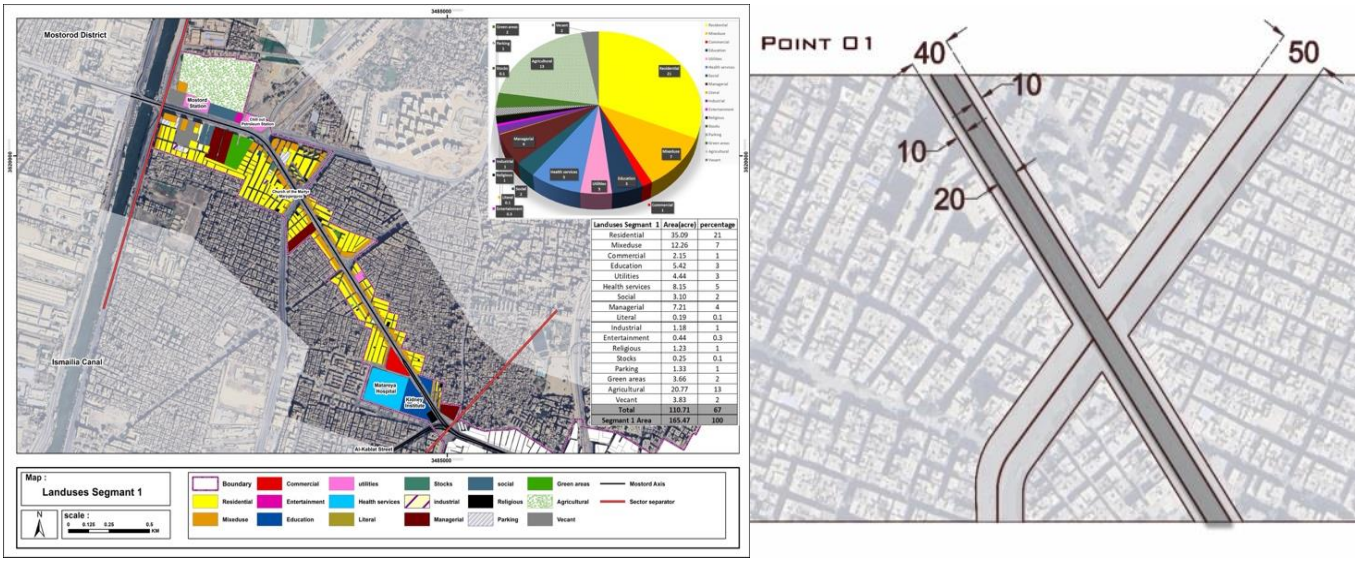


Figure 6. Ain Shams Corridor segment 1 (Mostord- Mataria) land uses and Traffic Study point (Researcher, 2024).

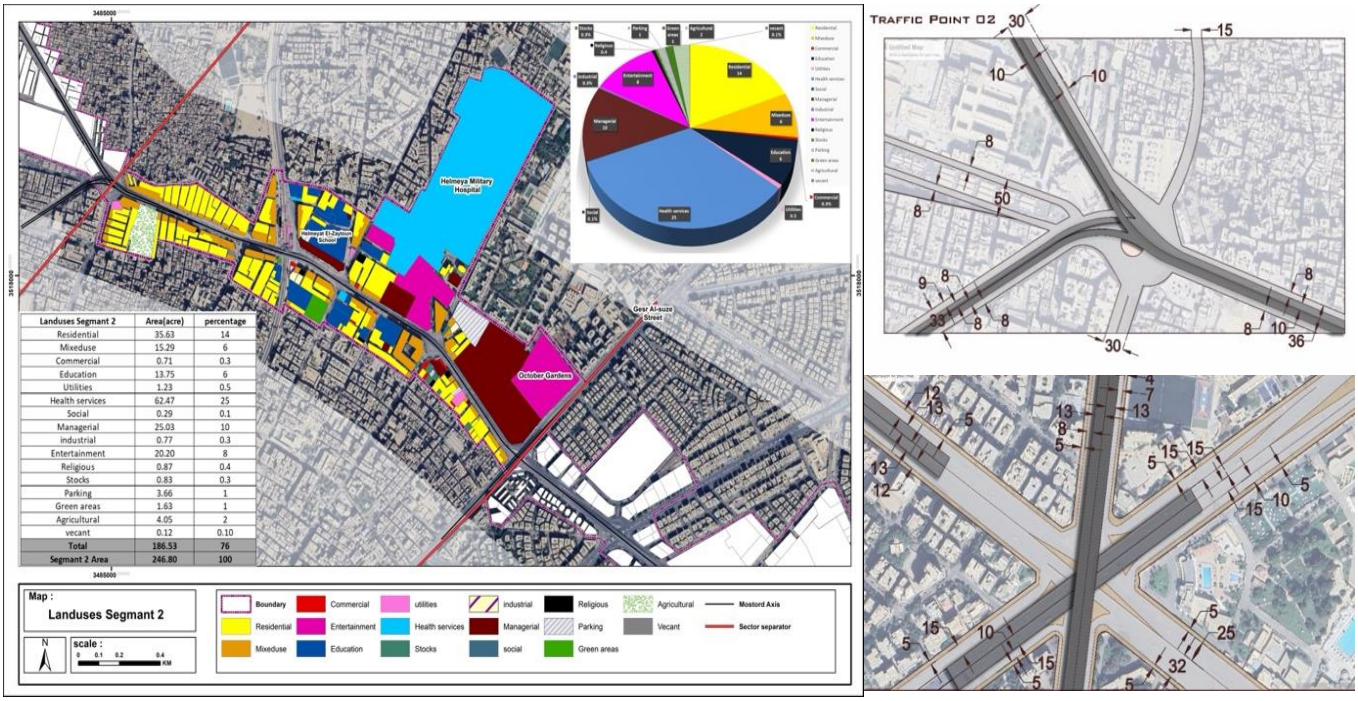
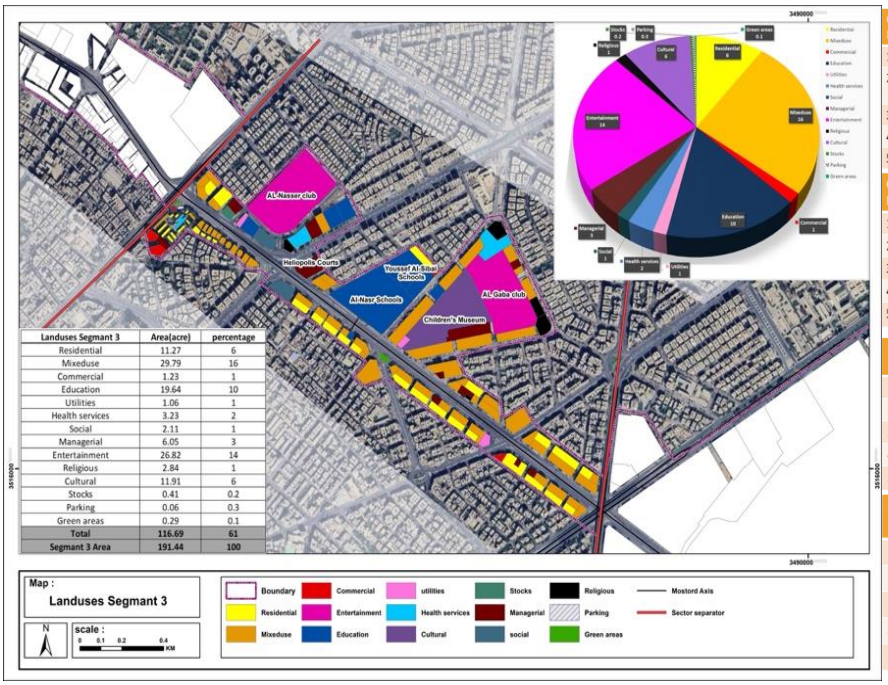


Figure 7. Ain Shams Corridor segment 2 (Ain shams- Gesr Elsuez crossing) land uses and Traffic Study point (Researcher, 2024).

The construction work has led to a 35% reduction in road width, primarily due to the installation of new bridges to facilitate through traffic. This has resulted in a negative impact on the traffic lanes designated for local movement. The study indicates that only 35-40% of the total traffic in both directions utilizes the corridor for through traffic from west to east GCMR. The remaining 60% experiences congestion in a single lane in each direction, highlighting significant traffic management challenges. The heavy mixed-use development on both sides of the corridor significantly contributes to heavy local traffic. The daily operation of restaurants, supermarkets, and other commercial activities has intensified the local traffic flow. Additionally, the lack of service roads and inadequate parking spaces in both directions further exacerbate the inefficiency of the corridor, warranting the need for comprehensive measures to address these shortcomings.



Landuses Segmant 3	Area(acre)	percentage
Residential	11.27	6
Mixeduse	29.79	16
Commercial	1.23	1
Education	19.64	10
Utilities	1.06	1
Health services	3.23	2
Social	2.11	1
Managerial	6.05	3
Entertainment	26.82	14
Religious	2.84	1
Cultural	11.91	6
Stocks	0.41	0.2
Parking	0.06	0.3
Green areas	0.29	0.1
Total	116.69	61
Segmant 3 Area	191.44	100

Count Points	Land Mark	Corridor Counts	Local Counts	Total
1	Mostorod	1400	2700	4100
2	Matria Square	1800	3200	5000
3	Helmia Crossing	2200	3800	6000
4	Gesr Suez Crossing	2600	4100	6700
5	Almaza Airport	1900	2900	4800

Count Points	Land Mark	Corridor Counts	Local Counts	Total
1	Mostorod	1400	2100	3500
2	Matria Square	1650	2400	4050
3	Helmia Crossing	2050	2900	4950
4	Gesr Suez Crossing	2300	3100	5400
5	Almaza Airport	2100	2700	4800

Count Points	Land Mark	Local Counts	Total
1	Mostorod	60	40
2	Matria Square	59	41
3	Helmia Crossing	59	41
4	Gesr Suez Crossing	57	43
5	Almaza Airport	56	44

Count Points	Land Mark	Total % of Local Counts	Total % of corrider Counts
1	Mostorod	66	34
2	Matria Square	64	36
3	Helmia Crossing	63	37
4	Gesr Suez Crossing	61	39
5	Almaza Airport	60	40

Figure 7. Ain Shams Corridor segment 3 (Gesr Elsuez- Alamaza) land uses and Traffic Study point and traffic Study results (Researcher, 2024).

5. Discussions

The main aim of analyzing traffic networks is to understand the connection between travel behavior patterns of users and the constantly changing network in a logical manner. Despite extensive research on predicting congestion and optimizing routes, there is still a lack of understanding regarding how congestion clusters are determined. Properly assessing congestion clusters in urban road networks and establishing the correlation between them holds both practical and theoretical significance in improving traffic operation efficiency. Monitoring the entire urban traffic network is expensive, and not all parts are consistently congested. Therefore, this approach offers flexibility to cater to the needs of cities. This method involves identifying areas where congestion pockets occur and then conducting analyses that allow for an assessment of the traffic condition across the entire urban network.

traffic is influenced by land use, and changes in land use can lead to different types of traffic movements. Similarly, London's Blunden notes that traffic serves as the link between the transport system and land use. Both elements are responsible for generating traffic, as changes in land use can create specific traffic patterns, while transport infrastructure developments can also generate traffic to specific

areas. This, in turn, can lead to the emergence of new uses and activities in the area, such as the establishment of factories or tourist attractions. Research in urban transport planning has emphasized the crucial role of transportation in people's daily lives, providing mobility within and outside the city. The economic structure of a community relies on transportation and mobility infrastructure, encompassing various modes of transport. Given the close relationship between urban land use and traffic, comprehensive data on traffic conditions, public transport, land use, population, economic activities, social dynamics, and urban services is essential for effective planning and development of urban areas, particularly in relation to highway schemes.

The field of transportation planning in the GCMR has made significant progress compared to earlier phases at the beginning of the 21st century. Evidence shows the implementation of road works, bridges, and regional corridors, focusing on promoting mass transit transportation. The introduction of a regional secondary ring road around the GCMR, as well as the movement corridor connecting the new cities around Cairo, including the Ain Shams corridor linking south GCMR new settlements and the ring road with the northern part of GCMR and extending to the New Cairo settlement and New Capital City, represents noteworthy developments. Nevertheless, there remains a noticeable absence of a definitive long-term policy in transportation planning. Planning decisions such as creating urban traffic corridors without considering the socio-economic and physical consequences on the adjacent areas to that corridor are considered reckless planning, as they are not based on thorough traffic studies but are mainly driven by political decisions.

The study found that only 35-40% of the total traffic in both directions utilizes the corridor for through traffic from west to east GCMR. This indicates that a significant portion of the remaining 60% experiences congestion in a single lane in each direction, highlighting the presence of significant traffic management challenges. The heavy mixed-use development on both sides of the corridor notably contributes to heavy local traffic. The daily operation of restaurants, supermarkets, and other commercial activities has intensified the local traffic flow, adding to the congestion issues.

In addition to the local traffic congestion, the lack of service roads and inadequate parking spaces in both directions further exacerbate the inefficiency of the corridor. These shortcomings warrant the need for comprehensive measures to address the traffic management challenges and improve the overall efficiency of the corridor. The current state of the corridor necessitates thoughtful planning and strategic interventions to alleviate congestion and enhance the traffic flow.

6. Conclusions

The economic structure of a community relies on transportation and mobility infrastructure, encompassing various modes of transport. Given the close relationship between urban land use and traffic, comprehensive data on traffic conditions, public transport, land use, population, economic activities, social dynamics, and urban services is essential for effective planning and development of urban areas, particularly about highway schemes.

The consideration of transport issues at the planning stages is paramount, particularly the necessity to integrate transport planning with land-use planning to achieve sustainable urban development in the GCMR. Integrated planning is especially critical for new towns and urban expansions. For example, the construction of a new ring road to connect the city with new towns must carefully consider the consequential impacts on land-use change in these areas. Rather than solely prioritizing connectivity, it may be more prudent to devise policies aimed at enhancing job opportunities in new towns, thereby reducing daily commuting on the ring road.

Sustainable development heavily relies on transport resulting from land use and urban growth. It is imperative to establish a cohesive link between land use, transport, and the environment, ensuring that short and medium-term transport plans align with long-term environmental and economic objectives.

Regrettably, there exists a disparity between the endorsement of studies and the actualization of their findings. For instance, in the GCMR, a mere 15% of over 60 transport-related studies conducted between 1975 and 2000 were implemented. This discrepancy presents a significant challenge for Egypt.

the involvement of high-level decision-makers and local councils is crucial in establishing an effective long-term urban transportation policy, which is currently lacking in the GCMR corridors. Therefore, it is imperative to establish an institutional framework for policy formulation, monitoring, and maintenance of the requisite information system to facilitate urban transport development conducive to sustainable urban growth. The study of the Ain Shams Corridor reveals several important lessons; while it may facilitate the passage of traffic traveling from south to north GCMR, the negative impact on local area traffic problems has become a major concern for local travelers, who make up at least 65% of daily travel. This contradicts the main goal of traffic management, which is meant to facilitate daily travel as much as possible.

The study indicates that only 35-40% of the total traffic in both directions utilizes the corridor for through traffic from west to east GCMR. The remaining 60% experiences congestion in a single lane in each direction, highlighting significant traffic management challenges. The heavy mixed-use development on both sides of the corridor significantly contributes to heavy local traffic. The daily operation of restaurants, supermarkets, and other commercial activities has intensified the local traffic flow. Additionally, the lack of service roads and inadequate parking spaces in both directions further exacerbate the inefficiency of the corridor, warranting the need for comprehensive measures to address these shortcomings.

The findings underscore the critical importance of addressing the congestion and traffic management challenges in the corridor. The significant imbalance in through traffic and local traffic distribution necessitates a focused approach to alleviate congestion and improve traffic flow. It is imperative to consider the diverse factors contributing to the heavy local traffic, including the ongoing commercial activities and mixed-use development along the corridor.

Furthermore, the study reinforces the importance of comprehensive measures to enhance the efficiency of the corridor. Implementing solutions such as dedicated service roads, improved parking infrastructure, and optimized traffic management strategies can play a pivotal role in mitigating congestion and addressing the specific needs of local traffic. By addressing these challenges, the corridor can achieve improved functionality, accommodate the diverse traffic demands, and enhance the overall transportation experience for commuters and businesses alike.

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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.

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Studies involving animal subjects: No animal studies are presented in this manuscript.
Studies involving human subjects: No human studies are presented in this manuscript.
Inclusion of identifiable human data: No potentially identifiable human images or data is presented in this study.

Conflict of Interests

The author declares no conflict of interest.

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Optimizing Indoor Comfort and Energy Efficiency using Right-Angled Triangular Responsive Facades in Cairo, Egypt

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ABSTRACT

Building energy consumption has been rapidly increasing in recent years due to several factors such as climate change and global population growth. Besides, the majority of buildings are not designed with the consideration of the alteration of the severe conditions of the external surrounding environment, which affects the indoor environment negatively. As a result, excessive HVAC systems are utilized in order to maintain the indoor environment and achieve the indoor human comfort. Thus, large amounts of energy are being consumed and the rates of the energy consumption are increasing rapidly. Responsive architecture is considered as one of the solutions that architects, and façade designers use in order to block the excessive solar radiation and direct natural light and thus enhance the indoor comfort zone. However, the majority of the façade's pattern designs are not following specific guidelines. This study contributes to the field by identifying an optimal right-angled triangular façade design that effectively enhances indoor thermal comfort, reduces solar radiation, and minimizes energy consumption, thereby providing a practical solution for improving building performance in response to climate change and urban growth challenges. This article will study four different façade pattern cases, which are common in the rotational movement, façade orientation and pattern dimensions; however, they differ in the orientation of the axes of movement. The four-façade pattern proposals will be investigated through simulating the solar radiation, consumed cooling energy and the indoor operative temperature during the maximum solar exposure day. A comparative analysis will be conducted between the results in order to highlight the most efficient right-angled triangular pattern that can be used on the south façade in Cairo, Egypt in order enhance the indoor thermal comfort, enhance the energy consumption rates, reduce the solar radiation and improve the building performance.

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1. Introduction

The rapid increase in building energy consumption, driven by climate change and global population growth, poses significant challenges to sustainable architecture and urban living. Many existing buildings fail to account for the severe external environmental conditions, leading to a reliance on excessive HVAC systems to maintain indoor comfort, which in turn exacerbates energy consumption issues. This study addresses these pressing problems by investigating the potential of responsive architecture, specifically through the design of façade systems that can adapt to environmental conditions.

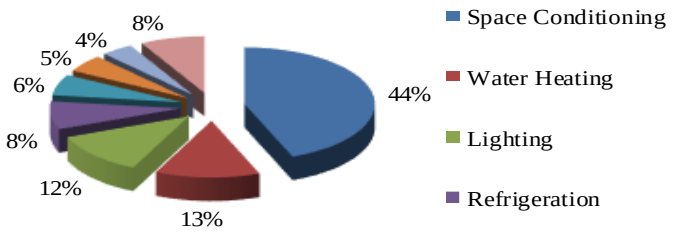


Figure 1. Building Energy Consumption by Type
(Source: Thermal Comfort: Designing for People, 2022)

The significance of this study lies in its aim to identify an optimal right-angled triangular façade design that enhances indoor thermal comfort while minimizing solar radiation and energy consumption. This research is vital as it not only contributes to the development of more sustainable building practices but also offers practical solutions that can significantly reduce the environmental impact of buildings in urban settings, particularly in regions like Cairo, Egypt, where extreme solar exposure is prevalent.

To achieve the objectives of this study, several research questions will be explored: What are the most effective façade configurations for maximizing indoor comfort? How do different façade patterns influence energy consumption and solar radiation absorption? What design guidelines can be established for future façade designs based on the findings of this research?

The paper begins with a comprehensive literature review on responsive architecture, outlining the current state of knowledge and identifying gaps in façade design practices. Following this, the methodology employed in this study will be described, including the design tools and software used to simulate different façade patterns. A comparative analysis of four distinct façade configurations will be conducted to determine the most efficient design for maximizing indoor thermal comfort and minimizing energy use. Ultimately, the findings will provide insights into effective façade design strategies that can enhance building performance and address the urgent energy challenges facing the built environment today.

2. Research Background

Worldwide, the rates of energy consumption have been increasing rapidly due to the global population growth and their power consumption, manufacturing power demands, climate changes and other several aspects. According to the international energy agency in 2021, buildings consumed 35 % of the global energy consumption. Energy consumption in buildings increased from 115 EJ in 2010 to 135EJ in 2021. Moreover, the carbon emissions by buildings increased by 5% in 2021 more than the emission in 2020. Nevertheless, energy consumed due to space cooling has increased three times since 1990. The energy consumed due to cooling loads in 2021 records the highest annual growth compared to the previous years (International Renewable Energy Agency, 2023). Energy is consumed in order to maintain the indoor comfort and thus cool or heat the buildings. HVAC systems are consuming 44 % of the building energy, as shown in figure (1). Thus, there is huge demand of designing buildings, which consumes less energy, and improving the air conditioning systems (Ardente et al., 2020).

Many researchers defined the building skin as the boundary where the building interact with the surrounding mediums. It reacts with the air, light, sun, moisture, heat and sound. It has the ability to maintain and control the indoor comfort conditions. Moreover, building skin is defined as the layer where the exchange of the energy and materials occurs in (Tabasi & Banihashemi, 2020). A well-designed shading technique on the building skin can protect the building from the alteration of the surrounding environment such as, direct solar gain, direct sunlight, glare, the extreme temperature and humidity. By designing an efficient skin, the indoor comfortable parameters can be maintained and thus the energy consumed can be controlled (Wang, Zhang, Tang, & Li, 2018). The majority of the buildings is static and fixed entities. However, buildings need to be designed to adjust to the unpredictable changes of the surrounding environment. The changes in climate, behavior and user's demand require building's flexibility and adaptation capacity. In order to maintain a stable comfortable interior environment, buildings that adjust to the outdoor environment are demanded. Although buildings need stability in their structure and elements, they are required to be designed to seek equilibrium using elements that depend on frequent adjustment in order to maintain variable meteorology (Preiser, Hardy, & Wilhelm, 2017).

3. Literature Review

3.1. Responsive Architecture

Responsive architecture is defined as "Buildings or building components that can adapt to external influences, external conditions, and the overall external environment (Mohamed, Abd El-Rahman, & Sadek, 2023). The building and its elements use physical states and force effects (light, heat, humidity, noise) in the form of sun, wind, and rain. These effects are used to change building elements or the building as a whole and to sensitively adapt in creating appropriate (self-sustaining, self-healing) sustainable architecture, buildings, and environments" (Katunsky & Huang, 2019). As the computer has a significant impact on the built environment, automated building components have been integrated in façade systems as a solution for decreasing the energy consumption and maintaining the indoor comfortable level. As an example of the automated building components, automated shading devices are used to control the solar radiation entering the building (Preiser, Hardy, & Wilhelm, 2017). Responsiveness in Architecture can be divided into two categories; either reshaping the building's elements to adapt the user's interaction or adapting to the interior and exterior environment. The two typologies can be achieved by changing the façade's pattern or by changing the material's properties, as shown in figure (2). The changing in the façade's pattern is called active system; however, the changing in the material's properties is called passive system (Kızılörenli & Maden, 2021). The article will focus on changing the façade's pattern in order to adapt to the interior and exterior environment.

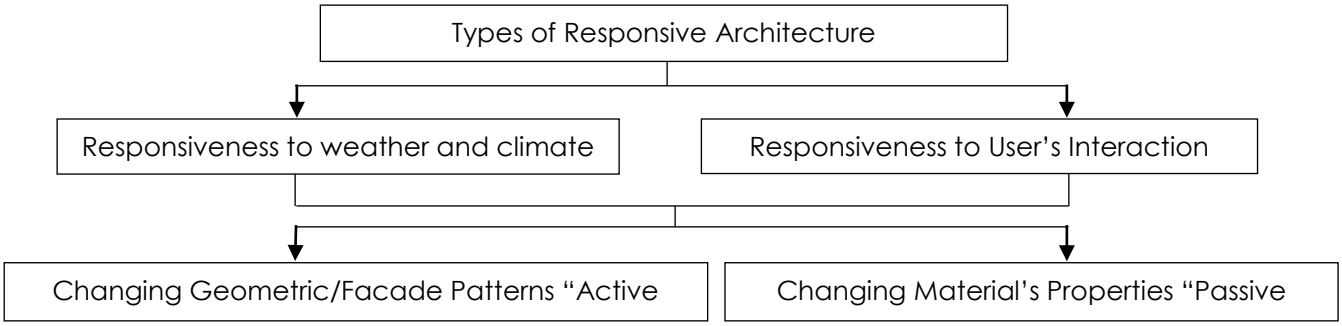


Figure 2. Types of Responsive Architecture (Source: Developed by Authors, 2024)

3.2. Climatic Conditions in Egypt

Climatic conditions of a region define its ecology, water availability, species distribution, land suitability for building and construction (Konapala, Mishra, Wada, & et al., 2020). Thus, classification of regions based on climate is crucial for development planning and building implementation. As a result, different climate variables such as temperature, humidity and rainfall, are being studied as the main contributor of the climate classification in order define and classify some geographical regions (Sa'adi, Shahid, & Shiru, 2021). In Cairo, the length of the day varies significantly over the year. As shown in figure (3), December 21 is considered the shortest day with 10 hours and 13 minutes of solar radiation, however, June 21 is considered the longest day of the year with 14 hours and 5 minutes of solar radiation (El-Shazly, 2021). As shown in figure (4), 4:35 am is the earliest sunrise on June 11, however the latest sunrise

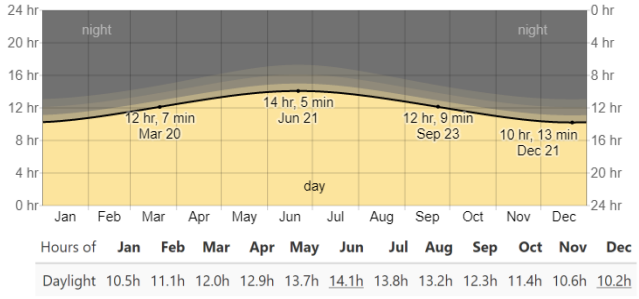


Figure 3. Hours of Daylight and Twilight in Cairo, Egypt (Source: Climate and Average Weather Year-round in Cairo, 2024)

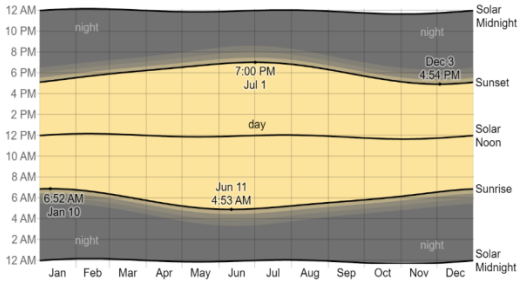


Figure 4. Hours of Daylight and Twilight in Cairo, Egypt (Source: Climate and Average Weather Year-round in Cairo, 2024)

is at 6:52 am on January 10. Moreover, 4:54 pm is the earliest sunset on December 3 and 7:00 pm is the latest sunset on July 1 (El-Shazly, 2021).

3.3. Selected Comfort Index

Human comfort is defined as the ways the space user perceives and feels towards the environment of a specific space. Space occupant perceives the indoor environment based on their health, productivity and wellbeing. The indoor human comfort is based on four aspects, thermal comfort, visual comfort, acoustic comfort and respiratory comfort (Song, Mao, & Liu, 2019). This study will focus on the thermal comfort aspect as it is considered as the most crucial aspect for the human comfort compared to visual, acoustic and respiratory comfort parameters. It was proved that thermal comfort has a greater influence on the space user's satisfaction (Solano, Caamaño-Martín, Olivieri, & Almeida-Galarraga, 2021).

Thermal comfort is defined as "a condition of mind that expresses satisfaction with the thermal environment in which it is located" based on ISO Standard 7730 (1994) and ASHARE Standard 5 (Chow, 2017). ASHRAE is a professional association, that defines guidelines and standards for thermal comfort. Moreover, thermal comfort is considered as the main factor of the operation of the HVAC systems in buildings [14]. HVAC systems consume 44 % of building energy (Ardente et al., 2020). By controlling thermal comfort inside buildings and thus reducing the HVAC systems, the energy consumed during the operational phase of the buildings can be reduced. As a result, the study will focus on the thermal comfort aspect in order to propose solutions for reducing the excessive energy consumed by buildings and thus enhance the building performance.

4. Research Methodology

4.1. Research Design

As shown in Figure (5), the research is composed of four sections, each aimed at investigating and analyzing the optimal right-angled triangular facade design that enhances indoor thermal comfort, reduces solar radiation, and improves energy consumption rates. The following sections outline the approach taken in this study:

Stage one: a comprehensive literature review on responsive architecture and climatic conditions in Egypt was conducted to establish a solid foundation for the research.

Stage two: the research selected a comfort index as well as identified the simulation model's spatial configuration where simulations were carried out to compare the selected comfort index with and without various proposed responsive facades.

Stage three: a comparative analysis was performed to evaluate the results and determine the optimal right-angled triangular facade design for enhancing indoor comfort and reducing energy consumption.

Stage four: discussion and analysis of the results were conducted in order to highlight the most efficient façade proposal in terms of reducing the solar radiation, improving the indoor thermal comfort and enhancing the building performance. This methodology ensures a systematic and comprehensive analysis of responsive facade patterns in Cairo, Egypt.

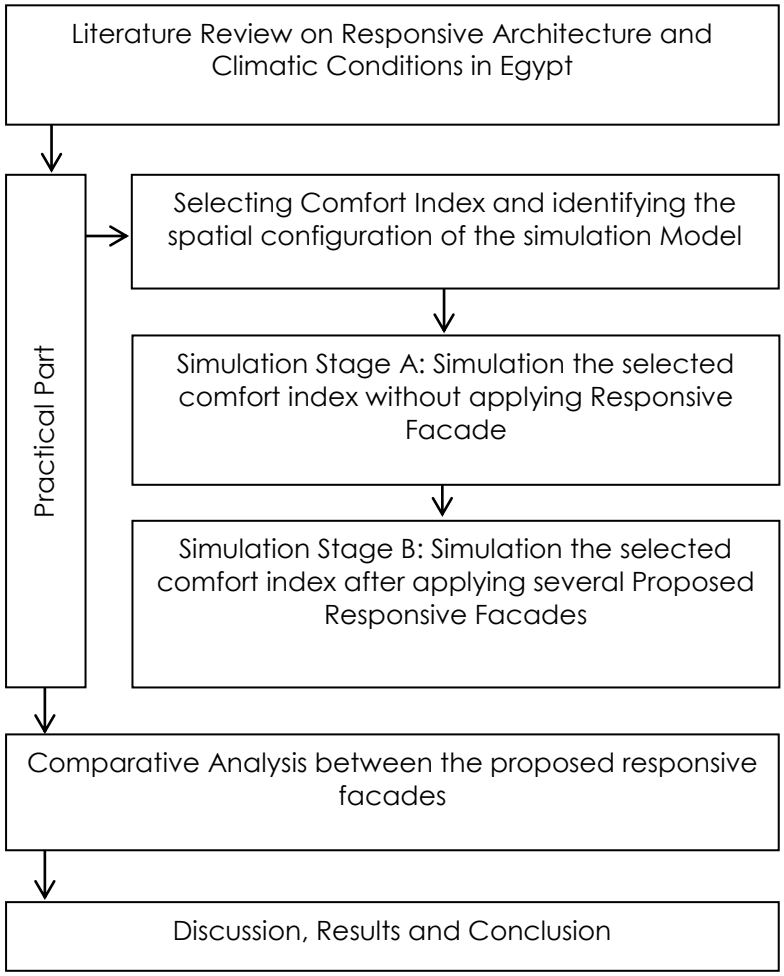


Figure 5. Research Methodology (Source: Developed by Authors, 2024)

4.2. Spatial Configurations of the simulation Model

The simulation model is located in New Cairo district, Cairo city in Egypt, as shown in figure (6). The simulation model

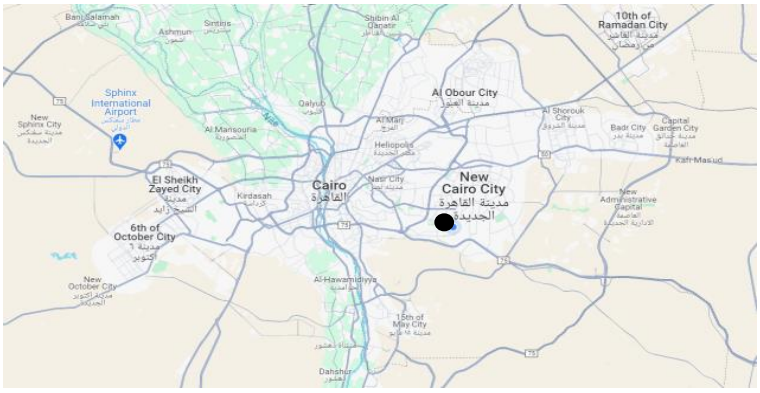
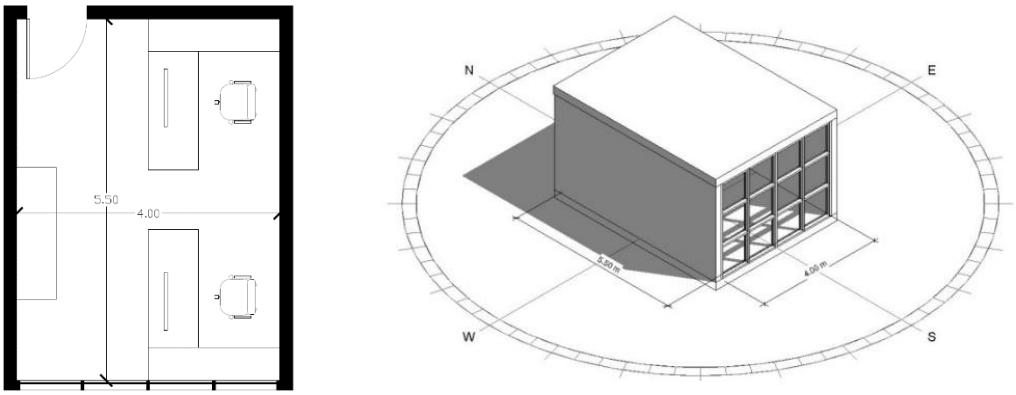


Figure 6. Empirical Case Study Location (Source: Developed by Authors, 2024)

is an office room with the below specifications, as shown in figure (7),

- Room Clear Dimensions: 4 meters * 5.5 meters
- Room Clear Height: 3 meters
- Window Dimensions: The window will be located on the south façade with a full coverage of the façade. The dimensions of the window 4m*3m
- Room Accessibility: Wooden Door with dimensions of 0.9m width and 2.2m height, located on the East Wall.
- Room Occupancy: Two users
- Room Furniture: Two chairs, two desks and one shelve
- Room Equipment: Two computers

The selected dimensions and specifications of the case study are derived from "Office space standards and guidelines" book, where it specified that the footprint for an office that occupies two users should be 22 square meters (Baker & Hutton, 2019).



Top View Dimensions are in meters 3D View

Figure 7. Empirical Case Study Specification (Source: Developed by Authors, 2024)

4.3. Methods and Simulation Tools

The empirical Study is carried out using Rhino 7, Grasshopper 11.2 Plugin, Ladybug 0.0.69 Plugin and Honeybee 0.0.69 Plugin. A shown in figure (8), the simulation process on Grasshopper plugin was divided into several stages. The first stage, each proposed responsive façade was created through an explicit script. Afterwards, the empirical room was created were the Honeybee zone, room program, room HVAC system and room construction material were defined. The room program and HVAC system were set according to ASHREA 90.1 2019. Then, the simulation process was implemented where the solar radiation, cooling energy as well as operative temperature were investigated.

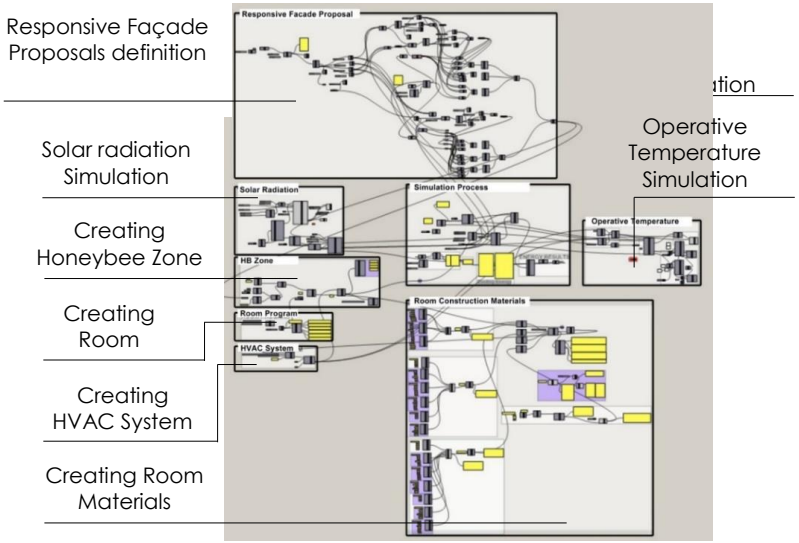


Figure 8. Empirical Study Simulation Grasshopper Definition (Source: Developed by Authors, 2024)

5. Research Analysis

The thermal comfort simulation is divided into two stages. In stage A, the solar radiation, room operative temperature and the cooling energy required for maintaining the indoor thermal comfort is examined without applying responsive façade on the south window façade. However, in stage B the same parameters after applying several responsive proposed facades on the south glazed façade will be examined. The two stages will be carried out in order to investigate the effect of the proposed responsive facades on the window façade as well as identifying the most efficient proposal in enhancing the thermal comfort, reducing the solar radiation, minimizing the cooling energy and improving the building performance.

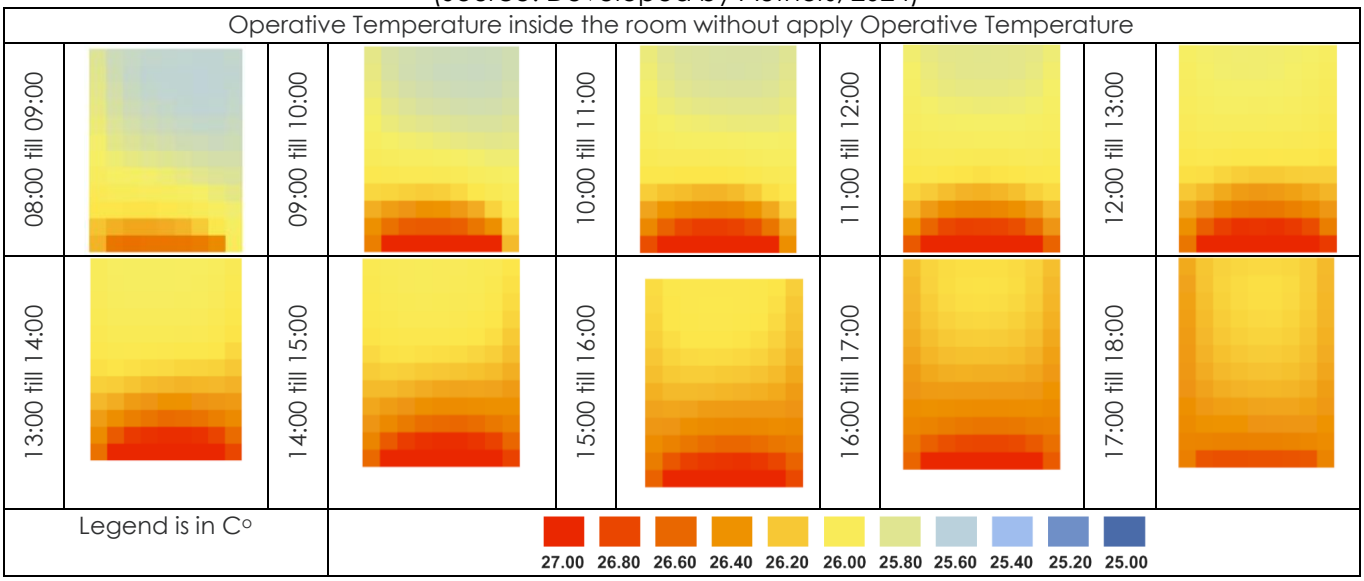
5.1. Thermal Comfort Without Applying Responsive Façade

Solar radiation on the south glazed façade as well as the cooling energy is simulated on June 21 without applying any proposed responsive façade, starting from 08.00 am till 06.00 pm with an hour interval time, as shown in table (1). Besides, the operative temperature consuming the cooling energy to maintain thermal comfort inside the room is simulated, as shown in table (2).

Table 1. Solar Radiation and Cooling Energy Analysis without applying Responsive Façade (Source: Developed by Authors, 2024)

Time During the Day	Solar Radiation on the Window Façade (KWh)	Cooling Energy (KWh)
08:00 till 09:00	2.254	0.557
09:00 till 10:00	3.187	0.595
10:00 till 11:00	4.202	0.688
11:00 till 12:00	4.362	0.783
12:00 till 13:00	4.071	0.814
13:00 till 14:00	4.018	0.905
14:00 till 15:00	3.507	0.974
15:00 till 16:00	2.523	1.008
16:00 till 17:00	1.819	1.024
17:00 till 18:00	1.493	0.955
Total during the day	31.436	8.303

Table 2. Operative Temperature inside the Room without applying Responsive Façade
(Source: Developed by Authors, 2024)



As shown in table (1), the solar radiation intensity differs during the day starting from 08:00 am till 06:00 pm, where the solar radiation is at its highest from 10.00 am till 14.00 pm, however the solar radiation is at its lowest from 5.00 pm till 06.00 pm. The responsive facades designs proposed by the research rotates around their axis of movement in order to block the entrance of the solar radiation and thus reduce the cooling energy and enhance the indoor operative temperature. According to the solar radiation and the cooling energy results, a grasshopper remapping process was done in order to create the moving angles of the proposed responsive facades, as shown in table (3). The results of the remap process were transformed to the nearest 15 degrees. The same proposed angles of movement will be used for the responsive façade proposals.

Table 3. Proposed angles of movement for the responsive façade proposals
(Source: Developed by Authors, 2024)

Axis of Movement of the Proposed Responsive Facades										
Time during the Day	08:00 till 09:00	09:00 till 10:00	10:00 till 11:00	11:00 till 12:00	12:00 till 13:00	13:00 till 14:00	14:00 till 15:00	15:00 till 16:00	16:00 till 17:00	17:00 till 18:00
Grasshopper Remapping Angles	66.1°	36.9°	5°	0°	9.1°	10.8°	26.8°	57.7°	79.7°	90°
Approximate Angles to the Nearest 15°	60°	30°	0°	0°	15°	15°	30°	60°	75°	90°

5.2. Thermal Comfort with Applying Proposed Responsive Façade

All the proposed responsive façade designs have the right-angled triangle properties. The research focused on investigating the right-angled triangle shape to applied in a responsive façade pattern. As the right-angled triangle is well-known for its simplicity in calculation. It allows for straightforward calculations using the Pythagorean theorem, which states that in a right triangle, the square of the

length of the hypotenuse is equal to the sum of the squares of the other two sides. This relationship simplifies many mathematical problems, especially in design and construction. Besides, in a right triangle, two squares can be inscribed such that they share a vertex at the right angle. This unique property allows for an efficient pattern design in terms of area and materials when designing structures that incorporate square patterns. Moreover, the right-angled triangle can be easily designed and embedded in both square and rectangular design patterns. This versatility makes them a popular choice in architectural designs and engineering applications (Khan & Ali, 2020).

After studying the properties of the right-angled triangle, it was concluded that the right-angled triangle can be applied in the pattern with two opposite diagonals, as shown in figure (9). Thus, the right-angled triangle with the rotational movement will be investigated using those two opposite diagonals. Besides, the two opposite diagonals will be studied on two different axes of movement, the vertical and the horizontal axes of movement, as shown in figure (9). The proposed pattern is designed within a 1m*1m rectangle. As the dimensions of the window on the south façade are 4m*3m, 12 motifs are created to cover the whole south glazed façade. Table (4) shows the movement of each proposed case according to the rotational movement. Moreover, table (6) shows that results of the solar radiation and the cooling energy required to maintain the thermal comfort zone after applying the proposed pattern of case 1. Moreover, table (7) shows the results of the operative temperature inside the room. Nevertheless, table (8) shows the operative temperature inside the room after applying the proposed responsive facades.

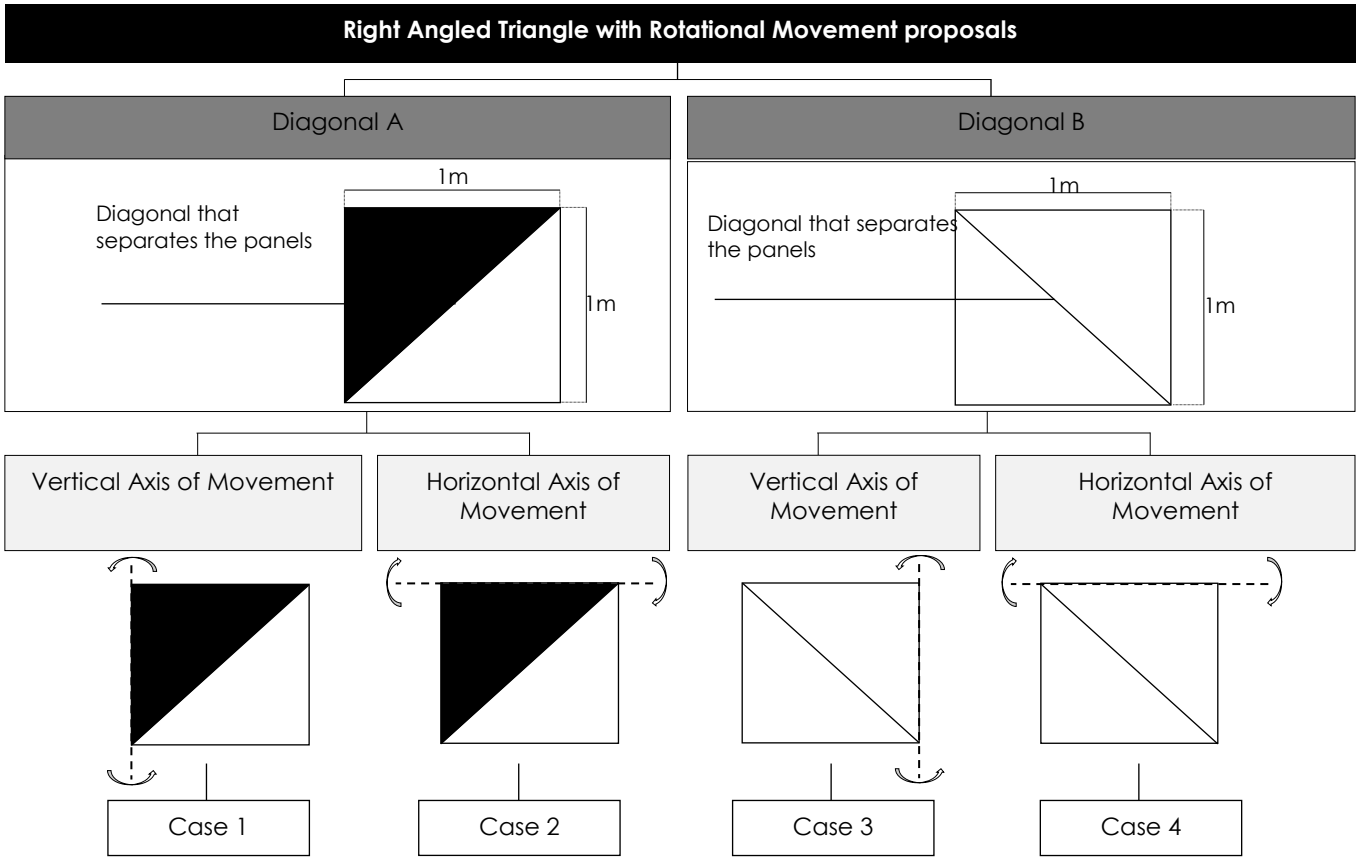
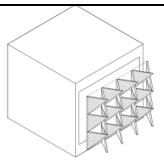
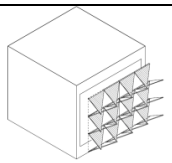
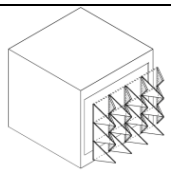
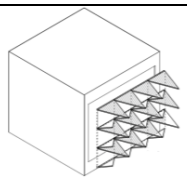
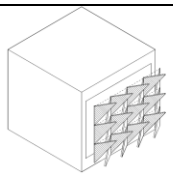
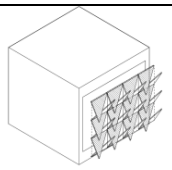
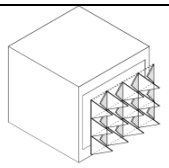
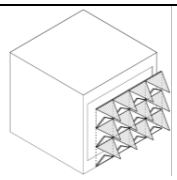
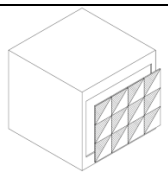
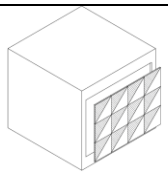
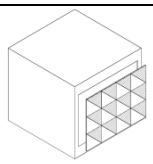
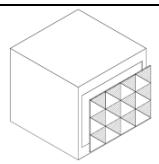
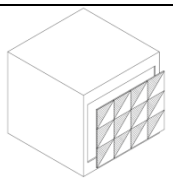
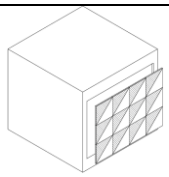
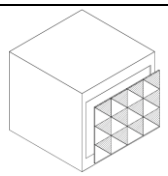
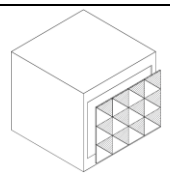
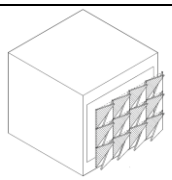
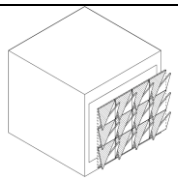
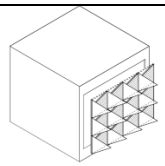
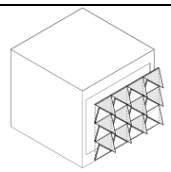
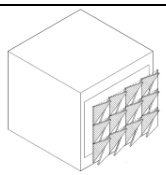
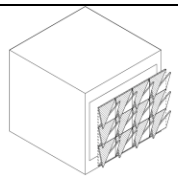
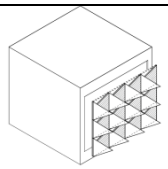
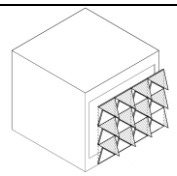
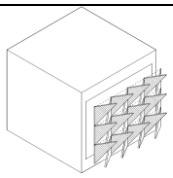
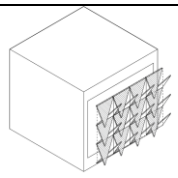
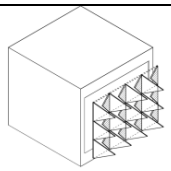
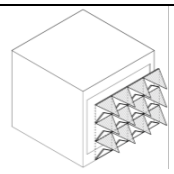


Figure 9. Right Angled Triangle with Rotational Movement Proposals (Source: Developed by Authors, 2024)

Table 4. Rotational Movements Configurations of the proposed Responsive Façade

Rotational Movements Configurations					
Time During the Day	Angle of Movement	Case 1	Case 2	Case 3	Case 4
08:00 till 09:00	60°				
09:00 till 10:00	30°				
10:00 till 11:00	0°				
11:00 till 12:00	0°				
12:00 till 13:00	15°				
13:00 till 14:00	15°				
14:00 till 15:00	30°				

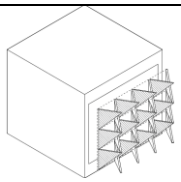
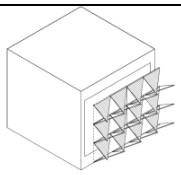
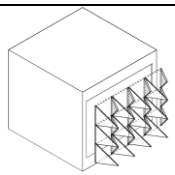
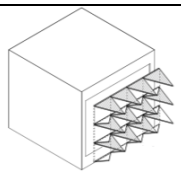
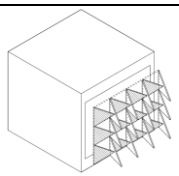
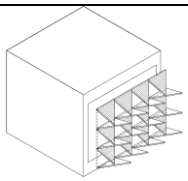
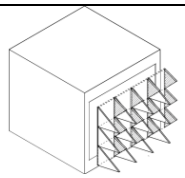
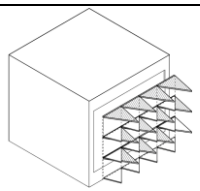
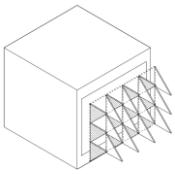
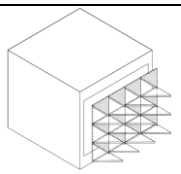
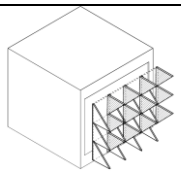
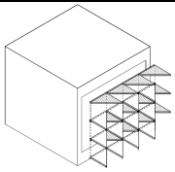
15:00 till 16:00	60°				
16:00 till 17:00	75°				
17:00 till 18:00	90°				

Table 5 shows a comparative analysis between the four proposed responsive façade designs where the four proposals rotate around their axis of movement starting from 08:00 till 18:00 with the same angle of rotation each one-hour interval of time. Besides, table 6 shows the results of the cooling energy after applying the four responsive facades proposals. Moreover, table 7 shows the operative temperature inside the room after applying the four proposed responsive façade designs.

Table 5. Solar Radiation Analysis Results after applying the investigated Responsive Façade (Source: Developed by Authors, 2024)

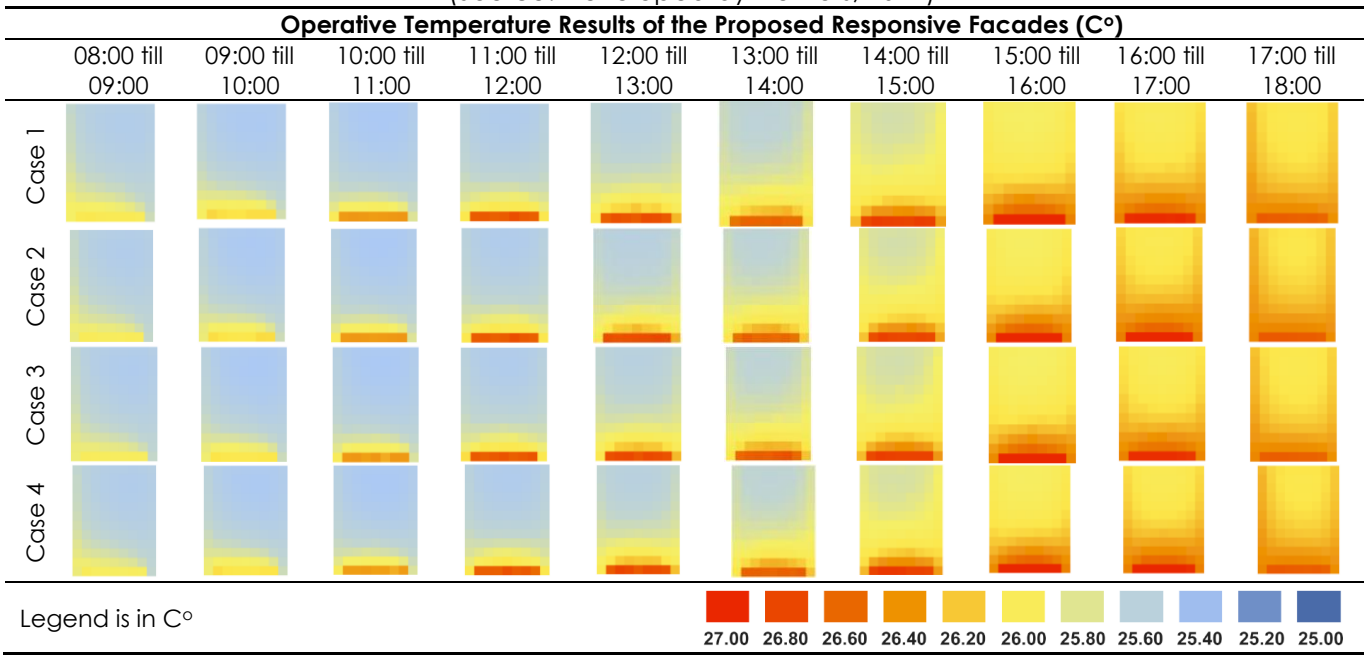
Solar Radiation Simulation Results of the Proposed Responsive Facades (KWh)					
Time During the Day	Angle of Movement	Case 1	Case 2	Case 3	Case 4
08:00 till 09:00	60°	1.204	1.138	1.178	1.108
09:00 till 10:00	30°	1.269	1.260	1.179	1.216
10:00 till 11:00	0°	1.191	1.191	1.191	1.191
11:00 till 12:00	0°	1.711	1.711	1.711	1.711
12:00 till 13:00	15°	2.338	2.349	2.334	2.354
13:00 till 14:00	15°	2.216	2.303	2.213	2.256
14:00 till 15:00	30°	1.913	1.979	1.971	1.903
15:00 till 16:00	60°	1.546	1.477	1.542	1.483
16:00 till 17:00	75°	1.066	1.130	1.037	1.087
17:00 till 18:00	90°	0.826	1.004	0.914	1.026
Total during the day		15.28	15.542	15.27	15.335

Table 6. Cooling Energy Analysis Results after applying the investigated Responsive Façade (Source: Developed by Authors, 2024)

Cooling Energy Simulation Results of the Proposed Responsive Facades (KWh)					
Time During the Day	Angle of Movement	Case 1	Case 2	Case 3	Case 4
08:00 till 09:00	60°	0.537	0.536	0.534	0.536
09:00 till 10:00	30°	0.552	0.550	0.549	0.551
10:00 till 11:00	0°	0.616	0.616	0.616	0.616
11:00 till 12:00	0°	0.713	0.713	0.712	0.712
12:00 till 13:00	15°	0.742	0.744	0.745	0.746
13:00 till 14:00	15°	0.826	0.828	0.830	0.830

14:00 till 15:00	30 ◦	0.905	0.904	0.902	0.907
15:00 till 16:00	60 ◦	0.967	0.969	0.963	0.966
16:00 till 17:00	75 ◦	0.991	1.002	0.982	0.999
17:00 till 18:00	90 ◦	0.932	0.943	0.930	0.940
Total during the day		7.781	7.805	7.763	7.803

Table 7. Operative Temperature Results after applying the investigated Responsive Façade (Source: Developed by Authors, 2024)



6. Discussion and Results

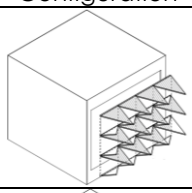
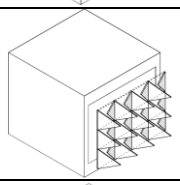
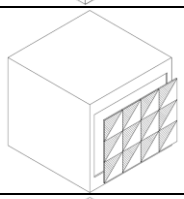
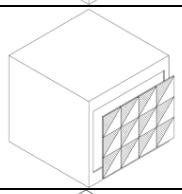
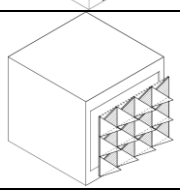
Energy consumption worldwide is rising rapidly due to factors like population growth, increased manufacturing demands, and climate change, with buildings alone accounting for 35% of global energy use in 2021 (International Renewable Energy Agency, 2023). Notably, energy for space cooling has tripled since 1990, and HVAC systems are responsible for 44% of building energy consumption (Ardente et al., 2020). This has led to a pressing need for energy-efficient building designs and improved air conditioning systems. The research focused on a right-angled triangular façade for a south-glazed building in Cairo, aiming to enhance indoor thermal comfort while minimizing solar radiation and energy consumption.

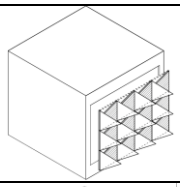
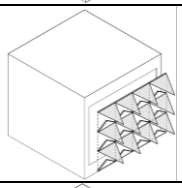
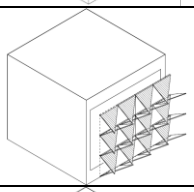
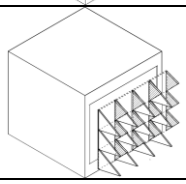
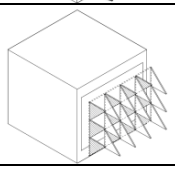
The study successfully achieved its initial hypotheses by demonstrating that implementing responsive façades can significantly reduce both cooling energies needs and solar radiation exposure. This is evidenced by the comparative analysis conducted between buildings equipped with the proposed responsive façades and those without. The study's hypotheses regarding the positive impact of the façade designs on energy efficiency and thermal comfort were supported by substantial findings.

The study proposed four different responsive façade designs that rotate around their axis of movement from 08:00 AM to 06:00 PM. The rotational angles were designed to change at hourly intervals based on solar radiation results obtained in Stage A. A remap process using Grasshopper allowed the four proposals to rotate from 0° to 90°, with a 15° increment at each hour. During peak solar radiation hours (10:00 AM to 12:00 PM), the façades were fully closed, while they opened completely during lower solar radiation periods (5:00 PM to 6:00 PM). The comparative analysis of the study concluded the following:

- Solar Radiation Reduction: Applying a responsive façade on the south-glazed façade in Cairo can reduce solar radiation by 50.62% to 51.43%. Although the differences among the four designs are minimal, Case 3 emerged as the most effective, achieving a reduction of 51.43%.
- Cooling Energy Reduction: The reduction in cooling energy among the proposals also showed slight variation, with Case 3 again leading with a 6.5% reduction. The other cases achieved reductions ranging from 5.99% to 6.29%.
- Indoor Operative Temperature: All four responsive proposals enhanced the indoor operative temperature within the investigated room, further supporting the study's hypothesis regarding improved indoor comfort.
- As the four responsive proposals shared similar properties, dimensions, and rotational movement, as a combined design can be proposed where the axis of movement can differ in each one-hour interval of time as shown in table (9). The combined proposal is created according to selecting the proposed façade with the lowest solar radiation result in each one-hour time interval. The combined proposal reduces the solar radiation with 52.35% and minimizes the cooling energy with 6.323%.

Table 8. Combined Responsive Façade Proposal (Source: Developed by Authors, 2024)

Combined Responsive Facade Proposal					
Time During the Day	Angle of Movement	Case Number	Rotational Configuration	Solar Radiation (KWh)	Cooling Energy (Kwh)
08:00 till 09:00	60°	Case 4		1.108	0.536
09:00 till 10:00	30°	Case 3		1.179	0.549
10:00 till 11:00	0°	Any one of the cases		1.191	0.616
11:00 till 12:00	0°	Any one of the cases		1.711	0.712
12:00 till 13:00	15°	Case 3		2.334	0.745

13:00 till 14:00	15°	Case 3		2.213	0.830
14:00 till 15:00	30°	Case 4		1.903	0.907
15:00 till 16:00	60°	Case 2		1.477	0.969
16:00 till 17:00	75°	Case 3		1.037	0.982
17:00 till 18:00	90°	Case 1		0.826	0.932
Total Result on June 21				14.979	7.778

In summary, the findings affirm that the proposed right-angled triangular façade designs effectively meet the initial objectives of the study, validating the hypothesis that responsive façades can enhance indoor thermal comfort while significantly reducing both solar radiation exposure and energy consumption. This highlights the importance of integrating such innovative architectural solutions in response to the growing challenges posed by climate change and energy demands in urban environments.

7. Conclusion

In conclusion, this research aims to identify the optimal design proposal for a right-angled triangular façade applied to a south glazed façade in Cairo, Egypt. The study focused on prioritizing indoor thermal comfort, minimizing solar radiation, reducing energy consumption, and improving overall building performance. By conducting a comparative analysis of four different responsive façade proposals, it was observed that applying a responsive façade on the south glazed façade significantly reduced solar radiation, minimized cooling energy requirements, and enhanced indoor operative temperature. The analysis revealed that among the four proposals, Case 3 was identified as the most efficient in reducing solar radiation on the south glazed façade. However, the difference in solar radiation reduction among the proposals was not substantial. Furthermore, the study found that applying a responsive façade on the south glazed façade in Cairo, Egypt, on June 21 resulted in a range of 5.99% to 6.5% reduction in cooling energy requirements for maintaining indoor thermal comfort. Case 3 is the most efficient proposal in reducing the cooling energy among the four proposals. Additionally, all four responsive proposals improved the indoor operative temperature inside the

investigated room. As a future recommendation, a combined design proposal could be considered, where the axis of movement is adjusted in each one-hour interval based on the proposed façade with the lowest solar radiation result. This combined proposal achieved a reduction of 52.35% in solar radiation and a decrease of 6.323% in cooling energy consumption. Overall, this research highlights the benefits of implementing responsive façade designs to optimize energy efficiency, minimize solar radiation, and enhance indoor thermal comfort in buildings with south glazed façades.

Research Limitation

The research is limited to a room located in Cairo, Egypt, featuring a wide opening that faces the southern façade. The results were gathered on June 21st, a day chosen for its peak solar radiation, providing a focused analysis of the room's performance and its energy consumption.

Future Research

The research results can be examined in the future with the below aspects,

- The effect of applying the proposed responsive facades on the visual comfort parameter
- The effect of applying the proposed responsive facades on the heating load
- Optimization between the solar radiation and the daylighting
- Investigating effect of applying the proposed responsive facades on the user's psychological factor
- Investigating the proposed responsive facades on the west, east facades
- Investigating the proposed responsive facades on during the whole year

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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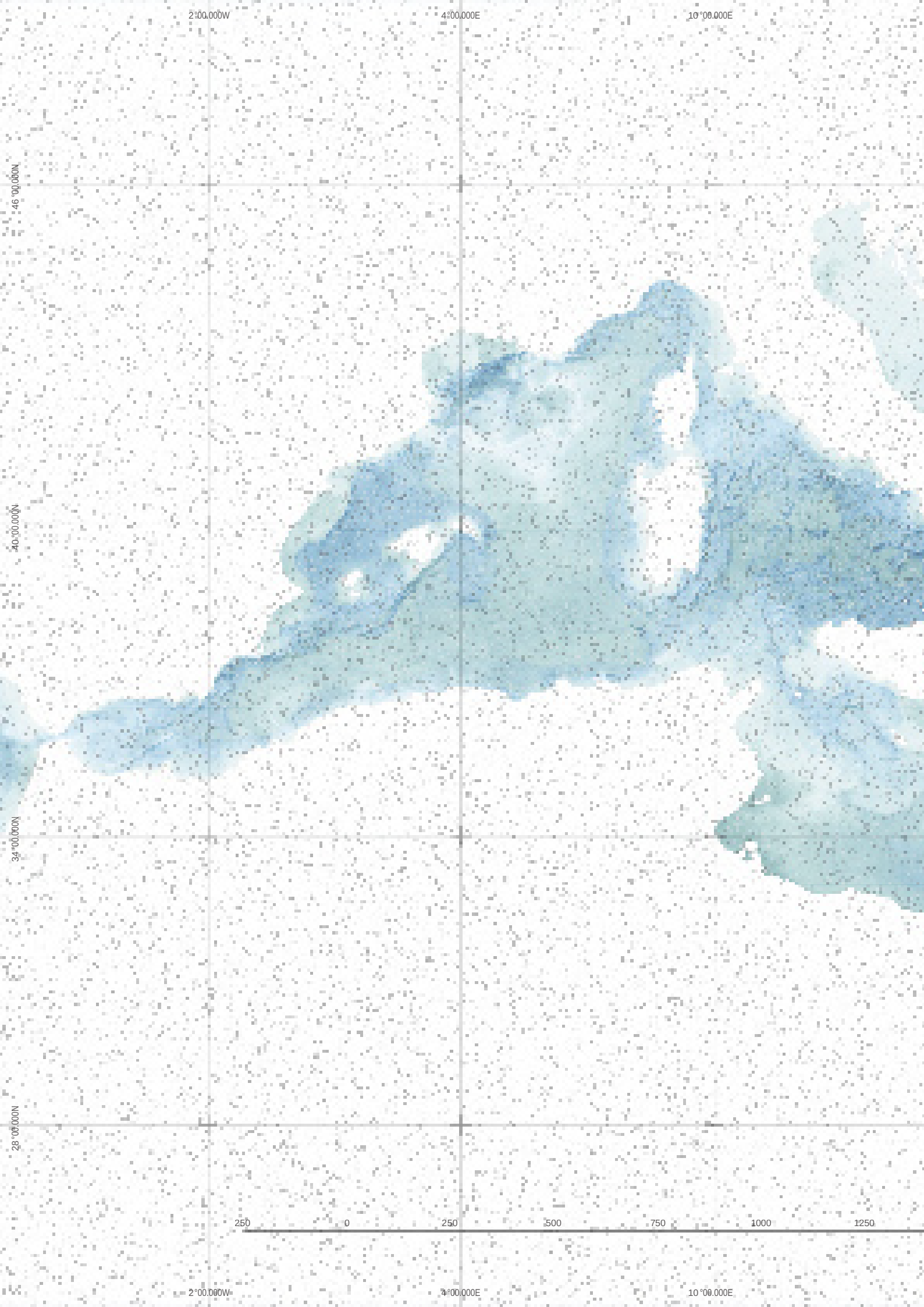
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1000
1250