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Phone: +90 506 189 99 66

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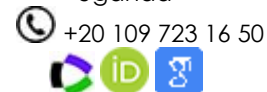


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Alanya Üniversitesi

Address:

Faculty of architecture, Alanya Üniversitesi, Cıkçilli Mah,
Saraybeleni Cad. No:7 07400, Alanya/Antalya/Türkiye

Phone: +90 506 189 99 66

Website: www.ijcua.com , <https://www.alanyauniversity.edu.tr/en>

E-mail: editor@ijcua.com



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Indexing

Coverages

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

- **Section A- Citizenship Rights and Responsibilities:** Citizenship Rights, Governances and practices, Urban and Social Identities, Walkable cities, Participatory projects, Urban ecology. Urban and social Identities, Well-Being, Acoustics, Smellscape, Authenticity, Quality of urban life, Public Health, Human behaviour and cities, Multiculturalism: Inequalities and diversities, Social distress, Psychology.
- **Section B-Territorial dynamics:** Urban Landscapes, Human urban geography studies, Spatial analysis: GIS and remote sensing, Spatial divergences, Interregional migrations, Urban Competitiveness, Globalization, Territorial planning, Conflict and Divided Territories, Urban Sprawl, Wadi territories, Regional Planning, Gated communities, Housing,
- **Section C- Urban Transformations:** Urban Regeneration, Housing Studies, Urban renewal, Heritage Studies, Housing Economics, Urban Sociology, Urban Morphologies, Socio-spatial Practice, African regionalism in Architecture, Pre-colonial cities, Landscape Architecture, Heritage Preservation. Urban Renewal, Gated Communities, Rapid Urbanization, Rehabilitation, Tourism and economical sustainability. Slums, Globalization, Community development, Political economy. Mediterranean Architecture and Urbanism, Emerging Cities, Smart Cities, Sustainable Urban Development.

Peer Review Statement

All research articles in this journal undergo a rigorous double-blind peer review process, starting with an initial evaluation by the editor, followed by double-blind reviews conducted by at least two expert referees. The purpose of peer review is to assist the editor in making editorial decisions, while also helping authors improve their manuscripts through feedback. In the double-blind process, neither reviewers nor authors are aware of each other's identities. The typical review period is 4 weeks.

- The selection of reviewers is at the discretion of the editor. Reviewers must be experts in the manuscript's subject matter, should not belong to the same institution as the authors, and must have no recent co-publications with them.
- Reviewers must disclose any conflicts of interest related to the research, authors, or funding sources to the editor without delay.
- Reviewers who feel unqualified to review a manuscript or cannot complete the review in a timely manner should notify the editor immediately.

- Reviews must be conducted objectively, avoiding personal criticism, and reviewers should clearly express their opinions with reasoned arguments.
- Manuscripts under review should be treated as confidential.

The Peer Review Process

Authors submit manuscripts via the online submission system, and they receive confirmation of receipt from the editorial office. The Chief Editor first reviews the manuscript, often with the help of Section Editors (or Co-/Associate Editors). A Section Editor oversees the manuscript through the entire review process and provides a recommendation or decision.

Initially, the manuscript is assessed for its alignment with the journal's scope and its adherence to formal requirements. If found unsuitable, it is directly rejected, and a rejection letter is sent to the author explaining the reasons. If the manuscript meets the journal's scope and guidelines, it is sent for peer review. Reviewers evaluate the manuscript and submit their reports to the Editor-in-Chief, who then makes one of the following decisions based on the feedback:

- Accept without revisions
- Accept with revisions
- Request a resubmission
- Reject

In case of acceptance, the final manuscript is sent to production. Authors may also be asked to revise their manuscript based on reviewers' comments and resubmit it for further evaluation. Review times vary between 4 to 8 weeks, depending on the discipline and additional information required. If rejected, the manuscript is archived, and a rejection letter is sent to the authors. Reviewers may be informed of the final decision.

Once the review process is completed, the manuscript is passed to the Copy Editor, who ensures that it adheres to the correct referencing style and journal formatting. The Layout Editor then prepares the manuscript, including figures and tables, for publication in formats such as PDF and HTML. Finally, the Proof Editor confirms that the manuscript is ready for publication after completing all the necessary stages.

The reviewers of a manuscript remain anonymous to each other, and in cases where their decisions differ (accept/reject), the editor may assign additional reviewers. The editorial team ensures that reviews meet high standards of quality. If authors raise concerns about the objectivity of a review, the team takes special care to ensure the review's fairness and quality. When necessary, additional reviewers are assigned to maintain objectivity and academic rigor. The manuscript submission and the peer review process are broken down into the following steps:

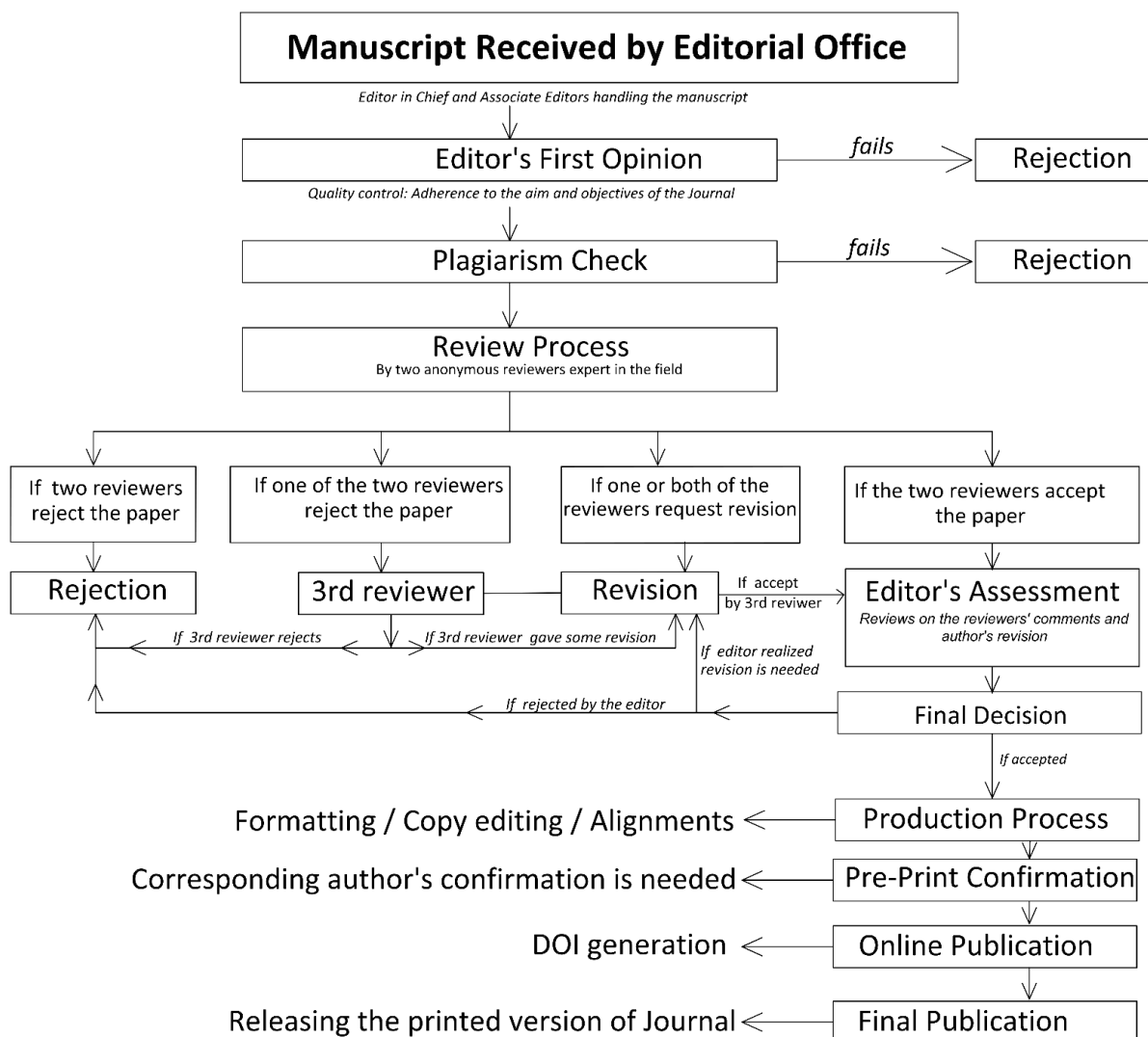


Figure 1. Peer Review Process.

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All manuscripts submitted to the Journal of Contemporary Urban Affairs will undergo plagiarism screening using iThenticate's plagiarism detection tools. Any manuscripts found to contain instances of plagiarism or self-plagiarism will be promptly rejected.

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Plagiarism occurs when someone uses the ideas, words, or other intellectual property of others, whether published or unpublished, without appropriate credit or permission, and presents them as their own original work. This misleads readers about the true contributions of the plagiarist. Plagiarism can involve content from abstracts, research proposals, institutional submissions, or any other form of unpublished or published materials, and it is considered scientific misconduct.

Self-Plagiarism

Self-plagiarism involves an author reusing portions of their prior work in new publications without proper citation. While this practice, often unintentional, is common—particularly in sections such as the methods—it typically violates copyright agreements with publishers. Unlike plagiarism of others' work, self-plagiarism is not always regarded as scientific misconduct, and policies on this practice may vary among journals. If a journal has a policy on self-plagiarism, it should be clearly communicated to authors.

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1. Notify the editor of the journal where the plagiarized article is published.
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4. The accused plagiarist will be asked for an explanation.
5. If no response is received within the specified time or the explanation is unsatisfactory, the article will be permanently retracted.
6. The author responsible will be banned from submitting to that journal for at least five years.
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Authors are responsible for ensuring that their submission does not violate copyright or ownership rights, such as for figures, tables, photographs, and other data. Authors must obtain and include permissions for any copyrighted material in their final submission and inform the editorial office and publisher when usage restrictions apply. Acknowledgements for such materials should be added in a dedicated section at the end of the paper, clearly crediting the source and copyright.

Adapted from: Bella H. Plagiarism. Saudi J Med Sci 2014; 2:127

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- » Duties of Reviewers
- » Duties of Publisher
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- » Confidentiality and anonymity
- » Fundamental errors in published works
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- » Sex and gender in research
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- » Journal policies on intellectual property
- » Journal policies on data sharing and reproducibility
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The editors of the *Journal of Contemporary Urban Affairs* are responsible for determining which submitted articles are suitable for publication. Their decisions are based on reports from referees and may involve consultation with other editors or reviewers. The editors also follow the journal's policies and ensure compliance with legal obligations regarding libel, copyright infringement, and plagiarism.

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Duties of Editors

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- Reviewing and consistently improving publication guidelines
- Participating in the journal's operations

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4. Verification of authors' backgrounds and qualifications.

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1. Disclosure of any potential conflicts of interest by the authors.
2. Accurate presentation of research findings with an objective discussion of their significance.
3. Sufficient detail in data and methods to allow replication by other researchers.

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Editors participate in four annual meetings via video conferences or virtual communications, advising on journal policy and scope, suggesting ideas, and proposing new initiatives and programs as necessary. They may review manuscripts, identify topics for special issues, or attract new authors and submissions when appropriate.

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2. In the *Journal of Contemporary Urban Affairs*, advisory board members serve as ambassadors.
3. Board members attend one or two annual meetings via video conferences or virtual communications, advising on journal policy and scope, and suggesting ideas or initiatives. They may review manuscripts, identify topics for special issues, or attract new authors and submissions when appropriate.

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All listed authors must have made significant scientific contributions to the research, approved the manuscript's content, and agreed to be an author. It is crucial to include everyone who has made a substantial scientific contribution. Author contributions can be described at the end of the submission, optionally using roles defined by CRediT (Contributor Roles Taxonomy). Submitting authors must provide an ORCID identifier, and all authors are encouraged to do the same.

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Declared conflicts of interest will be assessed by the editor and reviewers and will be included in the published article.

Credit Author Statement

In mid-2012, the Wellcome Trust and Harvard University co-hosted a workshop that brought together members of the academic, publishing, and funding communities to explore alternative models for contributorship and attribution. Following this workshop—and initially collaborating with a group of primarily biomedical journal editors and members of the International Committee of Medical Journal Editors (ICMJE)—a pilot project was initiated to develop a controlled vocabulary of contributor roles, known as a taxonomy.

The goal was to create a taxonomy that is practical, easy to understand, and minimizes the potential for misuse. CRediT (Contributor Roles Taxonomy) provides authors with the opportunity to share a precise and detailed description of their diverse contributions to published work. It is a high-level taxonomy comprising 14 roles that represent the typical contributions to scientific scholarly output. These roles help in clearly identifying each contributor's specific input to the research and publication process.

Role	Definition
Conceptualization	Ideas; formulation or evolution of overarching research goals and aims.
Data curation	Management activities to annotate (produce metadata), scrub data and maintain research data (including software code, where it is necessary for interpreting the data itself) for initial use and later re-use.
Formal analysis	Application of statistical, mathematical, computational, or other formal techniques to analyse or synthesize study data.
Funding acquisition	Acquisition of the financial support for the project leading to this publication.
Investigation	Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection.
Methodology	Development or design of methodology; creation of models.
Project administration	Management and coordination responsibility for the research activity planning and execution.
Resources	Provision of study materials, reagents, materials, patients, laboratory samples, animals, instrumentation, computing resources, or other analysis tools.

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For research articles with multiple authors, a brief paragraph specifying each author's individual contributions must be provided. An example of such a statement is as follows:

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- **Data Curation:** S.M., J.F., J.S., J.P.B.
- **Formal Analysis:** M.W., J.F., S.M., R.B.
- **Funding Acquisition:** J.F., S.M., R.B.
- **Investigation:** S.M., J.S., J.P.B., J.F.
- **Methodology:** J.F., S.M., R.B., M.W.
- **Project Administration:** S.M., J.F.
- **Writing—Original Draft:** S.M., J.F.
- **Writing—Review & Editing:** J.F., S.M., R.B., J.S., M.W., J.P.B.

All authors have read and agreed to the published version of the manuscript.

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Sources:

1. The presentation of the 14 roles has been adapted from the Consortia Advancing Standards in Research Administration (**CASRAI**) website.

2. <https://onlinelibrary.wiley.com/doi/full/10.1002/leap.1210>

Read more about CRediT [here](#)

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In an era marked by increasing socio-economic disparities and rapid urbanization, the journal acknowledges the urgent need to address the widening socio-economic gaps that profoundly impact contemporary urban societies. The complex challenge of balancing socioeconomic development with resilience in the built environment necessitates a platform for innovative and interdisciplinary dialogue. To this end, the journal aims to advance original, cross-disciplinary academic contributions that not only analyze these socio-economic divides but also propose actionable solutions to bridge them. By strengthening research in three core areas—Citizenship Rights and Responsibilities, Territorial Dynamics, and Urban Transformations—the journal seeks to illuminate the underlying factors contributing to socio-economic inequalities and to explore the emerging social and economic challenges that shape modern urban landscapes. Through this focused approach, the journal aspires to contribute meaningfully to the discourse on equitable urban development and to foster academic scholarship that can inform policy and practice, ultimately helping to create more inclusive, resilient, and sustainable cities.

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Original scientific paper

Strategies for Streamlined Urban Development: A Case Study of Land Use Succession in Upper Hill, Nairobi

*¹ Elizabeth M. K. Nguah , ² Dr. Owiti A. K'Akumu 

¹ Department of Architecture, School of Built Environment & Design, University of Nairobi, Kenya

² Department of Real Estate, Construction Management and Quantity Survey, School of Built Environment & Design, University of Nairobi, Kenya

¹ E-mail: jessiemoor16@gmail.com, ² E-mail: owiti.kakumu@uonbi.ac.ke

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ABSTRACT

This study examines the dynamics of Urban Land Use Succession (ULUS) in Upper Hill, Nairobi, highlighting the impact of neoliberal policies and private sector-led urban redevelopment. It investigates how land tenure, public infrastructure, and planning controls shape urban landscapes, leading to patchwork land use patterns and environmental misalignments. The case of Upper Hill, transitioning from a serene residential area to a bustling commercial hub, is explored to understand the determinants of ULUS and propose strategies for streamlined urban development. Employing Neoliberal Theory and hypothesis testing, the research identifies spatial policy as the primary driver of ULUS. The study suggests innovative approaches, including land assembly and the establishment of an Urban Redevelopment Authority, to harmonize urban development. These strategies aim to bridge the gap between private and public land development, ensuring coherent urban growth. The research contributes to the understanding of urban redevelopment, particularly in Kenyan contexts, by offering a model that integrates public and private interests. This model serves as a blueprint for managing urban transformation in Nairobi and other similar urban settings, promoting sustainable and equitable urban development.



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Highlights:

- The study established that the key determinant of ULUS is spatial policy (planning decisions, land tenure and public investment in infrastructure).
- Despite having a 10% footprint in the area, global capital was found to have no influence on ULUS.
- ULUS was resulting in conflicts such as patchwork land use patterns, overflowing sewers, and mounds of garbage.
- The study developed an alternative model for ULUS to reverse the conflicts comprising strategies such as preparation of ULUS policy, establishment of Urban redevelopment Authority, land assembly and readjustment and use of Public-Private Partnerships, cooperatives, and 'chamas'.

Contribution to the field statement:

This research developed an alternative model to streamline Urban Land Use Succession (ULUS), with strategies such as the development of an integrated policy, a growth management strategy, land assembly, and establishment of an Urban Redevelopment Authority, among others which formed the research's contribution to knowledge.

*Corresponding Author:

Department of Architecture, School of Built Environment & Design, University of Nairobi, Kenya

Email address: jessiemoor16@gmail.com

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1. Introduction

The Urban Land Use Succession (ULUS) phenomenon is anchored in neoliberalism theory which “emphasizes on collaboration and partnership between capital and citizen with little mediation by formal state institutions” (McCarthy & Prudham, 2004). This is based on the belief in open, competitive, and unregulated market as the optimal mechanism for economic development (Brenner & Theodore 2002:2 as cited in (Raco, 2005) It’s also anchored on principles including commodification of everything (Polanyi 1944 & Watts 1994 as cited in (McCarthy & Prudham, 2004) “creation of private property rights defended by the state” (Peck, 2001; Jessop, 2002 as cited in (McCarthy & Prudham, 2004, p. 276) “fiscal administrative cuts, and shifts from binding to voluntary public-private co-operation” (McCarthy & Prudham, 2004). The phenomenon has engendered spatial practices focusing on financing constructing, destroying and reconstructing the built environment (Weber, 2002) The belief in an open, competitive, and unregulated market free from state interference is replicated in Upper Hill where the County Government appeared to be endorsing the free choices of private landowners and investors. This stemmed from the shift in spatial policy from residential to commercial use in 1993, based on the Structural Adjustment Programs (SAPs) of the mid-1980s. The acquisition and redevelopment of property within a seemingly laissez-faire environment has been reinforced by the security of private property rights, as assumed in theory. Although the county government retained the power to approve development permission, individual gratification of the *homoeconomicus* or the ideal self-made man (McCarthy & Prudham, 2004) through free market ideology seemed to dominate. This market was financing, destroying, and reconstructing the built environment with participation by both local and international investors. However, the resultant urban form did not reflect the planning policy for the area in terms of building heights and ground coverage, among others.

Land in Upper Hill was held under both private and public land tenure regimes, which were subject to control by state rules and regulations. The latter was largely regarding planning, development control and infrastructure provision. The assumption of free market therefore implied that land held on private tenure was easily available to the market compared with that held on public tenure. Private land thus appeared to be redeveloped faster than public land, resulting in a patchwork pattern of development and a dichotomy of contradictory states.

Fiscal cuts in public spending were responsible for delays in the provision of requisite infrastructure such as roads, sewers, water and community facilities. Private actors confined themselves to the provision of infrastructure within their property boundaries, leaving the role of provision of strategic infrastructure to a state that was already constrained by fiscal cuts. The piecemeal execution of redevelopment therefore gave rise to disharmony on minimum setbacks and kinks in road alignment. Urban Land Use Succession problem manifested in the impermeability of the commercial area, an incongruous mix of old and new buildings, incoherent streetscape and traffic congestion, among others (Nguah, K'Akumu, & Kimani, 2023). The objectives of the research therefore were to identify the determinants of ULUS; establish the influence of each determinant and respective outcomes; establish the key determinant and suggest strategies for streamlining the phenomenon.

Using hypotheses testing the research established that spatial policy was the key determinant of ULUS (Nguah, K'Akumu, & Kimani, 2023). In this regard, the research used lessons and best practices from the development of New Castle Business Park and Salford Quays (Healey et al 1992 as cited in (Healey, 1995) and Singapore’s, Golden Shoe District, (Government of Singapore, 2016)) among others to formulate streamlining strategies. These strategies have been crystallized by the author into an alternative model for ULUS which formed the research’s contribution to knowledge.

The study’s focus on the determinants of urban land use succession departs from other studies which largely concentrated on its impacts. With most studies focusing on rural and peri-urban environments, the study provides additional literature to the few written on land use succession in urban environments or brownfields by scholars like Bourne and Ng.



2. Urban Land Use Succession

The concept of succession describes the “evolution of natural communities by sequent replacement and invasion and occupancy of one social area by members of another different social group” (Bourne, 1971, p. 1). The social areas were viewed as forming concentric rings around the city core, “with movement originating from the core to the outer ring” (Bourne, 1971, p. 2). As each concentric zone extended outward it replaced another lower density zone (Bourne, 1971) (Kingoriah, 1980).

Land Use succession processes included a probabilistic process of adjustment in the structure of land and building occupancy (Bourne, 1971), a change from simple to complex (Clarke, 1966), or from a young stage to a maturity stage (Frederic and Odum as cited in (Rudel, 2009), and a selective process where a peri-urban fringe was embedded within the built-up area (Barke, 1976). In Upper Hill, the invasion and succession were from a green, serene residential neighborhood to a concrete maze of commercial tower blocks.

There were three categories of Urban Land Use Succession depending on the actors involved, namely the public sector (He & Wu, 2007), Public-Private partnerships (Harding 1992 as cited in (He & Wu, 2007) and the private sector (Turok 1992 as cited in (He & Wu, 2007). While the public sector ULUS focused on social development, the private sector was interested in profit maximization and the Public-Private Partnership blended both extremes.

2.1 Determinants of ULUS

ULUS was determined by both external and internal factors to the property, with the largest proportion of ULUS being caused by external factors (Bourne, 1971). Internal changes included a decline in suitability, depreciation (Bourne, 1971) and fluctuations in relative bid rent potentials of housing (Bang, 2009). External changes included “growth in size or structure, change in land requirements, change in economic viability, technology preferences, alterations of the physical infrastructure (Bourne, 1971), social relations and capital re-switching (Bang, 2009).

2.2 Outcomes of ULUS

ULUS had both negative and positive outcomes, where negative outcomes included rising value of the property, pressure on existing infrastructure, patchwork land use patterns, environmental misfits, and displacement of low-income people among others (Healey et al 1992 as cited in He & Wu, 2007, Bang 2009). Positive outcomes included optimization of land use, improved amenities, road widening and stimulation of the economy (Barnley & Bar 1996 as cited in (Lum, Sim, & Malone-Lee, 2004).

2.3 Governance and Urban Land Use Succession

Governance was the process of coordinating political decision-making (Gaitano & Strom 2003 as cited in (Taşan-Kok, 2010), actors, social groups, and institutions (Melo & Baiachi, 2006 as cited in (Taşan-Kok, 2010) to attain collectively defined goals (Le Gales 1998, 2001 as cited in (Taşan-Kok, 2010). While executing their mandate both state actors and private actors supported or impeded market performance (Cao, 2009). Governance was thus necessary to coordinate these institutions to enhance the positive outcomes while mitigating the negative ones.

2.3.1 Integrated Policy Framework for ULUS

Implementation of ULUS required tools such as an integrated policy framework for the coordination of actors, a strategic framework and strong urban governance institutions. These would help stem conflicts such as the occurrence of pencil-type developments (Ng, 2002) and patchwork land use patterns (Qian, 2010). In Upper Hill, an integrated policy framework for the coordination of actors and a strategic framework appeared nonexistent. The ministry responsible for Lands, Housing and Urban Development, Kenya Urban Roads Authority (KURA), Kenya Power Company (KPC) and the County Government of Nairobi, performed different mandates in the area using different policies and legislations. This disjointed manner of operation left developers on their own.

Best practices used by the study to address the gap included urban regeneration and environmental sustainability, London 2012 Olympic Games and the Lower Lea Valley (Quaglia, 2016) use of strategic vision in Singapore’s Golden Shoe District (Government of Singapore, 2016) land assembly, land readjustment, coordination and phasing of development (Lum, Sim, & Malone-Lee, 2004); (Amirtahmasebi, Orloff, & Wahba, 2016) among others.



2.3.2 Institutional Arrangements

Institutional arrangements help in transmitting information on market conditions, enforce property rights and contracts and direct incentives (North 1990a as cited in (Cao, 2009). According to D'Arcy and Keogh, 1998 as cited in (Cao, 2009), these institutional arrangements include the property market and the governance process relating to the property market.

Kenya had harp-hazard development due to inadequate urbanization policies, planning guidelines and planning for urban areas (Ministry of Lands and Physical Planning, 2017) a situation which persists to date. Upper Hill was planned by the Department of Physical Planning under the Hill Area Zoning and Road Widening Plan of 1992 and the Action Plan of 2010. Currently, the planning and development of Upper Hill is guided by the National Land Use Policy and the Physical and Land Use Planning Act of 2019 (PLUPA). This policy and legislation are supposed to be cascaded into physical development plans and updated standards plus guidelines. It is expected that the County Integrated Development Plan (CIDP) would then draw from the spatial plans when allocating county resources to avoid duplication of effort and wastage of resources. However, the nexus between these institutional arrangements appeared weak in directing incentives for property redevelopment in the area, hence the entry of the private sector to fill the vacuum.

Property-led redevelopment has used Governance regimes including Urban Development Corporations (UDC), (Healey, 1995), Land Development Corporations (LDC), Urban Renewal Authority (URA) (Ng, 2002) Land Assemblage and Redevelopment Authority (LARA), (Qian, 2010) and Urban Redevelopment Authority (URA). Urban development corporations were established by governments to develop new suburban areas and existing ones and help underperforming areas to grow. Examples included the London Thames Gateway Development Corporation, LTGDC (Quaglia, 2016). In Kenya, such corporations in the built environment included the National Housing Corporation (NHC) which focused on the housing sector. In Upper Hill, these corporations seemed absent.

2.3.3 Capacity of Urban Governance Institutions

For urban governance institutions to function they needed capacity in terms of a stable predictable subsidy regime, insulation from political manipulations, and the presence of development experts (Healey, 1995). A strategic framework was also required for the deployment of this capacity (Healey, 1995). Nairobi had the Nairobi Metropolitan Strategy, of 1973, which was poorly implemented due to inadequate financial resources. This has continued to daunt the city to date (County Government of Nairobi, 2014).

2.4 Neoliberal Theory

To explain the situation in Upper Hill, the neoliberal theory was used especially its belief in open, and unregulated markets as the optimal channel for economic development (Brener & Theodore, 2002:2 as cited in Raco, 2005, McCarthy & Prudham, 2004). This market required the commodification of everything (Polanyi, 1944 & Watts, 1994 as cited in McCarthy & Prudham, 2004). The theory furthered the idea of political and ideological antagonism toward state interference on one hand yet on the other, the state is expected to defend private property rights and commodification (Peck, 2001; Jessop, 2002 as cited in McCarthy & Prudham, 2004). It argued for fiscal and administrative cuts (Jessop, 1994 as cited in McCarthy & Prudham, 2004). It brought to the fore “notions of the *homo-economicus*, the ideal, self-made individual” (Barnes, 1987; Barnes, 1988; Barnes and Sheppard, 1992; Bowles and Gintis, 1993 as cited in McCarthy & Prudham, 2004: 276) who must collaborate and partner with capital with no interference by state institutions (McCarthy & Prudham, 2004).

As assumed in theory, Kenya adopted SAPs in the late eighty's, including fiscal cuts in public sector spending. This may have led to a delay in upgrading of infrastructure in Upper Hill.

2.5 Key Independent and Dependent Variables

From the theory, the study isolated the phenomenon of ULUS as the dependent variable, while the determinants of ULUS were seen as the independent variables. The latter included planning decisions, land tenure, public investment in physical infrastructure and global capital.



3. Methodology and Research Strategy

The study used both survey and history strategies embedded within the case study strategy, to allow examination of contemporary events which the researcher could not manipulate. The survey allowed extraction of data from interviews with property owners, and caretakers on the source of development capital, incomes, change of user, building heights, and plot ratio, among others. This data could then be analyzed to develop trends and gauge the intensity of ULUS. History strategy on the other hand allowed the use of key informant interviews to get historical data on when the ULUS started, why it happened and what had been done by authorities to reverse negative consequences. The case study strategy allowed making inferences to other areas of Nairobi and beyond. These approaches yielded both qualitative and quantitative information which the research triangulated to form a comprehensive picture of the area.

3.1 Research Design

A research design comprising study questions, its propositions, a unit of analysis, logic linking data to propositions and criteria for interpreting findings was used to draw inferences concerning causal relations among variables under review (Nachmias & Nachmias 1992 as cited in (Yin, 2003)). The study questions included, what are the determinants of ULUS; the influence and outcomes of each determinant; the key determinant of ULUS; and what strategies can streamline the ULUS phenomenon. These questions guided the development of semi-structured interview schedules which were administered to a random sample of sixty-eight plots. An unstructured interview schedule was also developed to draw insights from key informants. The plot was used as the unit of analysis.

To isolate the key determinant of ULUS, the study used four (4) null hypotheses to test the influence of spatial policy and global capital on ULUS. Spatial policy was a latent variable comprising planning decisions, land tenure and public investment in infrastructure. The null hypotheses included: Ho1: Planning decisions do not have an influence on ULUS; Ho2: Land tenure does not influence ULUS; Ho3: Public investment in infrastructure does not influence ULUS; Ho4: Global capital does not influence ULUS.

T-student test distribution using two variables assuming both equal and unequal variances was used to test hypotheses. If the value of t Stat was greater than the value of t Critical, the null hypothesis (Ho) was rejected meaning the research hypothesis (Ha) was accepted. On the other hand, if the value of t Stat was less than that of t Critical, then the Ho was accepted. and Ha rejected. These tests allowed comparison of the variables and isolation of the variable with the greatest influence on ULUS. This isolation enabled the targeted application of strategies to streamline ULUS as per the study objectives.

3.2 Research Sampling

The researcher developed a base map showing the cadaster of Upper Hill and counted the population of plots to get five hundred and sixteen (516) plots. This became the sampling frame for Upper Hill. Determination of the representative sample was done using the formula:

$$n = \frac{Z^2 pq N}{e^2 (N-1) + Z^2 pq} \text{ as recommended by (Nachmias \& Nachmias, 2000).}$$

$$\text{Therefore, } n = \frac{1.96^2 * 0.95 * (1-0.95) * 516}{0.05^2 (516-1) + 1.96^2 * 0.95 * (1-0.95)} = 67.2 = 68.$$

This sample was selected because it was not possible to administer interviews in all the 516 plots given the limitation of time and cost.

Systematic sampling was used to locate the plots to be observed. This involved using the base map to select a random start and proceeding with the selection of every k^{th} element where k was the ratio of sampling frame size N and desired sample n . The ratio was obtained by substituting N with the population of 516 plots, and n with the sample size of 68 plots to get the interval of approximately $8(k=516/68=7.59=8)$. Every eighth plot was therefore selected by starting from a random start. This method ensured that the sample was representative as it enabled drawing of the sample across the expanse of the area.



3.3 Data Collection Methods

Two types of data collection methods namely primary and secondary research methods were used. To collect secondary data, an internet search using Google Scholar and visits to libraries were undertaken. Through this method, secondary literature on determinants, processes, outcomes and history of ULUS was collated. This enabled easy isolation of the variables for the study. Unstructured interviews, semi-structured interviews, observation and photography were used to collect primary data on land tenure, sources of capital and public investment in infrastructure. Primary data was important in clarifying the influence of the variables on ULUS. This was reinforced by data from key informants including the Ministry of Lands and Physical Planning, Ministry of Housing, Kenya Power Company (KPC), Kenya Urban Roads Authority (KURA), Nairobi County government and Nairobi Water and Sanitation Company (NAWASCO) among others.

3.4 Data Analysis and Presentation Techniques

Data from the literature was grouped into themes as per the variables under study and analysis was undertaken to identify variables, and gaps and draw lessons. Relevant statistical data was presented in charts and line graphs to give clarity and show trends and intensity of the phenomenon. Primary data was also grouped into themes concerning public investment in infrastructure, Land tenure, planning decisions, global capital and analyzed according to the objectives. The results of this analysis were presented using bar charts, pie charts and tables, from which the researcher observed trends, intensity and underlying relationships. Additional data from observation and plates was grouped into themes and used where necessary to support the results of the random survey.

Hypotheses tests were applied to data sets on ground coverage, private land tenure, public land tenure, adequacy of water and sewer, adequacy of transport services. T-student test distribution using two variables assuming both equal and unequal variances was used. If the value of t Statistics was greater than the value of t Critical, the null hypothesis (H_0) was rejected meaning the research hypothesis (H_a) was accepted. On the other hand, if the value of t Statistics was less than that of t Critical, then the H_0 was accepted, and H_a rejected.

4. Results

The study found that a strategic framework for Nairobi was yet to be prepared despite the expiry of the Nairobi Metropolitan strategy of 1973. The County Government prepared the NIUPLAN in 2014. The latter should have been preceded by the County Physical and Land Use Development Plan (CPLUDP) but at that time the Physical and Land Use Planning Act of 2019 had not been enacted. To date, there is no evidence of preparation of this critical plan to anchor the activities of the county in space.

In the absence of CPLUDP, planning of the urban area has been done on a piecemeal basis with the sectoral plans for water, sanitation and roads being used as firefighting tools. Upper Hill was planned in 1992 through the Hill Area Zoning and road widening plan prepared by the Director of Physical Planning (DPP). Its preparation after the introduction of SAPs of 1986 and the attendant fiscal cuts in public spending meant that implementation in terms of road widening was delayed resulting in traffic congestion. A subsequent action plan for road widening was prepared in 2010 that formed the basis for the upgrading and construction of roads by KURA. While upgrading the roads KURA reported facing serious challenges where solutions provided to manage traffic congestion in one area often gave rise to traffic challenges in another. It was not until the links to Ngong Road and Mbagathi were constructed that the traffic gridlock was overcome. Green Park Terminus was undertaken thereafter in 2020 only to be shelved in 2023, owing to resultant traffic challenges. Redevelopment was taking place without a comprehensive plan that would have viewed the area as part of an organic city and not an enclave.

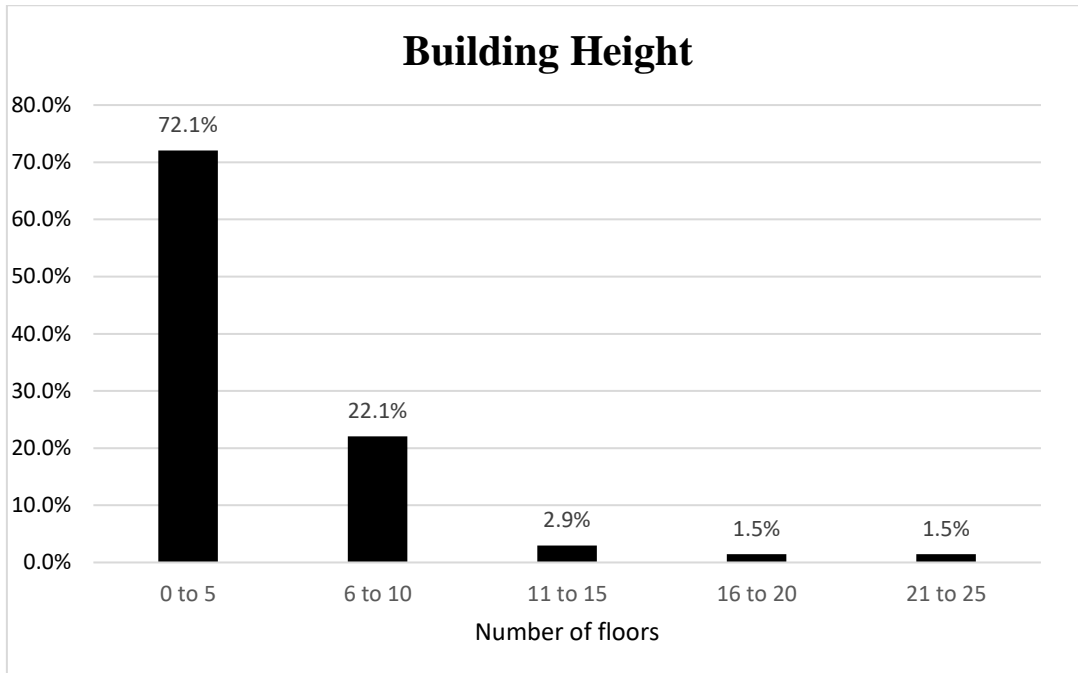


Figure 1. Building Heights. Source: Field Survey.

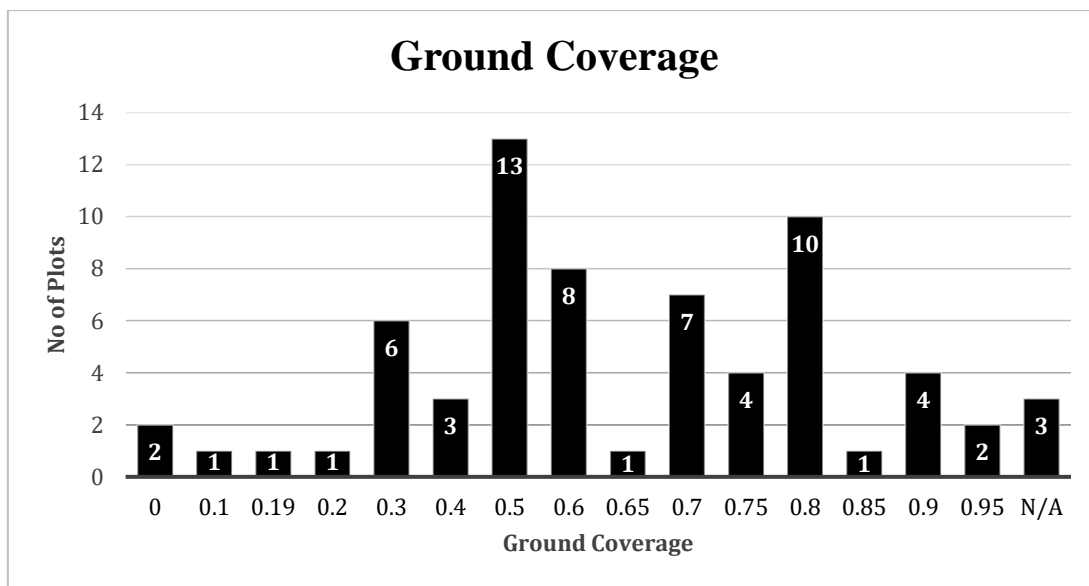


Figure 2. Ground Coverage.

The area has been governed by outdated standards of 2006 with floor levels, set at a maximum of five floors. The study found that in about 28% of sampled plots, buildings had gone beyond five levels while in about 1.5%, buildings had 21-25 floors. as shown in Figure 1. In addition, ground coverage and floor ratio had been set at 60% and 300% respectively. Thirty-two plots had development going beyond 60% ground coverage as shown in Figure 2 and some had overshoot the floor ratio to 700%. These standards were updated in the period 2021/2022 with floor levels being raised to seventy-five across the board. This regularized the existing situation, without commensurate investment in key infrastructure.

The study noted a lack of coordination in the activities of the private investors owing to the lack of a comprehensive plan and strategy for implementation. The County Government of Nairobi, the Ministry in Charge of Housing and Urban Development, KURA, and KPC among others were performing different activities in the area using different policies and legislation. Out of these, only KURA leveraged synergies with the DPP to overcome implementation challenges. The rest of the

actors were uncoordinated, resulting in an attendant waste of public resources. Business sectors and investors were also left to muddle through the redevelopment process on their own.

The study observed that land in Upper Hill was primarily owned by government Ministries, Departments, and Agencies (MDAs) with about 36% occupied by Kenyatta National Hospital and the University of Nairobi. Survey results indicated that about 66% of sampled plots were owned by private persons, 19.4% by the government, and 8% by religious institutions. Out of the 66% of plots owned privately, about 60% were redeveloped indicating that redevelopment was prominent on land owned by private individuals and entities. On the other hand, out of the 19.4% of plots owned by the government, only two plots were redeveloped with prefabricated buildings. Redevelopment under the prevailing land tenure where private properties were being redeveloped faster than public land, was giving rise to an incongruent mix of old and new buildings, a patchwork pattern of redevelopment, and an incoherent urban scape as shown in Figure 3.



Figure 3. Incongruent Mix of Old and New Buildings-Williamson, Prism.



Figure 4. Green-leafy Upper Hill North with insignificant redevelopment.



Figure 5. Upper Hill South with Skyscrapers.

The Northern side of Upper Hill retained its old colonial buildings and remained green and leafy as shown in Figure 3, However, redevelopment in Upper Hill concentrated between Valley Road and Hospital-Elgon Road where there was ease of access to transport services as shown in Figure 5. This was also the area where most of the conflicts were observed including loose telephone wires and cables, poor street alignment, garbage dumps, and overflowing sewers.



Figure 6. Overflowing Sewer along Mbagathi Link.

In Upper Hill, policymakers have also emphasized economic regeneration and city competitiveness neglecting the provision of community facilities and upgrading of utilities like sewer. This has resulted in poor environmental conditions as shown in Figure 6.



Table 1: Results of t-Test: Two-Sample Assuming Unequal Variances.

Variable	t Statistic	t Critical
Ground coverage	9.039209981	1.984467455
Private land tenure	2.991975707	1.977825758
Public Land Tenure	-1.110463342	1.977961264
Adequacy of water and sewer,	5.200453886	1.978098842
Adequacy of transport services	4.16515391	1.977825758
Global Capital	-3.88851	1.983972

The hypotheses test established that the key determinant of ULUS is spatial policy (planning decisions, land tenure, and public investment in infrastructure). Hypothesis tests on ground coverage, private land tenure, adequacy of water and sewer, and adequacy of transport services indicated that the value of t Statistic was greater than the value of t Critical as shown in Table 1. For this reason, the null hypotheses (Hos) were rejected, and the research hypotheses (Has) indicating that ground coverage, private land tenure, adequacy of water and sewer, and adequacy of transport services influenced ULUS, were accepted. In the case of public land tenure, however, the value of t Statistic was less than the value of t Critical. The null hypothesis (Ho) that public Land tenure does not influence ULUS was, therefore, accepted meaning the research hypothesis (Ha) was rejected.

Despite having a 10% footprint in the area, global capital was found to not influence ULUS. The hypothesis test indicated that the value of t Statistic was less than that of t Critical, and therefore null hypothesis Ho: Global capital does not have an influence on ULUS was accepted. This implied that the root cause of the land use conflicts in Upper Hill emanated from spatial policy.

5. Discussions

The study has established that the constituent variables of spatial policy influenced ULUS, hence making it the key determinant of ULUS. This was exhibited in two ways, first by MDAs performing different mandates in the area operating in silos and second by the weak capacity of the county government in plan preparation and implementation. The findings aligned with the literature which indicated that there existed weaknesses in the capacity for the development and implementation of policy among the departments charged with the built environment (Ministry of Lands and Physical Planning, 2017). This has left officers charged with development control with weak policy tools to undertake their tasks, often resorting to negotiations with property developers. These negotiations included allowing for higher densities which resulted in undue pressure on roads and sewers. This finding helps isolate the root cause of the ULUS phenomenon, hence the identification of targeted strategies to plug capacity gaps and improve the coordination of MDAs.

The lack of a comprehensive redevelopment plan and implementation strategy and reliance on piecemeal projects implied that the activities of private developers were uncoordinated. These projects were strewn throughout the plan area bringing about a patchwork pattern of development. This agreed with literature where the lack of a comprehensive redevelopment plan for property-led urban redevelopment driven by private individuals in Hong Kong resulted in uncoordinated, sporadic, and piecemeal or pencil-type developments (Ng, 2002). This finding provides a platform to require the county government to prepare a comprehensive redevelopment plan and implementation strategy to reverse the patchwork pattern of development.

The application of neoliberal policies on existing land tenure where both public and private land existed, has brought about the African socialist state and the neoliberal state. This was manifested in the concentration of redevelopment on private land while public land remained underdeveloped. This further enhanced the patchwork pattern of development giving rise to an incongruent mix of old and new buildings and incoherent uneven urban scape. This agreed with critiques of neoliberal policies



indicating that they often result in negative consequences including uneven spatial development and a poorly regulated landscape (Brenner et al 2010 as cited in (Peck, 2013). This helped to build a case for the development of strategies to bridge the two contradictory states to engender an even pattern of development.

The study found that redevelopment was concentrated in areas with ample transport services implying that public investment in infrastructure had a positive influence on ULUS. This further enhanced the patchwork pattern of development in Upper Hill. The transport services were supported by roads provided by the African Socialism State, thus conflicting with the neoliberal belief that collaboration and partnership between capital and citizens must take place without state interference (McCarthy & Prudham, 2004). It also counters the neoliberal belief in fiscal and administrative cuts through the privatization of public services (Harvey, 2003 cited in (McCarthy & Prudham, 2004). Indeed, these beliefs are responsible for the infrastructural gaps and attendant traffic snarl-ups, overflowing sewers, and mounds of garbage. It however agrees with critiques who see neoliberalism, as analogous to a parasite, occupying and drawing energy from the African Socialism state (Peck, 2013). It further agrees with critiques that neoliberalism results in negative consequences including uneven spatial development, a landscape of policy failures, and stuttering forms of misregulation (Brenner et al 2010 as cited in (Peck, 2013). This finding points to the need for a policy shift, towards state provision of strategic infrastructure, thereby providing the impetus for redevelopment by private investors.

The study established that global capital had no influence on ULUS, and this agreed with the findings that its use was insignificant compared to local capital. This was surprising because, under neoliberalism, it was expected there would be a free flow of global capital for redevelopment (Brenner & Theodore 2002:2 as cited in (Raco, 2005) (McCarthy & Prudham, 2004). This implies that this flow of capital is being obstructed by state controls on land tenure and land use. This finding shifts the focus from global capital to the significant role played by local capital in redevelopment, and the need for strategies and incentives to mobilize and aggregate it. Provision of incentives such as tax benefits on building materials have already been extended to both local and foreign investors in Konza Technopolis and Tatu City and there is no reason ordinary Kenyans cannot partake of the same incentives. In summary, the discussion points to the need for an alternative model of redevelopment addressing all the key findings to reverse negative outcomes as provided in Figure 7. This is expected to make Upper Hill a financial and business hub and a beacon for other Kenyan towns suffering similar challenges.

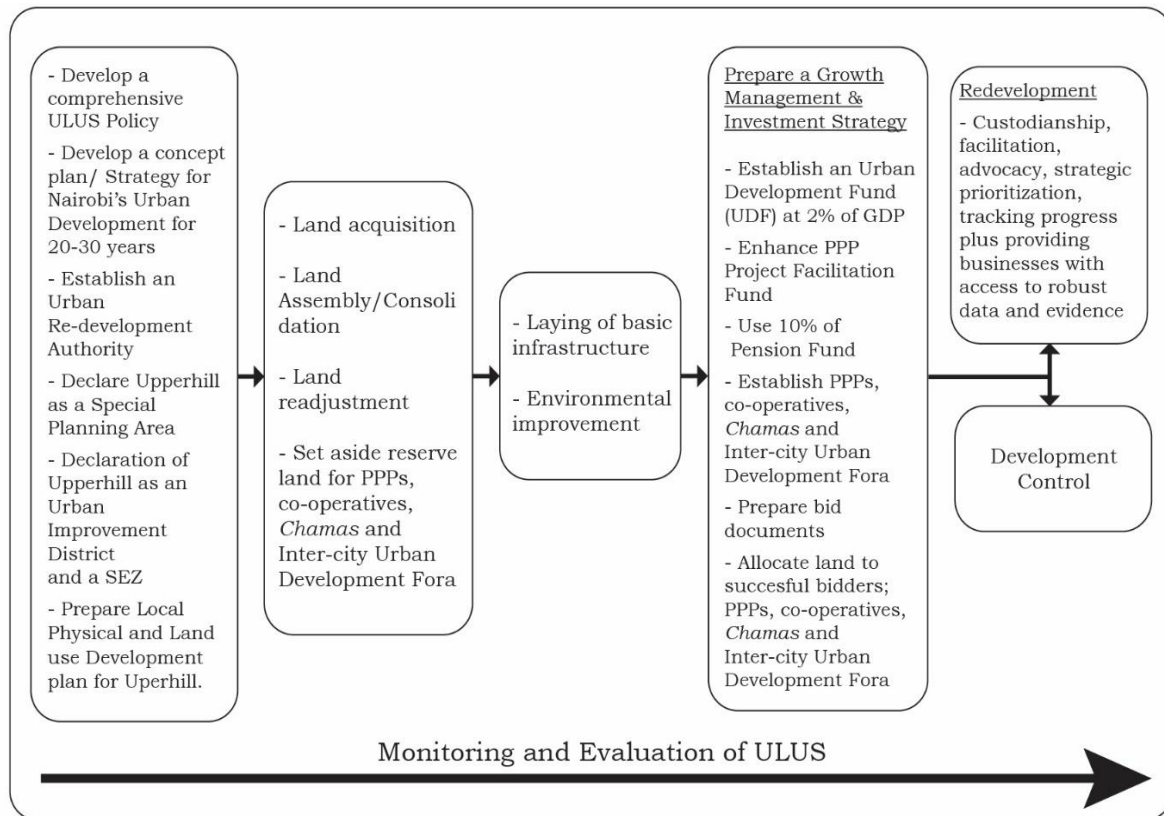


Figure 7. Alternative Model for ULUS.

6. Conclusions

Upper Hill was planned in 1992 when Hill Area Zoning and road widening plans were prepared changing its user from residential to commercial. This coincided with the SAPs of 1986 and the attendant fiscal cuts in public spending which delayed road widening. The absence of a comprehensive plan and strategy for redevelopment into a commercial and failure to update standards resulted in increased population density and pressure on existing infrastructure. A comprehensive plan to guide redevelopment is therefore critical and is recommended.

The redevelopment was concentrated where transport services were available, specifically along, the hospital, Ngong, and Valley roads, resulting in a patchwork pattern of development. The development of roads and provision of transport services in deficit areas like Upper Hill North will make them attractive for redevelopment. Since this investment may require, heavy capital outlay, financing must shift back to the state. In addition, a strategy for the phasing of development is recommended to ensure full development of one phase before moving to the next.

The application of free market, and neoliberal policies on the prevailing land tenure system has brought about the African socialist state and the neoliberal state resulting from the unequal pace of development between private land and public land. The attendant patchwork land use pattern and incongruent mix of old and new buildings imply that bridging the two states will be necessary. This can be achieved by developing a multipronged growth management and investment strategy including land assembly, land readjustment, and release of public land for comprehensive development through Public Private Partnerships, local landowners, cooperatives, and *chamas*.

Despite its presence in Upper Hill, global capital was found to not influence ULUS while spatial policy was found to be the key determinant of ULUS. A strategy to aggregate and mobilize local capital through the formation of cooperatives, interurban investment fora, and *chamas* is therefore recommended.

Though preparation and implementation of ULUS policy was the mandate of the national government and county government, respectively, coordination of actors was found wanting. Reassigning this role



to an Urban Redevelopment Authority with exceptional powers of intervention and decision-making will thus be critical. This body will coordinate planning, land acquisition, land assembly, and readjustment before inviting Public Private Partnerships, cooperatives, Intercity Urban Development Fora, and ‘chamas’ to undertake the redevelopment. It will also prioritize projects, and provide project facilitation and robust data to investors.

Development of a concept plan for Nairobi to guide long-term land use and transportation development for the next 30-50 years is also recommended to not only provide the vision and direction of growth but also anchor Upper Hill within the context of the whole county.

All the strategies have been used to develop a model for the redevelopment of Upper Hill which can be replicated in other areas around Nairobi’s CBD such as Kilimani, and Kileleshwa which are also experiencing pressure from the CBD. The model can also be applied to urban areas such as Nakuru and Mombasa which have distinct urban cores and zones of transition, and which are facing similar challenges as Upper Hill. This model can reimagine the zones of transition by unlocking their socio-economic potential for the benefit of businesses, urban dwellers, and the city at large. The model forms the study’s contribution to academia.

Further studies on capacity gaps in the County Government of Nairobi and the role of cooperatives in aggregating local capital for redevelopment are recommended to support the implementation of the strategies to streamline ULUS. It is expected that understanding the capacity gaps of the city would engender plugging those gaps by equipping officers with best practices in policy analysis and implementation. In addition, studies on the role of cooperatives would provide an understanding of their magnitude and aggregation capabilities for urban redevelopment to secure a stake for the Kenyan people.

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The author(s) declare(s) no conflicts of interest.

Data availability statement

Due to the nature of this research, participants of this study did not agree for their data to be shared publicly, so supporting data is not available.

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Original scientific paper

Unveiling the Impact of Urban Green Landscape on Quality of Life in Kaduna, Nigeria: Residents' Perceptions and Sustainable Strategies

*¹ Dr. Henry Ojobo , ² Dr. Oluwagbemiga Paul Agboola ,

³ Dr. Kasham Jummai Shamang 

¹ & ³ Department of Architecture, Faculty of Architecture, Kaduna State University, Kaduna, Nigeria.

² Faculty of Engineering and Architecture, Department of Architecture, Istanbul Gelisim University, Istanbul, 34310, TURKEY

¹ E-mail: henry.ojobo@kasu.edu.ng, ² E-mail: opagboola@gelisim.edu.tr, ³ E-mail: Kasham.shamang@kasu.edu.ng

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ABSTRACT

This study investigates the influence of urban green landscapes on the Quality of Life (QoL) in Kaduna Metropolis, Nigeria, focusing on residents' perceptions and sustainable urban development strategies. Conducted from May to July 2023, the quantitative research surveyed 377 residents using a questionnaire. Statistical analysis, including correlation and t-tests, was performed using SPSS version 23. Findings reveal a positive perception of urban green spaces, significantly contributing to residents' QoL. Key results include high satisfaction with green areas enhancing environmental beauty (Mean=4.88, SD=0.90) and providing recreational appeal (Mean=4.45, SD=0.95). Additionally, these areas significantly impact perceived value (Mean=4.78, SD=0.93), prestige (Mean=4.92, SD=8.18), and attachment to the environment (Mean=4.71, SD=0.831). Residents with accessible and functional green spaces express higher satisfaction levels (Cronbach's Alpha > 0.9). The study underscores the importance of urban greenery in improving urban living conditions and offers strategic recommendations for sustainable urban planning. Addressing a gap in literature, this research provides empirical insights into residents' perspectives within Kaduna Metropolis, contributing to academic discourse and practical urban development approaches.

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Highlights:

- Residents' positive perceptions of urban green spaces are significantly associated with higher levels of overall quality of life
- Enhanced quality of life is notably influenced by users' satisfaction and community ownership fostered by these urban green spaces.
- Urban green spaces have the potential to contribute to the socio-economic development of urban areas.
- Researchers, urban planners, and policymakers play pivotal roles in enhancing urban quality of life.
- The study introduces data-driven perspectives to the wider discussion on the social and economic dimensions of urban spaces.

Contribution to the field statement:

The study contributes to strategies for utilizing urban green spaces to improve residents' quality of life for sustainable urban development. By unveiling the impact of urban green landscapes, the manuscript contributes to the discovery of innovative methods and techniques for enhancing the quality of life in urban areas. The study's outcome provides insights into sustainable strategies that could be adopted by stakeholders to address challenges associated with green spaces.

*Corresponding Author:

Dr. Henry Ojobo

Email address: henry.ojobo@kasu.edu.ng

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1. Introduction

Quality of Life (QoL) stands as a multifaceted concept that encapsulates the diverse dimensions of individual well-being, encompassing socio-economic, environmentally pleasing, and emotional wellness. In the contemporary discourse on QoL, urban environments have become central arenas for its exploration and enhancement. Urban quality of life is not just about its impact on individual residents but also extends to the overall health and vitality of cities. With global urbanization accelerating, the imperative to create livable, sustainable, and enjoyable urban spaces becomes more pronounced. The combination of physical, mental, economic, and external factors that shape human and social development is intricately characterized as quality of life. This definition establishes a conceptual framework aligned with sustainable human development, within communities (Barreira *et al.*, 2021). Examining the development of social well-being, the effectiveness of current policies in addressing people's needs, and the impact of investments.

Quality of life is particularly pertinent in settings like parks and outdoor environments (Sallis *et al.*, 2006). Irrespective of the location of the landscapes, parks and greenspaces provide outdoor venues for relaxation and interactions. When individuals visit landscaped areas such as parks, they partake in a multi-sensory experience, considering it a vital space where individuals or social groups directly perceive a place (Shaw & Williams, 2004; Agboola; 2023b). Research on landscaped areas ranges from individual place and activity analyses (Chang & Gibson, 2011) to community-level investigations (Gomez *et al.*, 2015; Vogt *et al.*, 2020) to extensive studies on park accessibility (Larson *et al.*, 2016). Chang & Gibson (2011) explored recreation activities encompassing both leisure (at home) and tourism (involving travel), revealing varying levels of mental, social, and physical health among participants during the engagement. Quality of life is influenced by various factors, with key considerations including access to employment opportunities, educational resources, safety, and the availability of recreational and cultural amenities. Recognizing these priorities offers valuable insights for policymakers and urban planners aiming to improve residents' well-being. Promoting affordable housing initiatives and policies is essential for creating inclusive communities that allow residents to thrive without the burden of excessive housing costs (Yap *et al.*, 2019). Additionally, environmental concerns, as highlighted by Dyachia *et al.* (2017) and Agboola & Rasidi (2018), pose challenges impacting quality of life. Issues such as pollution, inadequate waste management, and the depletion of green spaces can profoundly affect residents' health and well-being.

Urban green spaces contribute to better physical health outcomes by promoting regular physical activity, leading to improved cardiovascular health and reduced lifestyle-related diseases. Recreational spaces in urban green areas encourage outdoor activities, fostering a healthier lifestyle. Parks enhance positive social interactions, safety, and community ownership. Vogt *et al.* (2020) explored retrofitted design features, focusing on trail hubs that increase access between neighbourhoods and parks, correlating with higher levels of vigorous physical activity. Larson *et al.* (2016) established links between health, quality of life (QOL), and happiness, finding positive associations in cities with substantial parkland. Addressing urbanization challenges goes beyond improving specific aspects of urban life; it is central to enhancing overall resident satisfaction and well-being. A comprehensive approach, encompassing traffic management, public transportation expansion, affordable housing initiatives, and environmental sustainability, is crucial (Jeon *et al.*, 2016; Mohsin *et al.*, 2020). Proactively tackling these challenges enables communities to pave the way for a higher quality of life, creating environments where residents can lead fulfilling and contented lives.

This research endeavours to delve into the intricate relationship between urban green spaces and the quality of life within the context of the Kaduna Metropolis. As urbanization accelerates globally, the significance of creating livable, sustainable, and enjoyable urban spaces becomes increasingly pronounced. Quality of Life (QoL) is a multifaceted concept encompassing socio-economic, environmental, and emotional well-being, playing a pivotal role not only in the individual lives of residents but also in the overall health and vitality of cities. The study is grounded in a conceptual framework aligned with sustainable human development, emphasizing the interconnectedness of physical, mental, economic, and external factors that shape human and social development within communities (Barreira *et al.*, 2021). With a particular focus on parks and outdoor environments, the research recognizes these spaces as essential components of urban landscapes, providing venues for relaxation, social interactions, and multi-sensory experiences. Parks, whether expansive or community-level, contribute significantly to residents' well-being, fostering positive social interactions, promoting safety, and encouraging a sense of community ownership.



The research acknowledges the influence of various factors on quality of life, ranging from access to employment opportunities and educational resources to safety, recreational amenities, and cultural offerings. The study emphasizes the importance of affordable housing initiatives in creating inclusive communities that allow residents to thrive without the burden of excessive housing costs. Additionally, environmental concerns, such as pollution, waste management, and the depletion of green spaces, are recognized as challenges that can profoundly impact residents' health and well-being. Specifically, the research aims to address the following objectives:

1. **Assess Residents' Perceptions:** Explore the perceptions of residents in Kaduna Metropolis regarding the impact of urban green spaces on their quality of life. Understand how individuals perceive the role of green areas in fostering well-being and satisfaction.
2. **Evaluate Health and Well-being Outcomes:** Examine the relationship between urban green spaces and residents' physical health, considering factors such as regular physical activity, cardiovascular health, and lifestyle-related diseases. Investigate how recreational spaces within green areas contribute to a healthier lifestyle.
3. **Analyze Social and Community Factors:** Investigate the social dynamics and community aspects influenced by urban green spaces. Explore how parks and outdoor environments enhance positive social interactions, safety, and community ownership, contributing to an improved quality of life.
4. **Identify Challenges and Opportunities:** Identify challenges related to urban green spaces in Kaduna Metropolis, such as accessibility, environmental sustainability, and potential threats to residents' well-being. Propose strategies and opportunities for sustainable urban development that leverage the positive aspects of green areas.

By addressing these specific research objectives, the study aims to provide actionable insights for policymakers and urban planners in the Kaduna Metropolis. The goal is to contribute to the development of tailored strategies that leverage the potential of urban green spaces to enhance the overall quality of life for residents, thereby fostering sustainable urban development in the face of ongoing urbanization challenges. Kaduna Metropolis stands out as a relevant and unique study setting due to its diverse urban challenges, cultural and socioeconomic diversity, specific regional context, ongoing urban growth, and potential implications for urban policies. By focusing on this distinctive setting, the research aims to provide insights that extend beyond the local context, contributing to the broader discourse on sustainable urban development and the role of green spaces in enhancing the quality of life in diverse urban environments.

Our findings highlight the role of urban green spaces in fostering social cohesion and community interaction. Parks and green recreational areas serve as focal points for social gatherings, events, and activities. Despite the growing body of evidence supporting the positive correlation between green areas and enhanced QoL, a notable gap exists in comprehending residents' perceptions, particularly within their immediate residential environments. The study's findings present a comprehensive examination of the relationship between urban quality of life and green areas. By delving into the nuanced interplay of these factors, this study seeks to provide valuable insights into how the strategic integration of green spaces can contribute to the improvement of urban living conditions. This study identifies and addresses a gap in the existing literature by focusing on residents' perceptions of the impact of urban green spaces on their quality of life within the specific context of Kaduna Metropolis, Nigeria. The findings highlight the crucial role of urban green spaces in influencing various dimensions of QoL, encompassing social, economic, cultural, ecological, physical, and psychological well-being. The originality of the study covers key aspects collectively shaping individuals' well-being and satisfaction in the urban environment. Recognizing the interconnectedness of these dimensions is crucial for a thorough understanding and enhancement of urban living, emphasizing the importance of a holistic approach to urban quality of life. The study delves into the impact of urban green landscapes on the quality of life in Kaduna. By exploring residents' perceptions and proposing sustainable strategies, it contributes valuable insights for urban planners, designers, and architects, showcasing the role they can play in enhancing the social and economic aspects of the built environment. Similarly, the study examines the impact of green spaces in the context of Kaduna, Nigeria, addressing a specific social and economic aspect of the built environment. This contributes to the broader discussion of emerging challenges facing global cities, providing a nuanced perspective from the field of environmental and urban studies.

2. Literature Review

2.1 Landscape Spaces and Urban Quality of Life

Landscape areas within residential environments go beyond aesthetics, significantly influencing well-being and quality of life. Landscaped green areas contribute crucially to overall neighborhood satisfaction (Crow *et al.*, 2006). Adverse effects of retail land use on satisfaction can be mitigated by higher tree or shrub coverage (Sullivan & Lovell, 2006; Ellis *et al.*, 2006). Water features and trees in neighborhoods encourage health-focused walking (Naderi & Raman, 2005), highlighting the multifunctional role of landscaped areas in enhancing residential livability and sustainability. Understanding and optimizing these roles are vital for urban planners, architects, and community developers prioritizing resident well-being.

Quality of life (QoL) encompasses various facets of urban existence, including wealth, employment, built environment, health, education, recreation, and social belonging. It is multidimensional, covering various urban life domains (Kırsar & Türkoğlu, 2017). Urban green areas, as determinants of QoL, are integral components of the urban spatial system, crucial as public services (Kırsar & Türkoğlu, 2017). This study focuses on the spatial dimension of QoL, categorizing parameters into eight key areas: residential, transport, security-safety, environment, socio-cultural, recreational, educational, and health. Transportation, residential, and environmental dimensions exhibit the highest number of parameters, reflecting their integral roles in urban life (Ab Rahman *et al.*, 2019). In recent decades, evidence, exemplified by Zhang *et al.* (2017), underscores urban green areas' substantial contribution to residents' overall quality of life. Cities prioritize values like security, peace, health, spatial quality, and ecological features, with open-green spaces crucial to achieving these goals. Despite urbanization's environmental challenges, such as air pollution and reduced green spaces, well-structured living environments and open green spaces are vital for maintaining urban life quality. Urban green spaces, despite environmental adversities, enrich the urban experience, serving as essential elements that foster nature interaction and community bonds. Mitigating negative impacts, these spaces significantly contribute to sustaining urban life quality, recognizing the fundamental human need for nature interaction (Jansson, 2013; Mshelia, *et al.*, 2020). The significance of parks plays a crucial role in enhancing the quality of life, particularly in urban areas.

Urban green areas are essential for elevating citizens' quality of life, playing a pivotal role in ensuring overall well-being. These spaces contribute significantly to sustainable urban development, positively impacting various aspects of urban life. Recognized for their positive correlation with quality of life, urban green initiatives demand comprehensive information for effective decision-making by public and private stakeholders (van Vliet *et al.*, 2021). Whether public, semi-public, or private, urban green areas are integral elements shaping urban life positively. They operate on multiple levels, including environmental, and ecological, actively influencing the image and character of urban areas. With their versatility, these spaces serve as crucial facilitators, promoting interaction between human activities and the environment, thereby enhancing the overall quality of life. As local champions, urban green areas contribute significantly to community satisfaction and a sense of place. Moreover, the cultural services provided by these green spaces have tangible impacts on neighborhoods and the built environment, fostering a sense of community and place satisfaction (Jennings *et al.*, 2016). Urban green areas are key indicators of quality of life (QoL), influencing residents' perceptions and well-being. Integrated into the urban spatial system, these spaces are crucial public services (Kırsar & Türkoğlu, 2017). Research confirms their positive impact on urban QoL, enhancing social, ecological, and psychological well-being (Zhang *et al.*, 2017; Yılmaz *et al.*, 2017). In today's urban landscape, factors like security, peace, health, space quality, and open-green areas are essential for life quality.

The multifunctionality of urban green spaces extends to environmental, and socio-cultural, aspects, shaping the character and image of urban areas. These areas act as local promoters of QoL, fostering a sense of place, community satisfaction, and tangible impacts on neighborhoods and the built environment (Sirgy, *et al.* (2004; Jennings *et al.*, 2016). As various research prioritizes QoL, environmental variables, particularly green spaces, play a crucial role in improving citizens' well-being (Mostafa, 2012). Amid the focus on socio-economic measures, this study underscores the significance of urban green areas as essential tools to measure progress and enhance overall QoL. Improved information on the quantity and quality of urban green spaces for effective strategic urban planning becomes imperative (van Dinter *et al.*, 2022). This study contributes to understanding the intricate relationship between these spaces and quality of life (QoL). As concerns about QoL grow, the use of community indicators has become prevalent for assessing current quality of life and tracking progress

(Mostafa, 2012). Despite numerous local governments prioritizing enhancing citizens' quality of life, efforts often focus on neglecting environmental variables like green spaces. To enhance QoL through urban green areas, and comprehensive information about the landscaped spaces in the cities (van Dinter *et al.*, 2022).

2.3. Conceptual Framework for Urban Quality of Life

The conceptual framework for urban quality of life serves as a comprehensive structure that systematically organizes and explores the multifaceted elements influencing the well-being and satisfaction of individuals within urban environments. This framework (Figure 1) integrates diverse dimensions, recognizing the intricate interplay between social, economic, and environmental factors. Mohit (2013) emphasized the correlation between the landscape environment and the concept of quality of life through two primary indicators: (i) objective indicators, encompassing the measurement of tangible conditions, and (ii) subjective indicators, reflecting people's feelings about various living factors (Nasution & Zahrah, 2014). The conceptual framework in Figure 1; acknowledges the dynamic nature of urban environments and quality of life, considering the evolving socio-economic, environmental, and cultural dynamics. The framework emphasizes the interdependence of objective and subjective indicators, recognizing that both tangible conditions and individual perceptions contribute to the overall assessment of urban quality of life. This conceptual framework provides a holistic perspective for researchers, urban planners, and policymakers, guiding the comprehensive assessment and improvement of urban quality of life. It encourages an inclusive approach that considers both quantifiable factors and the subjective experiences of individuals within the urban landscape.

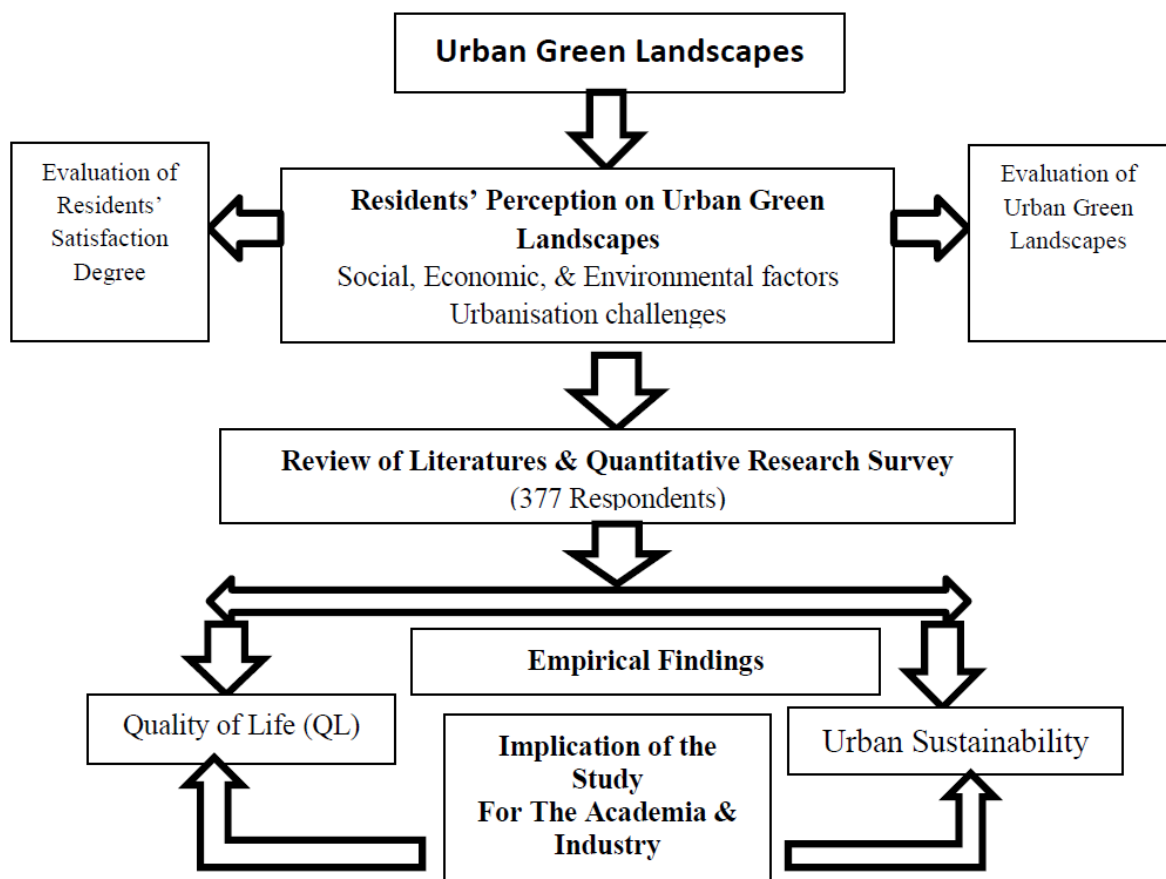


Figure 1. Study's Framework.

Based on the theoretical framework and the stated objectives, the study formulates the following hypotheses to guide the investigation into the relationship between urban green spaces and the quality of life in Kaduna Metropolis:

1. Hypothesis related to Residents' Perceptions:

- Null Hypothesis (H0): There is no significant association between residents' perceptions of urban green spaces and their overall quality of life in Kaduna Metropolis.



- Alternative Hypothesis (H1): Residents' positive perceptions of urban green spaces are significantly associated with higher levels of overall quality of life in Kaduna Metropolis.
- 2. **Hypothesis related to Health and Well-being Outcomes:**
 - Null Hypothesis (H0): There is no significant correlation between the presence of urban green spaces and residents' physical health outcomes, including regular physical activity, cardiovascular health, and reduced lifestyle-related diseases.
 - Alternative Hypothesis (H1): The presence of urban green spaces is significantly correlated with improved physical health outcomes among residents, including increased levels of regular physical activity, better cardiovascular health, and reduced prevalence of lifestyle-related diseases.
- 3. **Hypothesis related to Social and Community Factors:**
 - Null Hypothesis (H0): Social and community factors influenced by urban green spaces do not significantly contribute to an enhanced quality of life for residents in Kaduna Metropolis.
 - Alternative Hypothesis (H1): Positive social interactions, safety, and community ownership fostered by urban green spaces significantly contribute to an improved quality of life for residents in Kaduna Metropolis.
- 4. **Hypothesis related to Challenges and Opportunities:**
 - Null Hypothesis (H0): Challenges associated with urban green spaces, such as accessibility, environmental sustainability, and potential threats to residents' well-being, do not significantly impact overall quality of life in Kaduna Metropolis.
 - Alternative Hypothesis (H1): Addressing challenges and leveraging opportunities related to urban green spaces significantly contributes to sustainable urban development, positively impacting the overall quality of life for residents in Kaduna Metropolis.

3. Material and Method

3.1 Measurement of the quality of life

The concept of quality of life encompasses various dimensions, each marked by numerous environmental attributes, emphasizing the influential role of places in overall well-being. Many planning and design approaches assume intentional design can enhance well-being. Given most individuals' predominant urban residence, exploring connections between urban area characteristics and residents' perceived quality of life is crucial (Marans, 2015). A literature review identifies seven primary dimensions crucial for urban quality of life: i) Environmental urban, ii) Political urban, iii) Physical urban, iv) Mobility urban, v) Economic urban, vi) Social urban, and vii) Psychological urban. These dimensions are intricately interconnected, shaping the overall urban experience (Firouzbakht, *et. al*, 2020; Serag, *et al.*, 2013). Notably, the environmental quality of dwellings and the local household conditions are important predictors of community quality of life. This study adopts a survey technique that integrates quantitative and qualitative data to better understand inhabitants' quality of life perspectives regarding green space usage in Kaduna District. The study compensates for the existence of green places using a satisfaction-based measuring' approach, which is informed by Marans' model, which defines the link between satisfaction with green areas in the local residential surroundings and overall quality of life. The poll captures persons' opinions about socio-environmental conditions and behaviours while assessing the quality of urban living on both objective and subjective aspects (Marans, 2015). The satisfaction model is used to guide the measurement approach, which takes into account both objective and subjective characteristics.

The study model elucidates the complicated link between green spaces and the near-home environment in determining the quality of life. Quality of life, as seen as the interaction of wants, requests, and satisfaction, is dependent on levels of satisfaction from addressing these needs and requests within the residential environment. Green spaces improve people's quality of life, especially in cities. The quality of life indicators in this study primarily focuses on the role of green areas in the immediate residential context, specifically picking measures that are directly related to the presence of these areas. The study develops theoretical foundations by investigating residents' perceptions and proposing sustainable strategies. Methodologically, it provides insights into how the quality of life in urban areas can be assessed and improved, contributing to the theoretical and methodological foundations in the study of social and economic problems associated with contemporary urbanization. Through the empirical study on the impact of urban green landscapes, the manuscript brings a

scientific view to the emerging challenges faced by urban environments. It adds data-driven perspectives to the broader discourse on the social and economic aspects of urban spaces.

3.2 Description of the Study Area: Kaduna Metropolis

Kaduna Metropolis (Figure 2), located in north-central Nigeria, serves as the capital of Kaduna State, blending traditional and modern elements with cultural richness. Positioned at approximately 10.5264° N latitude and 7.4388° E longitude, the city features diverse topography, including plains, hills, and water bodies, contributing to its visual and ecological diversity. With a population of 1,187,000 as of 2023, Kaduna Metropolis reflects Nigeria's cultural diversity, with the harmonious coexistence of various ethnic groups due to historical migrations and urbanization trends. The Kaduna city boasts a diverse architectural heritage, encompassing colonial-era structures to contemporary designs, and its infrastructure includes roads, educational institutions, healthcare facilities, and ongoing development projects aimed at improving residents' quality of life. Kaduna Metropolis offers a multifaceted blend of historical roots and modern dynamism, making it a significant focus for studies exploring and enhancing the quality of life in this culturally rich urban landscape, supported by proactive urban development initiatives and policies implemented by the government. In terms of the justification for choosing the Kaduna metropolis; the city serves as a uniquely relevant study setting for the exploration of the nexus between urban green spaces and quality of life due to several distinctive characteristics, making it a noteworthy focus of investigation.

- **Diversity of Urban Challenges:** Kaduna Metropolis encapsulates a diverse range of urban challenges commonly faced by rapidly urbanizing regions. The city grapples with issues such as traffic management, public transportation expansion, affordable housing, and environmental sustainability. The prevalence of these challenges provides a rich context for understanding how the integration of urban green spaces can serve as a multifaceted solution to enhance overall resident satisfaction and well-being.
- **Cultural and Socioeconomic Diversity:** The city's population is characterized by cultural and socioeconomic diversity, reflecting a microcosm of broader urban demographics. Investigating the impact of green spaces on quality of life in such a varied setting allows for nuanced insights into how different demographic groups perceive and benefit from these areas. This diversity is crucial for designing inclusive strategies that cater to the needs and preferences of a heterogeneous urban population.
- **Regional Context:** Kaduna Metropolis is situated within a specific regional context, influenced by local environmental conditions, cultural practices, and economic dynamics. Examining the relationship between urban green spaces and quality of life in this context allows for the identification of region-specific challenges and opportunities. The findings can potentially contribute to the development of targeted interventions that align with the unique characteristics of the region, setting a precedent for other urban areas facing similar contextual factors.
- **Urban Growth and Development:** The city's ongoing urbanization presents an opportunity to study the impact of green spaces amidst rapid development. As urban areas expand, the preservation and integration of green areas become increasingly critical. Understanding how urban green spaces can be strategically incorporated into the evolving urban landscape of Kaduna Metropolis offers valuable insights for sustainable urban development practices, with potential applications in other burgeoning cities.
- **Policy Implications:** Kaduna Metropolis, like many urban centers, is likely subject to various urban policies and interventions. Investigating the relationship between green spaces and quality of life in this setting provides an opportunity to assess the effectiveness of existing policies and propose evidence-based recommendations for future urban planning initiatives. The study's outcomes can inform policymakers on strategies to optimize the contributions of green spaces to residents' well-being.

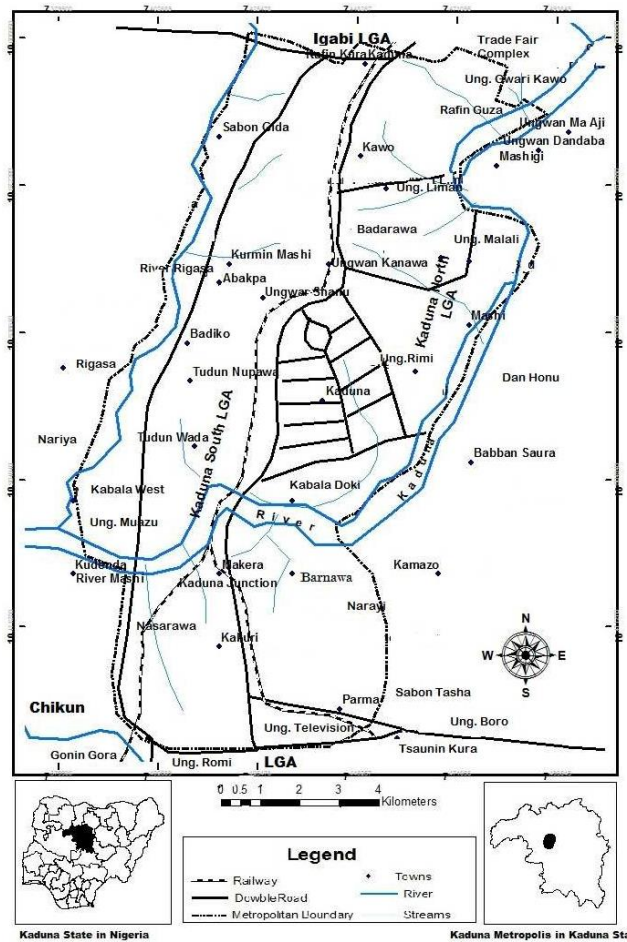


Figure 2: Map of Kaduna Metropolis **Source:** Geographical Information Survey Unit, KASU (2023). Department of Environmental Management, Kaduna State University. Kaduna. Nigeria

3.3. Sampling, Measurement Tools and Data Collection

This study examines Kaduna residents' perceptions of the impact of urban green spaces on quality of life. Data were collected through a questionnaire in Kaduna District, with a sample size of 377 determined using the Raosoft Sample size calculator based on the population of Kaduna District (1,133,000; in 2021). The margin of error was set at 5%, with a confidence level of 95% and a response distribution of 50%. The questionnaire, conducted from May to July 2023, employed a face-to-face method, involving 402 participants randomly sampled from various neighbourhoods of Kaduna District, focusing on adults over 18 years old. The questionnaire, divided into three sections with 24 questions, explored Quality of Life (QoL) in Kaduna District, focusing on green areas and the immediate residential environment. Demographic information was gathered in the first section, overall quality of life in the second, and satisfaction with landscape features and green areas in the third (both subjective perceptions and objective indicators). Quality of life in this study is defined based on preference satisfaction. The obtained data underwent analysis using Statistical Package for the Social Sciences (SPSS version 23), a widely used software package for statistical analysis in various fields. Green area users responded, generating variables for regression analysis. Statistical methods, including frequency, percentage, correlation analysis, and t-tests, were applied to independent variables to determine differences and significance levels. Reliability analysis, measured by Cronbach Alpha, found the data reliable, with gender, income level, and the number of children included as independent variables in the evaluation.

4. Data Analysis and Results

Table 1 presents the analysis and results, detailing demographic characteristics and overall quality of life satisfaction in the immediate residential environment. The sample size of 377 respondents has a balanced representation of females (52.50%) and males (47.48%). Across age groups, 62 (16.44%) are in the 18-25 range, 66 (17.50%) in 26-35, 118 (31.29%) in 36-45, 66 (17.50%) in 46-55, 35 (9.28%) in 56-65, and 30 (7.95%) in 66 years and above. In terms of marital status, 125 (33.15%) are single, 196 (51.98%) are married, and 56



(14.85%) are widowed or divorced. Regarding education, 23 (6.10%) have no schooling, 127 (33.68%) are high school graduates, 82 (21.75%) and 65 (17.24%) have Associate and Undergraduate degrees, and 27 (7.16%) are Postgraduates. Participants rated overall life quality on a 5-point Likert scale, with Cronbach’s alpha (α) at 0.899, and the general life quality score for the entire sample is 3.98 (Table 2). A Cronbach’s alpha exceeding 0.9 is excellent, and above 0.8 is considered good, indicating respondents' high satisfaction with the quality of life.

Table 1. Demographic characteristics of the respondents.

Independent variables		Frequency (f)	Percentage (%)
Gender	Female	179	52,50
	Male	198	47,48
Age status	18-25	62	16,44
	26-35	66	17,50
	36-45	118	31,29
	46-55	66	17,50
	56-65	35	9,28
	66 years and above	30	7,95
Education level	Not attended	23	6,1
	Primary school	53	14,05
	Secondary/High school	127	33,68
	Associate degree	82	21,75
	Undergraduate	65	17,24
Marital status	Postgraduate	27	7,16
	Single	125	33,15
	Married	196	51,98
Household capacity	Widow/divorced	56	14,85
	1-2 numbers	43	11,40
	3-4 numbers	138	36,60
	5-6 numbers	149	39,52
Employment	6 and above	47	12,46
	Employed	286	75,86
	Unemployed	42	11,14
	Retired	27	7,16
Total	Decided not to work	23	6,10
	Total	377	100,0

Table 2: The respondents’ overall satisfaction level on the quality of life.

Variables of the Quality of Life	Number (N)	Mean Values (M)	Std. Deviation (SD)
Residential buildings	377	3,96	0,81
Kaduna Metropolis	377	3,98	0,83
Education	377	4,83	0,88
Work-Life Balance	377	3,92	0,87
Economic Well-being	377	4,84	0,82
Standards of living	377	3,81	0,90
Health status	377	3,86	0,81
Infrastructural facilities	377	3,82	0,88
Social and Cultural Factors	377	3,87	0,88
Personal Happiness and Satisfaction	377	4,85	0,80
Social relations with family, friends, and neighbor	377	3,89	0,85
Community Life	377	4,80	0,86

1,00-1,79: Respondents not satisfied at all; **1,80-2,59:** Respondents not satisfied; **2,60-3,39:** Respondents not-decided; **3,40-4,19:** Respondents satisfied; **4,20-5,00.** Respondents are very satisfied.



Participants were surveyed to identify factors influencing the presence of landscaped elements in their Kaduna metropolis homes (Table 3). Out of 377 respondents, 1281 responses were collected, allowing participants to select multiple factors. Analysis revealed that the most prevalent consideration for choosing residence in the Kaduna metropolis was a "secured neighborhood," cited by 303 (23.65%) respondents. Other significant factors included "having a playground and relaxation facility in the neighborhood" (18.26%), "neighborhood with a private landscaped garden" (16.15%), and "a greater proportion of landscaped green areas compared to other neighborhoods" (14.59%). The top consideration for choosing residence in the Kaduna metropolis is a "secured neighborhood," cited by 303 respondents (23.65%). This underscores residents' priority for safety in their housing decisions. The second most common factor is the preference for a "neighborhood with a playground and relaxation facility," with 234 responses (18.26%), emphasizing the significance of recreational amenities in residential areas for residents seeking leisure and relaxation near their homes.

Residents in the Kaduna metropolis show a notable preference for a "neighborhood with a private landscaped garden," as indicated by 207 responses (16.15%). This suggests a substantial value placed on having personal green spaces, potentially for leisure, gardening, or creating a tranquil home environment. Additionally, the consideration of a "greater proportion of landscaped green areas compared to other neighborhoods" is significant, with 187 responses (14.59%). Residents not only prioritize the presence of green spaces but also compare their quantity and quality across different neighborhoods when making housing decisions. The possession of "landscaped green areas around the immediate residential neighborhood" is valued by 148 respondents (11.55%), emphasizing the importance of well-maintained greenery near homes. Other contributing factors, though less prevalent, include the significance of a "children's playground," mentioned by 103 participants (8.04%), and the desire for a "serene residential immediate environment," indicated by 99 responses (7.75%). These findings underscore the importance of family-friendly amenities and a peaceful atmosphere in residents' decision-making processes. Overall, safety, recreational amenities, and green spaces play significant roles in residents' housing choices in the Kaduna metropolis. In the context of Kaduna metropolis, residents' housing choices are notably influenced by three key factors: safety, recreational amenities, and green spaces. The emphasis on "safety" suggests that individuals prioritize living in neighborhoods perceived as secure, underlining the importance of a secure environment in their decision-making process. The prominence of "recreational amenities" indicates a desire for facilities like playgrounds and relaxation areas, suggesting that residents value access to spaces for leisure and relaxation within their immediate vicinity. Additionally, the consideration of "green spaces" underscores the significance of natural environments, with residents preferring areas with private landscaped gardens and a higher proportion of landscaped green areas compared to other neighborhoods. In summary, residents in Kaduna prioritize safety, access to recreational facilities, and the presence of green spaces when selecting their homes, reflecting a broader focus on well-being and quality of life in their housing decisions.

Regarding residents' satisfaction with the landscaped environment in the Kaduna metropolis, the results are summarized in Table 4. A significant 89.92% (339 individuals) expressed complete satisfaction with the scenic green landscaped areas, while only 3.18% (12 individuals) reported dissatisfaction, and 1.59% (26 individuals) were partly satisfied. Evaluating the effects of these green spaces on citizens, 86.73% (327 respondents) indicated a positive impact, 3.97% (15 individuals) reported harm, and 9.28% (35 individuals) noted no effect at all. This assessment provides valuable insights into residents' satisfaction levels and perceived effects of the green landscaped areas, showcasing a predominantly positive sentiment. The high satisfaction rate indicates that the majority find these areas visually appealing, enjoyable, or fulfilling in some way. While the majority (86.73%) reported positive effects of green landscaped areas, a minority (3.18%) expressed dissatisfaction. Understanding these concerns can reveal specific areas for improvement. A moderate 1.59% found partial satisfaction, indicating room for enhancements. Additionally, 3.97% noted negative effects, emphasizing the need to explore challenges associated with green spaces. Interestingly, 9.28% perceived no effect, reflecting diverse preferences or the necessity for more nuanced inquiries to capture subtler impacts. Summarily, this assessment offers valuable insights for enhancing the quality and effectiveness of green landscaped areas in the Kaduna metropolis. The assessment serves as a guide for urban planners and policymakers in Kaduna to enhance the overall quality and effectiveness of green landscaped areas, ensuring they align with residents' expectations and preferences.



Table 3: Respondents’ appraisals of the availability of landscaped elements in their homes' environment.

Variables of the building possession	Frequency (f)	Percentage (%)
1. Secured neighborhood	303	23,65
2. Having a playground and relaxation facility in the neighborhood	234	18,26
3. Neighborhood with private landscaped garden	207	16,15
4. Greater proportion of landscaped green areas when compared to other neighborhood	187	14,59
5. Possession of landscaped green areas around the immediate residential neighborhood.	148	11,55
6. Possession of children's playground	103	8,04
7. Possession of serene residence immediate environment	99	7,72
Total	1281	100

Table 4: Residents’ Satisfaction with Kaduna Metropolis about the Landscaped Environment.

Satisfaction with green landscaped area	Frequency (f)	Percentages (%)
The scenery green landscaped area makes me satisfied	339	89,92
The scenery green landscaped area makes me dissatisfied	12	3,18
The scenery green landscaped area makes me partly satisfied	26	1,59
Total	377	100
Effect of the scenery green landscaped areas on the citizens		
The scenery of green landscaped areas has a positive effect	327	86,73
The scenery of green landscaped areas has a negative effect	15	3,97
The scenery of green landscaped areas has no effect at all	35	9,28
Total	377	100

From Table 5, 5.30% of respondents never visited landscaped green areas in the Kaduna metropolis, and 12.46% did not venture outside the metropolis. A majority, 78.24%, visited the metropolis 1-2 times weekly, reflecting a positive engagement with local green spaces for leisure or recreation. Frequencies of 3-4 times (12.99%) and 4-5 times or more (3.44%) within the metropolis indicated varying degrees of commitment to utilizing green areas. The study highlights respondents' regular interaction with local green spaces, suggesting an integration of nature-related activities into their weekly routines. Notably, 53.84% of respondents visited green areas outside the Kaduna metropolis 1-2 times a week, indicating a dual preference for both local and external green spaces. This trend suggests diverse preferences or a curiosity to explore different environments. Additionally, 12.99% reported visiting within Kaduna metropolis 3-4 times a week, highlighting a smaller yet dedicated group with a strong affinity for local green areas, possibly influenced by factors like proximity, convenience, or unique amenities offered. The limited visits (3.44% within the Kaduna metropolis and 2.12% outside) among those who frequent green areas 4-5 times a week or more suggest a smaller but committed group valuing frequent nature engagement. Investigating this group's characteristics and motivations can offer insights for urban planning. The discovery that 12.46% never visited green areas beyond the Kaduna metropolis prompts inquiries into accessibility, awareness, or appeal of such spaces. Exploring the reasons behind this trend informs strategies to promote visits to external green areas. This exploration provides insights for urban planning, suggesting a need to understand characteristics and motivations to enhance overall green space utilization and promote external visits. The data underscores the importance of understanding the characteristics and motivations that influence residents' interactions with green areas. Identifying the factors that contribute to residents' preferences and patterns of engagement can inform urban planners about the specific needs and desires of the community. This understanding is crucial for enhancing the overall utilization of local green spaces within the metropolis. Additionally, the discovery of a dual preference for both local and external green spaces highlights the need to create appealing and accessible environments in both contexts. By addressing factors such as proximity, unique amenities, and overall appeal, urban planners can develop



strategies to encourage more frequent and diverse visits to green areas, contributing to the well-being and satisfaction of the residents.

Table 6 illustrates residents' perspectives on the accessibility and limitations of landscaped green areas, with 68.16% expressing satisfaction, and 12.46% feeling dissatisfied. Additionally, 7.69% find access difficult, 5.03% feel insecure, and 6.63% mention overcrowding. These varied opinions provide a nuanced understanding of residents' experiences. Notably, the majority, 68.16%, are content with access, reflecting the perceived alignment of green areas with their intended purposes. This positive sentiment indicates effective utilization for recreation or relaxation, portraying the green spaces as well-received and valuable resources in the community. Recognizing the 12.46% of respondents dissatisfied with accessing landscaped green areas is crucial, signifying potential discrepancies between design and residents' needs. Exploring their reasons offers insights for improvements. The 7.69% facing difficulty accessing these areas may highlight physical or logistical barriers, necessitating attention to enhanced inclusivity and broader accessibility. Addressing these concerns ensures that green spaces cater to diverse resident needs. The 5.03% expressing feeling unsecured when accessing landscaped green areas raises safety concerns, emphasizing the need for robust security measures. Addressing safety issues is pivotal for creating an inviting environment that encourages community engagement in these areas. Safety significantly influences residents' quality of life perceptions, with well-lit streets and effective policing strategies enhancing overall satisfaction. Additionally, 6.63% of respondents noted overcrowding concerns, emphasizing the importance of thoughtful management to prevent negative impacts on the user experience despite high popularity. Addressing these nuanced perspectives is crucial for ensuring green spaces effectively cater to diverse resident needs, promoting satisfaction and community engagement. By addressing these, urban planners and policymakers can ensure that green areas become integral components of the community, promoting satisfaction, well-being, and a strong sense of belonging among residents.

Table 7 illustrates the impact of green landscaped areas on Kaduna metropolis residents' quality of life, with an average satisfaction score of 4.99 and a reliable Cronbach's Alpha of 0.880. The results highlight positive perceptions, with respondents indicating that these areas enhance the beauty of their environment (Mean=4.88, SD=0.90) and make it more visually appealing for visits (Mean=4.45, SD=0.95). The findings also show that green landscaped areas contribute to the perceived value (Mean=4.78, SD=0.93), prestige (Mean=4.92, SD=8.18), and attachment to the environment (Mean=4.71, SD=0.831). Overall, residents express satisfaction, affirming the positive impact of these areas on their well-being and living experience. The focus on the visual appeal of green areas underscores their significant role in enhancing the environment's beauty, contributing to a visually pleasing urban landscape. The mean score of 4.45 (with a standard deviation of 0.95) for making the environment more visible to visit highlights the attractiveness and accessibility of these spaces, encouraging resident engagement. The perceived increase in the environment's value, with a mean score of 4.78 and a standard deviation of 0.93, suggests residents attribute economic and cultural significance to green areas, enhancing overall desirability. A high mean score of 4.92 (with a low standard deviation of 0.818) for making the environment more prestigious indicates residents' associate prestige with well-landscaped areas, positively impacting community image. Lastly, the mean score of 4.71 (with a standard deviation of 0.831) for making the environment more attached indicates residents feel emotionally connected to their surroundings, fostering community well-being. Overall, the findings affirm residents' satisfaction with green landscaped areas and underscore their positive influence on various aspects of residents' lives and the overall urban landscape. Resident feels emotionally connected to their surroundings, contributing to a sense of attachment and community well-being. These positive outcomes underscore the importance of well-designed green spaces in enhancing residents' satisfaction and the overall quality of urban living.

The results in Table 8 reveal the relationship between green landscaped areas in residential environments and gender. With a Cronbach's Alpha value of 0.899 and a mean satisfaction level of 4.58, the internal consistency and satisfaction measurement reliability are high. The examination of the relationship between green landscaped areas and gender shows a significant level ($p < 0.05$) for all variables, indicating a noteworthy association. Notably, females exhibit higher significance levels compared to males. This statistical analysis, indicative of residents' satisfaction, establishes a baseline for understanding the impact of gender on perceptions. The identified significant relationship underscores that gender differences influence how residents perceive and value the contributions of green areas, suggesting varied experiences and preferences between



men and women. The findings suggest that men and women have distinct experiences and preferences when it comes to assessing the contributions of green areas, emphasizing the importance of considering gender dynamics in the planning and management of residential landscapes.

Table 5: Frequency of respondents' visiting the landscaped green areas.

Frequency of going to landscaped green areas	Around Kaduna metropolis		Outside of the Kaduna metropolis	
	Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)
Never	20	5,30	138	12,46
1-2 times a week	295	78,24	203	53,84
3-4 times a week	49	12,99	28	7,42
4-5 times a week or more	13	3,44	08	2,12
Total	377	100	377	100

Table 6. Residents' opinions on the levels of accessibility and limitations of the landscaped green areas.

Accessibility to the landscaped green areas	Frequency (f)	Percentage (%)
1. Accessing the landscaped green areas satisfies my intentions	257	68,16
2. Accessing the landscaped green areas does not satisfy my intentions	47	12,46
3. Accessing the landscaped green areas is difficult	29	7,69
4. Accessing the landscaped green areas makes me unsecured	19	5,03
5. Accessing the landscaped green areas is always crowded	25	6,63
Total	377	100

Table 7. The effects of the green landscaped areas on quality of life.

Landscaped Green areas in Kaduna metropolis	N	Mean	Std. Deviation
1. Landscaped green areas make my environment more beautiful	377	4,88	0,907
2. Landscaped green areas make my environment more visible to me to visit	377	4,45	0,951
3. Landscaped green areas make my environment more valuable	377	4,78	0,930
4. Landscaped green areas make my environment more prestigious	377	4,92	0,818
5. Landscaped green areas make my environment more attached	377	4,71	0,831
Total	377	4,99	100

1,00-1,79 I strongly disagree, 1,80-2,59 I do not agree, 2,60-3,39 no idea, 3,40-4,19 I agree, 4,20-5,00 agree

Table 8. Relations between Contributions of Green Landscaped Areas in Residence Immediate Environment and Gender (T-Test)

Variables of the contributions	N	Mean	Std. deviation	Gender	Mean	Std. deviation	Std. Error Mean	Sig. (2-tailed)
1. My family and I can get closer to nature in green, landscaped areas.	377	3,98	0,896	Female	4,91	0,820	0,069	0,003
				Male	4,02	0,810	0,057	0,001
2. I get drawn away from the bustle of the city by green, landscaped areas.	377	3,87	0,834	Female	4,21	0,934	0,058	0,003
				Male	4,08	0,800	0,045	0,002
3. My atmosphere is made beautiful by a green and well-landscaped environment.	377	3,83	0,928	Female	3,26	0,815	0,078	0,002
				Male	3,10	0,822	0,082	0,001
4. My physical and mental well-being are positively impacted by a landscaped green environment.	377	3,09	0,913	Female	4,28	0,966	0,045	0,002
				Male	3,11	0,899	0,081	0,002
5. I feel calmer and more at ease in green, landscaped areas.	377	4,92	0,951	Female	3,99	0,933	0,064	0,002
				Male	3,12	0,888	0,093	0,003
6. Green landscaped Areas increase the overall quality of space	377	4,77	0,900	Female	4,22	0,944	0,053	0,012
				Male	4,01	0,701	0,054	0,012
7. Cleanliness and health are enhanced by a landscaped green environment.	377	4,48	0,916	Female	3,77	0,955	0,027	0,011
				Male	3,00	0,818	0,082	0,013

1,00-1,79: I strongly disagree; 1,80-2,59: I do not agree; 2,60-3,39: No idea; 3,40-4,19: I agree; 4,20-5,00: I agree.

5. Discussion

These results offer a comprehensive overview of residents' quality of life perceptions, emphasizing safety, community engagement, green spaces, addressing challenges, and accounting for demographic variations, aligning with Lahoti *et al.* (2023) and El Din *et al.* (2013). Understanding these factors is vital for informed decision-making and policy development to enhance overall well-being. The diverse factors influencing the availability of landscaped elements in homes in the Kaduna metropolis reflect resident priorities. The strong emphasis on security, recreational amenities, and well-maintained green spaces indicates varied preferences contributing to the overall livability of residential areas. Urban planners and developers can leverage these insights to create neighborhoods aligned with the diverse needs of the community, fostering sustainable and attractive living environments in the Kaduna metropolis.

The findings present a nuanced picture of the utilization of landscaped green areas in and around the Kaduna metropolis, in line with Adegun *et al.* (2021). Varying visit frequencies within and outside the metropolis highlight the dynamic nature of residents' interactions with green spaces. Access to green spaces and recreational amenities significantly shaped residents' perceptions of their living environment. Proximity to parks, playgrounds, and other recreational facilities correlated with a higher quality of life, supported by Adegun *et al.* (2021) and Kaczynski *et al.* (2014). Consistent with Shores and West (2008), the availability of green spaces was linked to improved mental well-being and a greater sense of connection to nature.

These insights are crucial for optimizing green area design and management to align with local preferences and needs, benefiting urban planners, policymakers, and community stakeholders. They align with



previous work by Nielsen *et al.* (2019) and Sharifi *et al.* (2017). Future research could explore the qualitative aspects of residents' experiences for a comprehensive understanding of the relationship with green spaces in the Kaduna metropolis (Sharifi *et al.*, 2017; Kowaltowski, *et.al.* (2006). The majority of surveyed citizens derive satisfaction and positive well-being effects from green landscaped areas, consistent with Agboola's study (2023a) emphasizing their role in creating a sustainable and healthy environment. However, a minority expresses dissatisfaction or perceives negative effects, emphasizing the importance of understanding individual preferences and concerns. These findings guide urban planners and policymakers in tailoring green space initiatives to meet diverse community needs, aligning with Armitage *et al.* (2012), and Agboola (2023b); where qualitative research offers deeper insights into specific aspects contributing to satisfaction or dissatisfaction for more targeted interventions.

This finding indicates satisfaction with green areas in the immediate residential environment, highlighting their significant contributions to life quality. This aligns with previous observations by Kondo *et al.* (2018), emphasizing the positive links between exposure to green areas and quality of life. Policymakers need to understand public needs and requests for green areas to enhance overall life quality. Varied responses on accessibility and limitations underscore the importance of considering diverse community needs. While the positive majority opinion is promising, concerns raised by the minority, especially regarding difficulties, security, and overcrowding, must be addressed for inclusive and sustainable green spaces. This information can guide urban planners and policymakers in refining design and management strategies to optimize the overall user experience and effectively serve residents' well-being in the Kaduna metropolis.

Our research consistently shows a significant positive correlation between access to urban green spaces and improved mental well-being, aligning with Kondo *et al.* (2018). Proximity to green areas is associated with lower levels of stress, anxiety, and depression, as reported by respondents living nearby compared to those without such access. This aligns with previous studies by Moore *et al.* (2018) and Velarde *et al.* (2007), indicating that green spaces act as a buffer against the negative impacts of urban living on mental health. Understanding the impact of green landscaped areas on quality of life is crucial for urban planning and community well-being, with this study providing insights into residents' perceptions of these areas' effects on various aspects of their lives.

This study aligns with Romice *et al.* (2017), emphasizing green areas as a crucial urban element positively contributing to quality of life. Green landscaped environments demonstrate how thoughtfully designed spaces enhance well-being across generations, making them essential for urban development. Meeting the needs and functions of green areas is vital for improving the quality of life, particularly in urban settings. Overall, the results highlight that satisfaction positively influences quality of life, specifically in the Kaduna metropolis. Residents perceive the aesthetic, economic, and cultural contributions of green landscaped areas, emphasizing their significance in urban planning and community development. The high satisfaction levels and positive associations suggest that continued investment and maintenance of green spaces can be a valuable strategy for enhancing overall community well-being.

The relationships between gender and the impact of green landscapes in immediate residential areas unveil nuanced differences in satisfaction, perceived effects, and preferences. Recognizing these distinctions is vital for creating residential environments tailored to the diverse needs and perceptions of both genders, contributing to more inclusive and sustainable urban spaces. Interestingly, higher significant levels in females compared to males suggest that women generally exhibit a stronger positive connection between green landscapes and perceived quality of life. Influenced by factors such as preferences and interactions with their environment, these findings align with Kruize *et al.* (2020) and Kondo *et al.* (2018). Possible explanations for these gender-related variations include differences in how men and women use and experience green spaces, with women possibly placing more emphasis on aesthetic and social aspects and deriving greater psychological and emotional well-being benefits from greenery in their immediate surroundings.

These findings highlight statistical associations, suggesting the need for additional qualitative research or surveys to uncover reasons behind observed gender differences. Understanding these nuances is crucial for urban planners, policymakers, and community developers to tailor strategies addressing the diverse needs of both male and female residents. Consistent with research by Jim & Chen (2006) and Ma *et al.* (2019), which emphasizes the role of gender in shaping residents' satisfaction and perceptions of green landscapes, the study calls for acknowledging and addressing gender-related variations. This can contribute to more inclusive urban



planning strategies. The findings align with existing literature, reinforcing the connection between gender and the contributions of green landscapes in residential environments. This comparison validates observed gender-based differences, emphasizing the need to incorporate these insights into urban planning and development practices.

6. Conclusion and Recommendation and Future Study

This study originally emphasizes the socio-economic impact of contemporary urbanization and underscores the crucial role of urban green spaces in shaping the Kaduna metropolis' quality of life. The study, focusing on Kaduna, Nigeria, offers a specific context for understanding challenges related to green spaces. While it may not directly compare with other global cities, it contributes by providing a detailed analysis of challenges and proposing sustainable strategies, which could serve as a reference for comparative studies in the future. By unveiling the impact of urban green landscapes, the study contributes to the discovery of innovative methods and techniques for enhancing the quality of life in urban areas. It provides insights into sustainable strategies that could be adopted by urban planners and policymakers to address challenges associated with green spaces.

The findings offer insights valuable for theoretical discussions in academia and practical applications for global urban planners and policymakers, extending beyond Kaduna. Beyond identifying the positive correlation between green spaces and quality of life, the paper proposes Kaduna-specific strategies, contributing to sustainable urban planning that prioritizes green infrastructure. Crafted with diverse indicators, in the correlation between residential green spaces and quality of life, the study finds consistent results in terms of user opinions, satisfaction, and subjective in addition to objective measures. In line with Marans' paradigm, the study focuses on the interaction of subjective and objective measures, revealing the level of green space utilization and happiness in Kaduna. Notably, inhabitants in the projected developing neighborhood are quite satisfied with their immediate green spaces, which contributes greatly to our understanding of the relationship between green spaces and residents' well-being.

Elevating satisfaction with residences and their surroundings is crucial, especially in the Kaduna metropolis. The study emphasizes the importance of integrating green areas into residential neighborhoods to enhance utilization and satisfaction, providing guidance for future strategies. Supported by both quantitative and qualitative data, the survey informs city-scale urban green planning and evaluates inputs specific to the Kaduna metropolis, highlighting the positive impact of current green environments on the city's quality of life. The immediate residential environment is pivotal in meeting human needs and desires, with the study emphasizing the role of technology, such as information access and online platforms, in influencing quality of life. Integrating technology for improved communication and accessibility emerges as a promising approach to boost overall satisfaction. The study's outcomes have significant implications for quality of life and green area policies in the Kaduna metropolis, suggesting periodic case study repetition to inform ongoing strategic plans. It serves as a valuable resource for planners and designers, offering insights for coordinated interventions to enhance services and overall quality. Notably, amidst the initial impacts of the COVID-19 pandemic, the study underscores the crucial role of urban green spaces, especially in immediate residential surroundings, emphasizing the need to enhance such spaces for a better quality of life and a healthier living environment. Addressing the multifaceted challenge of enhancing urban quality of life requires a holistic approach that considers various facets of city living. Strategies to achieve the goal of the urban quality of life are explained in Table 9.



Table 9: Strategies to Enhancing Urban Quality of Life.

S/No	Strategies	Explanations
(i)	Sustainable Urban Design	Embrace sustainable urban planning principles, including mixed-use zoning, pedestrian-friendly infrastructure, and public transportation, promoting environmental sustainability and overall well-being.
(ii)	Green and Open Spaces:	Develop and maintain accessible parks, green belts, and recreational areas within urban spaces to foster physical and mental well-being, exercise, relaxation, and community interaction.
(iii)	Cultural and Recreational Facilities:	Invest in cultural institutions and recreational facilities to provide opportunities for leisure, cultural enrichment, and a vibrant urban life.
(iv)	Affordable Housing Solutions:	Implement policies promoting affordable housing options to ensure diverse residents can access suitable and affordable living spaces in the urban environment.
(v)	Quality Education and Healthcare:	Improve access to quality education and healthcare services, contributing significantly to residents' well-being and enhancing urban attractiveness.
(vi)	Community Engagement:	Foster community engagement through participatory urban planning, empowering residents in decision-making processes to align development with their needs.
(vii)	Social Inclusion and Diversity:	Promote social inclusion and celebrate diversity by creating inclusive public spaces, events, and facilities that cater to a diverse population.
(viii)	Safety and Security Measures:	Implement effective safety measures, including well-lit public spaces, visible policing, and community policing initiatives, to create a secure urban environment.
(ix)	Smart Technology Integration:	Utilize smart technologies for transportation, waste management, and energy use to improve urban efficiency, sustainability, and residents' convenience.
(x)	Public Transportation:	Invest in and improve public transportation systems to reduce traffic congestion, air pollution, and commute times, fostering a more sustainable and livable urban environment.
(xi)	Health and Wellness Initiatives	Implement initiatives prioritizing health and wellness, such as promoting cycling infrastructure, pedestrian-friendly spaces, and access to fresh and healthy food options.
(xii)	Environmental Sustainability:	Prioritize environmental sustainability through green building practices, waste reduction, and conservation efforts, enhancing the overall quality of the urban environment.

Embracing a comprehensive strategy to address these diverse aspects, urban planners and policymakers can strive to establish cities that provide a high quality of life for all residents. The amalgamation of these strategies fosters the creation of vibrant, sustainable, and inclusive urban environments. The results have significant implications for urban planning and development, especially concerning the connections between contributions of green landscaped areas in immediate residential environments and gender. The findings provide valuable insights to inform strategies aimed at developing more inclusive, sustainable, and aesthetically pleasing urban environments. The implications for urban planning and development are included in the Table 10. This study proposes a future assessment of specific design elements. In other words, necessary studies focusing on specific design elements of green landscaped areas that contribute to residents' satisfaction could be explored. Hence, analysing aspects such as layout, amenities, and ecological features could provide actionable insights for optimizing the design of landscaped spaces.

Table 10: The implications for urban planning and development.

S/No	Implications	Actions
(i) Inclusive Design:	The observed gender-based differences in satisfaction levels and preferences for green spaces highlight the need for inclusive design. Urban planners should consider a diverse range of preferences and needs, ensuring that green spaces cater to both male and female residents.	Develop design guidelines that integrate features appealing to different genders, such as private landscaped gardens, recreational spaces, and elements that contribute to a serene environment.
(ii) Safety Measures:	Safety concerns, especially for women, have been identified as influencing factors. Urban planning should prioritize safety measures within and around green spaces to encourage	Implement well-lit pathways, visible security measures, and community policing strategies to create a secure environment within and around green spaces.



	broader usage and enhance the overall well-being of residents.	
(iii) Community Engagement:	Recognizing the diverse perspectives revealed by gender-based differences, community engagement becomes crucial. Involving residents in the planning and decision-making process ensures that their voices are heard and that green spaces align with their expectations.	Conduct community workshops, surveys, and participatory planning sessions to gather input from residents, with a focus on understanding gender-specific preferences and needs.
(iv) Aesthetic Enhancement:	Women tend to express higher satisfaction with aesthetically pleasing green spaces. Urban planners should consider aesthetic enhancements that contribute to the visual appeal of green areas, making them more enjoyable for all residents.	Incorporate landscaping features, public art installations, and seasonal plantings to enhance the aesthetic appeal of green spaces, creating visually pleasing environments.
(v) Recreation and Social Spaces:	The desire for playgrounds, relaxation facilities, and spaces for social interaction is prominent. Urban planning should prioritize the creation of versatile green areas that offer recreational opportunities and foster community connections.	Design multifunctional green spaces with areas for play, exercise, and socializing, promoting a sense of community and well-being.
(vi) Public and Private Green Spaces:	The preference for private landscaped gardens indicates a desire for more personal and intimate green spaces. Urban planners should balance public and private green areas to accommodate both communal and individual needs.	Incorporate private garden spaces within residential complexes, along with well-designed public parks, to provide a variety of green experiences for residents.

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Original scientific paper

Public Housing Project Delivery in Nigeria: Quality versus Quantity

*¹ Dr. Oluwafemi Kehinde AKANDE , ² MSc. Lilian Chioma OBI-GEORGE ,

³ MTech Jonam Jacob LEMBI , ⁴ MTech Ibrahim Adamu UMAR , ⁵ MSc. Amos Musa TARNI , ⁶ MSc. Adanna Joy NWOKORIE , ⁷ PhD Candidate Paul Baba HARUNA 

^{1, 2, 3, 4 & 7} Department of Architecture, Federal University of Technology, Minna, Nigeria.

⁵ Department of Architecture, University of Jos, Nigeria

⁶ Department of Architecture, Federal Polytechnic, Nekede, Owerri, Nigeria

¹ E-mail: akande.femi@futminna.edu.ng, ² E-mail: e.chioma@futminna.edu.ng, ³ E-mail: j.lembi@futminna.edu.ng, ⁴ E-mail: umar.adamu@futminna.edu.ng, ⁶

⁵ E-mail: tarnia@unijos.edu.ng, ⁶ E-mail: anwokorie@fpno.edu.ng, ⁷ E-mail: pbharuna@futminna.edu.ng

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ABSTRACT

The outbreak of COVID-19 and its consequences have altered people's perceptions of the availability of high-quality housing. Nigeria, the most populous country in sub-Saharan Africa, has taken many initiatives to address its growing population's housing demands. However, considerable focus has been placed only on housing quantity at the expense of housing quality. This study aims to investigate the interplay of factors affecting the provision of high-quality public housing projects in Nigeria. The objective is to identify the factors that significantly influence project success and failure in the delivery of quality public housing projects. A descriptive survey design with 351 randomly selected households and built environment experts (BEPs) was used. A self-developed structured questionnaire was used to collect data from households, buildings, and professionals over the course of three months. The findings indicate that in several buildings, the indoor air temperature and relative humidity extend acceptable limits (for example, 28 °C and 70% RH), which can have an effect on indoor air quality. Meanwhile, responses from the BEPs revealed that in order to develop high-quality housing, adequate project financing, evaluation of suitable building materials, and project management expertise were required. The study's conclusion emphasises that considering only the number of houses required to accommodate Nigeria's growing urban population is insufficient; rather, other factors such as appropriate design for improved air quality, high-quality and appropriate building materials, adequate project financing, and project management expertise would result in the quality delivery of livable public housing in Nigeria.

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Highlights:

- Nigeria's housing efforts are more focused on quantity over quality, leading to poor living conditions despite government initiatives.
- Rapid urbanization in Nigeria intensifies the housing deficit, with a current need for 20 million units and N21 trillion for financing.
- The quality of housing projects delivered is influenced by various factors, with project management expertise, construction materials, and project money being the most significant.
- In housing project management, flexibility and financial sufficiency should be given top priority since they can support the effective completion of housing projects.

Contribution to the field statement:

The originality of this article resides in its use of a multidimensional approach to analysing housing provision in Nigeria. It examined Nigeria's housing shortage in a way that went beyond the traditional methodology used by other researchers. It imparts to those involved in the housing industry a fresh and precise comprehension of the essential distinction between quantity and quality housing. The authors also emphasise that more research may widen the focus on the supply of high-quality housing, which has not gotten much attention in the current studies.

*Corresponding Author:

Department of Architecture, Federal University of Technology, Minna, Nigeria.

Email address: akande.femi@futminna.edu.ng

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1. Introduction

In accordance with Habitat (2015), a billion new houses will be needed worldwide by 2025 to accommodate growing urban populations, and it is also anticipated that the meagre resources will be pushed and squeezed by housing needs. As stated by Addo (2016), the majority of available housing is located in overcrowded regions with inadequate infrastructure, poor building quality, and insufficient environmental facilities. This highlights significant talks at national and global summits such as the 1992 Rio-de-Janeiro Summit on Environment and Development, the 1996 Istanbul Habitat Summit, the 2002 World Summit in Johannesburg, and the 2002 La Havana Summit. Meanwhile, Jacobs *et al.*, (2002) stated that decent housing is an important aspect in determining and maintaining a dynamic community.

In the world, Africa is now the continent with the least urban population, accounting for 11.3% of the global urban population. Sub-Saharan Africa is the continent's poorest region. Cities in the region are rapidly growing, with Africa's urban population predicted to reach 1.2 billion by 2050, representing a 58% urbanisation rate (Laros and Jones, 2014). African urbanisation is linked to a rise in demand for affordable housing and other ancillary urban services, which most countries cannot provide (Habitat, 2012). As a result, housing professionals have highlighted the need to reduce the rate of housing scarcity and poverty in developing cities (Riley *et al.*, 2001). Nigeria, one of the fastest-urbanizing nations in the world is currently dealing with the biggest issue brought on by urbanisation: a shortage of housing as a result of a high rate of rural-to-urban migration, which raises social, economic, environmental, and political issues.

In the view of Mbazor (2018) new research on the housing situation in Nigeria, there are currently 23 houses for every 1000 people, while there is an estimated housing shortfall of 16–17 million dwellings. The housing gap has to be filled with \$140 billion, or an average of \$7,551.24 per unit which is approximately ten times the proposed 2016 Nigerian budget. Access to inexpensive housing, which has largely remained an unfulfilled dream for the vast majority of people, especially the middle and lower classes, is made worse by this circumstance. Owning the huge millions of houses to house the Nigerian populace, the government has made several efforts, put up policies, regulations, and established organisations to address the huge housing deficits. However, it appears that they have just scratched the surface, especially given that the country's population has been rising at an exponential rate. Despite the efforts put in place by the Nigerian government since independence in 1960, there is still a huge housing shortage which is further exacerbated by huge low-quality housing in existence. This is due to much emphasis being placed on housing quantity at the detriment of housing quality.

The above-stated problem is brought to the fore by the introduction of COVID-19 and its consequences which have also altered people's perceptions of the availability of high-quality housing. Thus, owing to the limited quality housing provision for the Nigerian populace, Nigeria's housing shortage has gotten worse over time, despite the efforts of successive governments battling it since the country's independence (Mbazor, 2018). Hence, Habitat (2001) stated right to appropriate housing (i.e., safe, secure, healthy, accessible, and affordable) completely codified in the Habitat Agenda, with the goal of ensuring adequate shelter for all is yet to be fully accomplished in Nigeria. In order to address Nigeria's needs for quality housing and not just the quantity required, this study aims to investigate the interplay of factors affecting the completion of high-quality public housing projects in Nigeria. The objectives are to (i) identify the key variables responsible for poor public housing project delivery and (ii) evaluate how the factors significantly influence project success and failure in the delivery of quality public housing projects.

2. Literature review

One of the Sustainable Development Goals of the UN involves housing. The broader 2030 Agenda for Sustainable Development includes the 17 Sustainable Development Goals (SDGs) set forth by the United Nations. By 2030, enabling access for all to suitable, safe, and affordable housing and basic services, and upgrading slums is one of the ten objectives of Goal 11 Sustainable Cities and



Communities (Ofem and Ufot-Akpabio, 2020). Indicators of housing quality for nations that are members of the Organisation for Economic Co-operation and Development (OECD) ought to assess both the external characteristics of the home and the neighbourhood's overall environmental factors. Important elements are the facilities offered, the calibre of the building materials, the insulation, and the indoor air quality. If these are determined to be inadequate, the result will be a low-quality house, which impacts social capital, health, and the capacity to participate in social activities.

2.1. Current housing challenge posed by housing deficit in Nigeria

The severe dearth of comfortable, practical, and reasonably priced housing for the growing population is one of the most challenging socioeconomic problems facing the Nigerian nation today. Although the root causes of the issue have been identified, and copious amounts of money and intense effort have been dedicated to solving it, the problem has proven resistant to long-term fixes. As of December 2018, the nation's housing shortage is expected to be 20 million units, a 15.0% increase above January 2019 forecasts. It will need almost N21 trillion to cover the deficit. With 200 million people living in the country, the current scarcity is disturbing and of concern. There was a 7 million housing shortage in Nigeria in 1991, 12 million in 2007, 14 million in 2010, and 20 million units currently lack homes. Furthermore, just 10% of Nigerians who wish to own a home can afford to buy one or build one themselves. According to Moore (2019), models of housing distribution from industrialised nations can be applied in Nigeria with varying degrees of modification to match the nation's current political and economic realities to stop the country's developing trend of housing shortage. Table 1 shows the evolution of Nigeria's housing deficit from 1991 to the present, together with the projected amount and reasons for the shortfall.

Table 1: Trend in Nigeria’s housing deficit (1991-2019) (Moore, 2019).

Year	Housing deficit	population	Cause
1991 -1993	4 -7 million	104 million	Mortgage inefficiency
2007	8 – 10 million	145 million	Slum demolition and urban migration
2013-2015	16 – 17 million	178 million	Overpopulation urban expansion and increased poverty
2017-2019	18 – 22 million	184 million	Increased poverty, overpopulation and urban migration

2.1.1 The Importance of Housing Quality over Housing Quantity

Quality housing cannot be compromised in order to meet the necessary quantity, notwithstanding Nigeria's severe housing shortage. Reducing the quality of housing in order to achieve the necessary amount results in inadequate and unhealthy housing delivery, which eventually increases the required quantity. As stated by Yoade *et al.* (2018), housing quality is defined as the total of a certain dwelling unit's physical, environmental, and satisfaction level as measured against predetermined liveability qualities at a given time. The perfect house is one that fosters personal development and the achievement of life's objectives while also offering sufficient physical and mental health care for its occupants. Meanwhile, in the opinion of Smith (1991), a house encompasses not just a physical building but also elements of community, security, and economic well-being. The internal and external architecture of a house, along with the features of its inner surroundings, are the main aspects of housing quality. It might include aspects of the community as well as ideas like environmental sustainability. It affects numerous facets of development and economic activities. Hence, it could be argued that housing provides a social status indicator, a favourable image, a sense of belonging, and social connections. The four components of housing quality are as follows, as identified by Stats NZ (2019): (i) housing habitability, or the extent to which a dwelling and its surroundings offer a physically safe, physically secure, and physically healthy environment. It is focused on a home's layout, construction, materials, and services, as well as how well it has been cared for over time. (ii) Environmental sustainability: How closely housing materials, construction methods, and design interact with the environment to preserve



habitability both now and in the future. Resilience to climatic impacts, such as rising sea levels, rising temperatures, droughts, and extreme weather, is a part of this. The resilience, durability, and resource efficiency of housing are factors that contribute to its environmental sustainability. (iii) Housing functionality: the degree to which housing design, construction, and location support the unique physical, mental, emotional, cultural, and social needs of individuals, families, and communities. (iv) Social and cultural sustainability: the degree to which housing design is adaptable enough to respond to changes in the specific physical, cultural, and social needs of individuals, families, and communities, thereby supporting functionality over time.

In the view of Olotuah (2016) housing is referred to as the entirety of a residential neighbourhood, setting, or micro district, including the building's physical layout as well as all services, amenities, utilities, and equipment required for each resident's and their family's overall health and social well-being. Notably, social inclusion and stable communities are predicated on high-quality housing (Grady, 2011). Both Ebong (1983) and Onibokun (1970) concurred that basic characteristics of residential housing should be present in order to draw in potential occupants and boost utilization for the accomplishment of the intended goals for which it was provided. These standards encompass appropriate home layout, sufficient airflow, suitable lighting, a well-functioning drainage system, consistent hygiene, safety, lack of congestion, sufficient water supply, and convenient access to roads.

2.1.2 Indicators of Nigerian Housing Quality

Numerous studies have highlighted the substandard housing conditions in Nigeria. Research by Adeoye (2016) and Mbazor (2018) provides evidence of this. Specifically, evaluations in Ado-Ekiti revealed poor conditions of essential housing elements such as floors, ceilings, walls, and roofs, rendering them unfit for habitation. Yoade and colleagues (2018) also found significant issues in the houses of Ede, including severe overcrowding. Furthermore, the research points out the lack of basic amenities like electricity, potable water, and adequate sanitation facilities in the densely populated areas of Ibadan. Mbazor's (2018) further research highlights the inadequacy of housing and infrastructure in Akure. Owwoye and Omole's (2012) studies indicate that many houses are in poor condition due to the low income of the occupants, leading to insufficient kitchens, bathrooms, and toilets. Jiboye (2010) also found that in Birnin Kebbi's low-density areas, residents suffer from a lack of basic physical facilities, contributing to an unsanitary environment and inadequate housing.

In a study on the evaluation and measurement of residential housing quality, Meng and Hall (2006) stated that housing quality was the degree to which occupants found dwelling units and the surrounding environment acceptable. This included the layout and functionality of the structures, the kind of materials used, the use of the available space, the utilities and services offered in the units, and the utilities themselves. Okewole and Aribigbola (2006) supported this assertion in a study on innovations and sustainability and the conception and implementation of housing policies in Nigeria by noting that factors like a house's physical condition, the internal and external amenities and services it offers, and other elements that contribute to a conducive living environment were used to assess housing quality.

The quality of housing that is now offered in low-income residential areas is inadequate and uninhabitable, as noted by Babalola *et al.* (2020). However, if housing designers, developers, and managers focus on factors that raise housing quality adequacy, the quality of housing can be considerably improved. Additional research by Akande (2021) and Akande *et al.*, (2023) emphasised the importance of end users' indoor environmental quality and health consequences when it comes to housing provision in Nigeria. Their results support Europe's (1988) recommendation for adequate housing, which claims that inadequate housing has three major negative effects on occupants' physical health and promotes the spread of infectious diseases. In addition to the negative effects on health, the guidelines mentioned that substandard housing also interferes with occupants' physiological needs and can lead to injuries.

It is possible to argue that the four essential components of quality housing—habitability, sustainability, functionality, and socio-cultural affordability—are absent from Nigeria's existing housing delivery system based on the literature analysis on housing provision in the country. Thus, neither the demands nor the expectations of the populace have been fully satisfied by the current housing supply, nor has it performed up to expectations. Even though the nation's economy is growing and significant resources are being allocated to the housing sector, unethical practices have adversely affected both the calibre and number of available houses. In the view of Midgley and Tang (2001), institutional frameworks and organisational structures committed to people-centred development are necessary, and also deliberate efforts on the part of state and non-state actors. Harrison (2004) argued that a wide range of actors, including professionals, bureaucrats, and other decision-makers, need to be involved in the creation, interpretation, and application of housing quality standards in order to satisfy the present housing needs. If this were not the case, the majority of the teeming populace would not have access to adequate housing, and the provision of housing would be driven either by a sense of duty or as a self-serving goal rather than by ensuring the welfare of future generations (Patel, 2016). However, this aspect has received less attention in the literature, and as a result, little is known about the part played by built environment professionals (BEPs) in the development and implementation of high-quality housing. This study is guided by a conceptual framework (illustrated and presented in Figure 1) developed by the authors.

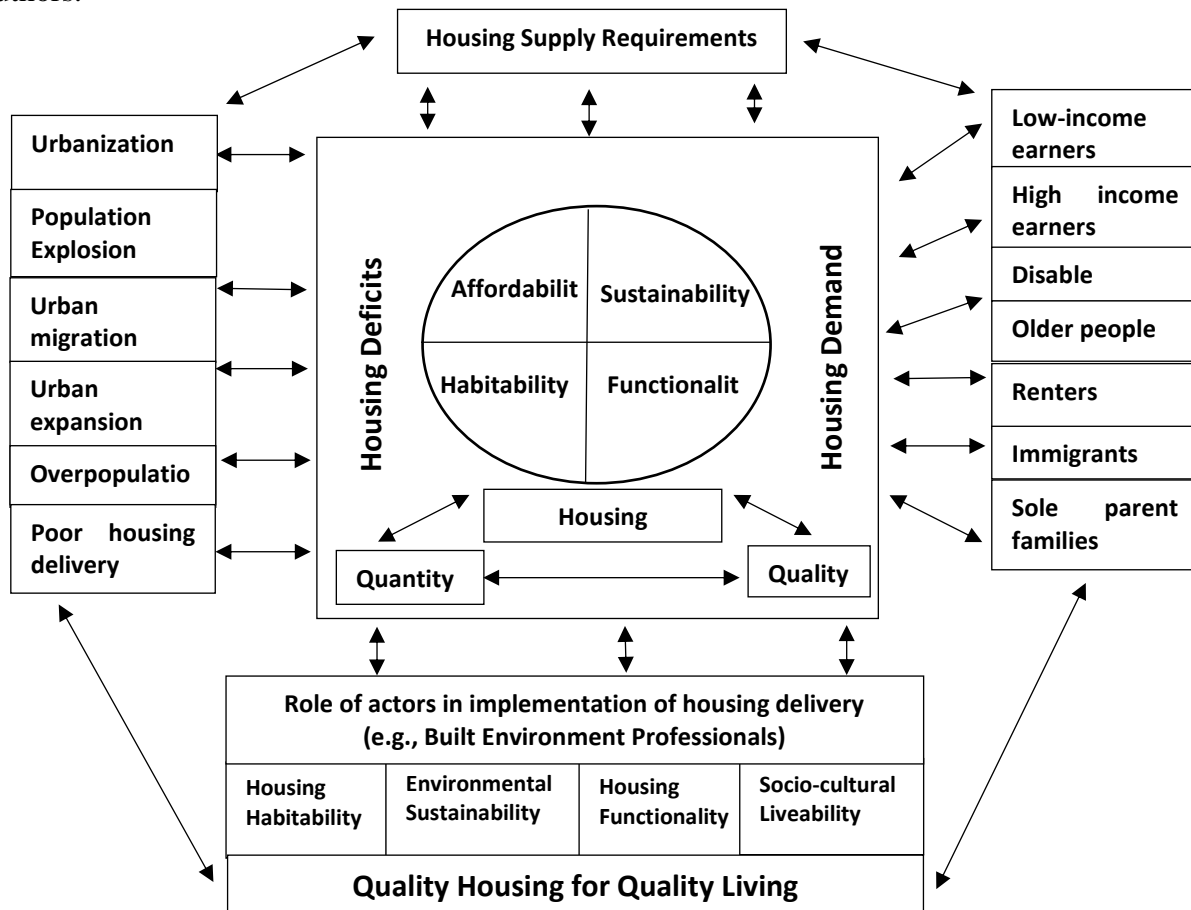


Figure 1: Conceptual Framework developed to address the factors challenging Nigeria's housing quantitative and qualitative delivery.

Note: The conceptual framework was developed to guide the appropriate data collection needed to identify and address the factors challenging Nigeria's housing quantitative and qualitative delivery.

3. Material and Methods

3.1. Study Area

This study focused on three Nigerian states: Abuja, Bauchi, and Niger (Figures 2a & 2b). Abuja was chosen being the country's federal capital territory and a city where significant housing development projects are ongoing. Meanwhile, Bauchi and Minna were selected to represent cities with lesser levels of construction activity. Abuja is located in the Federal Capital Territory (FCT) in Nigeria and has a population of 776,298 people (Ogwueleka, 2013) at 9°4'N 7°29'E. Bauchi is in Nigeria's North-East geopolitical zone geographically situated between latitudes 9° 3' and 12° 3' north and longitudes 8° 50' and 11° east.

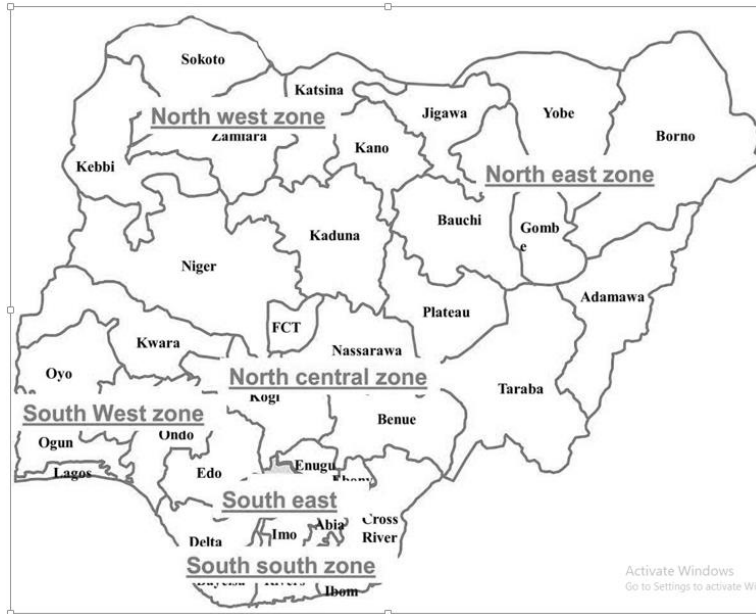


Figure 2a: Map of Nigeria showing geographical regions.

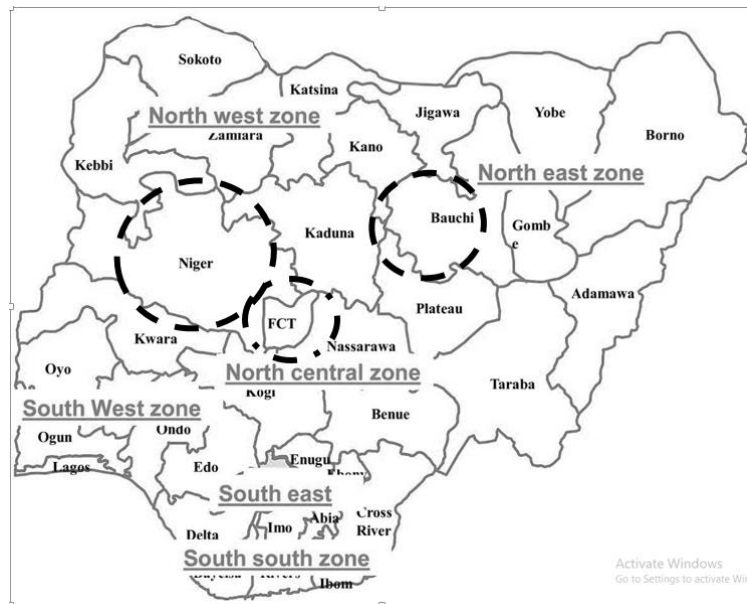


Figure 2b: Map of Nigeria showing the study area.

Niger is the largest state in Nigeria and is located in the North Central area at 10°00'N 6°00'E. Other prominent cities in Niger state include Bida, Kontagora, and Suleja. The state has an extremely warm climate, with an annual average temperature of 34 degrees Celsius. It is warm or hot all year, with only a few months that are particularly tropical. This study adopted a quantitative



approach and used structured questionnaire survey to collect data from households and built environment professionals (BEPs) in the study areas as respondents.

3.1.1 Research design and instrument

A quantitative research approach and design were used in this study. This strategy was chosen because it allows for statistical analysis to quantify and generalise data (Culka, 2018). The researchers' well-designed questionnaire was utilised as the primary method of data collection because it could quickly reach a variety of audiences in the study area (Fosnacht *et al.*, 2017). The questionnaire was divided into two versions, one for households and one for BEPs involved in housing project execution, and was distributed on paper. The household questionnaire collected respondents' background information, indoor environmental data (temperature, humidity, etc.), health complaints, physical aspects of the houses (ventilation, indoor air quality, etc.), and housing quality. The BEP questionnaire also collected respondents' background information as well as additional information on the factors causing low-quality housing project delivery. These were retrieved from the extant literature using a five-point Likert scale, with 1 representing strongly disagree, 2 representing disagree, and 3 representing neutral. 4 = Agree 5 = strongly agree. Because of its high-reliability coefficients and greater possibility of eliciting responses that adequately reflect the subject matter, the Likert scale was chosen. The questionnaires for the study were piloted to allow for revisions as needed. This backs up Adu Gyamfi *et al.*'s (2022) claims that researchers can utilise a pilot survey to better understand or improve research themes, choose the most effective approach, and estimate the time and resources needed to conduct the more in-depth study version. Following pilot testing, a reliability coefficient (Cronbach's alpha) of 0.80 was determined to evaluate and ensure the data is reliable and adequate for judging the goal of the research. The achieved value was greater than the required threshold value of 0.70 to 0.95 for reliable variable performance as indicated by Tavakol and Dennick (2011).

3.1.2 Population, sampling, and response rate

From a housing stock of 2,000 and an estimated population of 3,000,000 within the study areas, 120 houses and 235 BEPs were chosen utilising purposive, stratified, and systematic selection procedures. To select houses based on their categories and distinctive qualities, purposeful sampling was used. The study employed maximum variation sampling, sometimes referred to as heterogeneous sampling, as a purposive sampling approach in order to collect a wide range of perspectives on housing quality and housing projects due to the diversity of dwelling types. Stratified sampling was used to divide the entire study area into strata due to the large number of people living in the study areas. Households from each zone or stratum were selected to participate, and each stratum was handled independently (Kusi, 2012). The sample for this investigation was taken using the sample size table that Krejcie and Morgan (1970) suggested. According to the Table, the suggested sample size for a population of over 3,000 is 314 people, which validates the sample size of 420 people used in this study. The rationale for the sample size chosen by the researcher is based on the following factors: (i) the population size with which the researchers are dealing and the amount of error that the researchers are willing to tolerate; (ii) the researchers' desire to collect sufficient data and have an estimate with a desired level of accuracy; and (iii) the study's limited available resources and the focus of the research question. Furthermore, the table proposed by Krejcie and Morgan (1970) was designed for scenarios in which the researchers aim to have 95 percent assurance of the results of the full population that had been surveyed. A total of 351 responses were gathered from this sample size (refer to Table 2), indicating an efficient response rate of 83.6% for the projected population within the study location.



Table 2: Respondents' response rate.

Location	Distribution (No)	Returned (No)	% of response rate
	A	B	(B/A*100)
Abuja	150	120	80.0%
Bauchi	120	116	96.6%
Bida	100	75	75.0%
Minna	50	40	80.0%
Total	420	351	83.6%

3.2 Data collection and data analysis

Using Mean Response Analysis (MRA) statistics, the variables in the questionnaire were analysed and ranked based on the responses of the participants. The mean score was calculated using a five-point Likert scale. The MRA formula is as follows: Mean score = $(5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1) / (n_5 + n_4 + n_3 + n_2 + n_1)$, where n_5, n_4, n_3, n_2, n_1 represent the number of respondents in relation to the five-point Likert scale used. This ranking helped determine which characteristics had the most influence on the quality of public housing developments. To establish the key predictors of factors influencing housing quality, the mean ratings were compared to the theoretical mean rating of 3.50. As a result, any mean value of 3.50 or higher indicated the manifestation of an influencing factor on housing quality, whilst mean values less than 3.50 indicated the expression of no influence. Based on the findings of the two surveys, the analysis used factor analysis, descriptive analysis, and inferential statistics. Version 20 of the Statistical Package for the Social Sciences (SPSS) was utilised for data analysis. A Pearson's correlation test with $p=0.05$ was utilised to ascertain whether there was a significant relationship between the observed variables. Moreover, the ideal inter-item correlation mean (factor loadings) should fall between 0.2 and 0.4 in terms of factor dependability. In this study, a value of at least 0.3 was applied (Pallant, 2020).

4. Results

Men made up the majority of survey participants (65.8%) in the household survey. For a Nigerian home with an average of four family members, the plurality (47.6%) of them reported a monthly income of less than N20,000 (\$50), or about \$1.25 per day. Kerosene (0.7%), firewood (24.6%), charcoal (2.6%), or a mix of the three (14%), are used in about 50% of homes. The relative humidity (RH) and temperature inside vary from 29% to 82% and 22°C to 40°C, respectively, exceeding the ASHRAE standard. Three important conclusions on window types, building orientation, and indoor air quality were also reached for dwelling design. The results show a correlation between the type of window, indoor air quality, poor building orientation, and the frequency of health complaints among the occupants of the homes under investigation. The household survey's findings suggested a potential connection between the major building orientation and the frequency of the illnesses that respondents reported having. The kind of window in the respondents' bedrooms and their response to the incidence of the prevalent disease in the homes were cross-tabulated in order to investigate the relationship between the type of window in the bedroom and the prevalence of the diseases indicated. Only the prevalence of specific illnesses (such as malaria, measles, and tuberculosis) was shown to be significantly correlated with the types of windows in the respondents' bedrooms. Because more houses lacked adequate ventilation, the majority of them were reported to have poor indoor air quality. This might be the result of improperly installed or insufficient windows, which prevent the building's interior from receiving the necessary amount of airflow to replace its utilised air. The demographic data for the BEPs is displayed in Table 3. The data indicates that individuals holding a Master's degree (36.3%) surpass those with a Bachelor's degree (23.9%) and an HND (19.5%).



Table 3: Summary of background profile of the BEPs respondents (n=235).

Characteristics	Percentage	Characteristics	Percentage
Level of Education		Area of Specialization	
GCE O/Level	.9	Architecture	36.0
OND	7.1	Building	10.5
HND	19.5	Engineering	21.1
Bachelor Degree	23.9	Estate Management	8.8
Master's Degree	36.3	Quantity Surveying	7.9
Doctorate Degree	8.8	Project Management	6.1
Others	3.5	Others	9.6
Professional Association		Years of Experience	
Association of Project Managers	13.5	1 - 5yrs	28.1
Nigeria Institute of Architects	30.8	6 - 10yrs	34.2
Nigeria Institute of Quantity Surveys	5.8	11 - 15yrs	18.4
Nigeria Institute of Management	8.7	15- 19yrs	12.3
Others	41.3	20yrs and above	7.0
Average Number of Building Projects Handled Over the Last 5yrs		Cost of Building Projects Managed Over the Last 5yrs in Nigeria Naira	
1 - 5yrs	27.7	1 - 5 million	18.8
6 - 10yrs	39.3	6 - 10 million	17.9
11 - 15yrs	17.9	11 - 15 million	15.2
15- 19yrs	5.4	15- 19 million	7.1
20yrs and above	9.8	20Million and above	41.1
Course Taken in Project Management		Knowledge of Project Planning Techniques	
Yes	74.0	Yes	82.6
No	26.0	No	17.4

The percentage of respondents with a PhD was just 8.8%, and the percentage with an Ordinary National Diploma (OND) was much lower at 7.1%. The overwhelming majority of responders appear to be educated based on the data. In addition, Table 3 demonstrates that the majority of respondents (36%) were project managers (6.1%), engineers (21.1%), builders (10.5%), estate managers (8.8%), quantity surveyors (7.9%), and architects. This implies that professionals working in the built environment can benefit from the research. The fact that 71.9% of these respondents have worked for a company for more than five years shows how entrenched their careers are. This suggests that they have enough expertise to offer a meaningful response. It was concluded that the respondents are professionally and experience-wise well-equipped to offer reasonable insight into the topic under investigation based on the results of the background information provided by the respondents. Furthermore, Table 3 shows that 30.8% of respondents are members of the Nigeria Institute of Architects, which is followed by the Nigeria Institute of Management (8.7%), the Association of Project Managers (13.5%), and the Nigeria Institute of Quantity Surveys (5.8%).

4.1. Extent of project funding influence on the quality of public housing projects

Based on mean evaluations, Table 4 arranges the degree of project financial influence on the quality of public housing complexes. Based on a one-sample t-test value of 3.5, the results indicate that the breadth of project finance was deemed statistically significant (p = 0.05). For the project, the average fundraising influence score varied from 4.06 to 3.51. "Cost of funding the project" (mean = 4.06; SD = 0.80; t (119) = 7.69; p = 0.00 < 0.05) was the highest-ranked factor in relation to the level of project funding influence. Other factors included "adequacy of finances for the project" (mean = 3.51; SD = 0.62; t (119) = 0.29; p = 0.76). Based on the mean score, a threshold of 3.50 was used to determine the most significant impact of project finance on the project's quality. These consist of the following: "adequacy of finances for the project" (mean = 3.51; SD =



0.62; $t(119) = 0.29$; $p = 0.76$), "cost of funding the project" (mean = 4.06; SD = 0.80; $t(119) = 7.69$; $p = 0.00$), and "source of finance for the project" (mean = 3.77; SD = 0.81; $t(119) = 3.69$; $p = 0.00$). The cost and the source of money are the only two project funding variables that have an impact on the project's quality.

Table 4: Extent of project funding influence on quality of the public housing projects.

S/N	Project funding	MS	SD	t-value ($\mu = 3.5$)	df	Sig. (2-tailed)	R
PF1	Cost of funds for the housing project	4.06	0.80	7.69	119	0.00*	1
PF2	Source of finance for the housing project	3.77	0.81	3.69	119	0.00*	2
PF3	Adequacy of finances for the housing project	3.51	0.62	0.29	119	0.76*	3

Note: SD = Standard Deviation; R = Rank; Sig. = Level of significance; MS = Mean score. The higher the mean score the greater the extent of project funding influence on the quality of public housing projects; df = degrees of freedom, *Significant at the 95 per cent level ($p < 0.05$).

4.1.1 Extent of construction materials' influence on the quality of public housing project

The level of influence that construction materials have on the quality of public housing projects was evaluated by mean scores in Table 5. A one-sample t-test value of 3.5 reveals that the extent of construction materials is statistically significant ($p = 0.05$) according to respondents. The mean score for the building materials varied from 3.82 to 3.40. From the highest ranked "Quality of materials for the public housing project" (mean = 3.82; SD = 0.68; $t(119) = 5.22$; $p = 0.00 < 0.05$) to the lowest ranked "Source of materials for the project" (mean = 3.40; SD = 0.75; $t(119) = -1.33$; $p = 0.18$), there was a range in the impact of construction materials on project quality. Based on the mean score, a threshold of 3.50 was used to determine the most important impact of building materials on project quality. The variables "Cost of materials for the project" (mean = 3.52; SD = 0.87; $t(119) = 0.312$; $p = 0.00$), "Quality of materials for the public housing project" (mean = 3.82; SD = 0.68; $t(119) = 5.22$; $p = 0.00$), and "Source of materials for the project" (mean = 3.40; SD = 0.75; $t(119) = -1.33$; $p = 0.18$) are related to the project. The quality of the project is only impacted by one of the material factors, namely the quality of the materials.

Table 5: The extent of construction materials influence the quality of the public housing projects.

S/N	Construction materials	MS	SD	t-value ($\mu = 3.5$)	df	Sig. (2-tailed)	R
CM3	Quality of materials for the housing project	3.82	0.68	5.22	119	0.00*	1
CM2	Cost of materials for the housing project	3.52	0.87	0.31	119	0.75	2
CM1	Source of materials for housing	3.40	0.75	-1.33	119	0.718	3

Note: SD = Standard Deviation; R = Rank; Sig. = Level of significance; MS = Mean score

4.1.2 Factors responsible for poor quality housing project delivery

Several requirements must be met by the acquired data before factor analysis can be performed. The Kaiser-Meyer-Olkin (KMO) metric, for instance, classifies sample adequacy as follows: KMO 0.5 - 0.7 is considered bad; KMO 0.7 - 0.8 is considered acceptable; KMO 0.8 - 0.9 is considered great; and KMO > 0.9 is considered fantastic. This experiment yielded a KMO of 0.879 (Table 6), which is considered excellent as it is higher than the recommended value of 0.6 (Kaiser, 1970).



Table 6: Correlation Matrix of Factors responsible for public building project failure.

Correlation	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	
X1	1																							
X2	.667	1																						
X3	.607	.494	1																					
X4	.798	.428	.428	1																				
X5	.596	.491	.455	.442	1																			
X6	.748	.440	.403	.356	.513	1																		
X7	.600	.517	.477	.537	.391	.493	1																	
X8	.540	.469	.432	.423	.300	.651	.464	1																
X9	.626	.490	.341	.461	.565	.621	.418	.514	1															
X10	.400	.474	.358	.358	.365	.353	.325	.456	.388	1														
X11	.582	.425	.490	.415	.319	.300	.466	.498	.447	.625	1													
X12	.486	.683	.492	.430	.374	.427	.447	.476	.356	.372	.499	1												
X13	.671	.647	.549	.403	.397	.333	.453	.457	.448	.430	.574	.578	1											
X14	.450	.393	.357	.472	.443	.378	.515	.316	.332	.307	.398	.419	.444	1										
X15	.548	.365	.359	.427	.409	.356	.367	.485	.376	.490	.505	.430	.611	.366	1									
X16	.513	.440	.451	.372	.468	.444	.467	.400	.324	.482	.580	.564	.593	.340	.591	1								
X17	.644	.516	.359	.300	.494	.501	.375	.445	.341	.313	.423	.584	.551	.390	.571	.570	1							
X18	.484	.516	.489	.422	.453	.444	.486	.364	.340	.358	.305	.482	.533	.561	.382	.403	.470	1						
X19	.584	.413	.423	.424	.515	.476	.357	.499	.380	.546	.337	.506	.486	.488	.467	.380	.524	.529	1					
X20	.489	.407	.359	.435	.544	.461	.318	.373	.356	.331	.375	.386	.365	.322	.460	.477	.326	.514	.523	1				
X21	.713	.450	.357	.377	.346	.506	.555	.380	.348	.307	.490	.545	.589	.342	.384	.489	.504	.459	.424	.493	1			
X22	.549	.316	.495	.510	.460	.477	.410	.359	.324	.654	.439	.407	.432	.369	.530	.457	.411	.449	.502	.550	.563	1		
X23	.452	.337	.338	.372	.490	-.439	.450	.539	.450	.539	.425	.394	.435	.315	.309	.355	.542	.325	.406	.457	.373	.561	1	



Likewise, Bartlett's Test of Sphericity (BTS) (Bartlett, 1954), which assesses the suitability of the correlations between variables, is also passed by the data used in this investigation. The BTS verified the factorability of the correlation matrix and attained statistical significance (P -value = 0.001). Therefore, using the findings from the respondents' evaluations, the correlation matrix was investigated as a suggested default for factor extraction, as indicated in Table 6. This discovery is the basis for determining the elements crucial to the completion of housing projects in Nigeria. Principal components analysis (PCA) and factor analysis are the two methods of factor analysis that might be used for the research. Stevens (2012) states that although factor analysis and PCA often yield similar results, PCA is preferred because of its ease of use. Consequently, the PCA was applied in this study. But before PCA, the suitability of the data for factor analysis was assessed, and a look at the correlation matrix showed that there were coefficients of 0.3 and higher. To determine if the measurement data was adequate to verify and validate the factor analysis, the Meyer-Olkin (KMO) test and Bartlett's sphericity test were employed. Given that the test values for the KMO test range from 0 to 1, findings above 0.7 are necessary in order to give EFA (Hair *et al.*, 2006). There may be sufficient correlations between the variables to continue the investigation, according to a statistically significant Bartlett test ($p = 0.05$) (Pallant, 2020).

By focusing the explanatory power on the first factor—that is, identifying the primary components of the data—Principal Components Analysis (PCA) was utilised to extract factors. The screen test, parallel analysis, and Kaiser's criterion were used to figure out how many factors should be retained. One of the most widely used methods is Kaiser's criterion, also known as the eigenvalue rule, which essentially sets aside elements with an eigenvalue of 1.0 or higher and other factors for additional research. Using this method, factors with an eigenvalue of 1.0 or higher are kept for additional analysis. Of the twenty-three components, four had eigenvalues larger than one, according to the PCA. 42.728%, 7.867%, 7.655%, and 4.868% of the variance are explained by this, which also represents -42.728%, -7.867%, 7.655%, and 4.868% of the variance. This inquiry also used Catell's scree test. To do this, the eigenvalues of each element must be plotted, and the plot must be examined to determine the point at which the form of the curve becomes horizontal. Any factor(s) beyond the elbow or break in the plot, according to Catell (1966), should be assessed since they will primarily account for the variance in the data set. After the third component, there is a definite discontinuity, as seen by the Scree plot (Figure 3). The Catell's scree test resulted in the retention of three components for additional study. This confirmed the findings of the Parallel Analysis, which showed three components with eigenvalues larger than the matching criterion values for an identically sized data matrix generated at random.

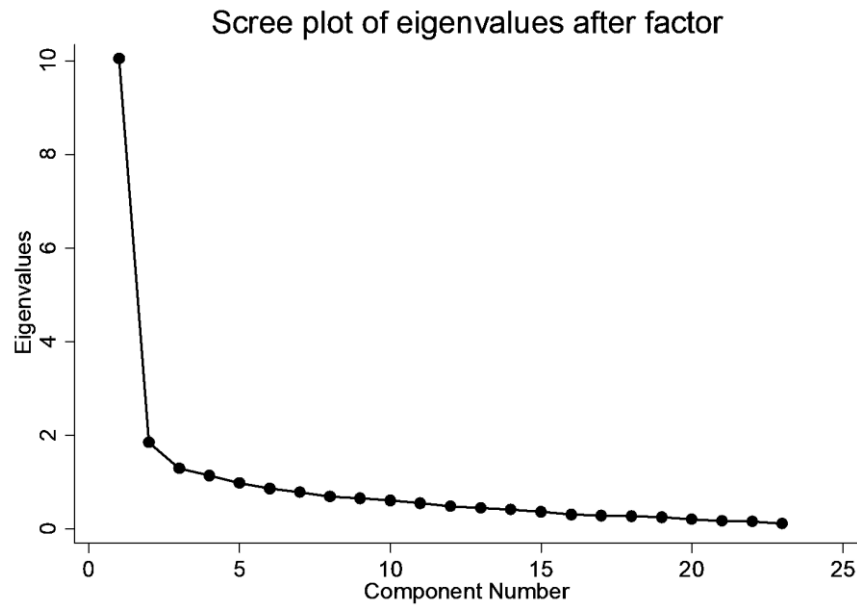


Figure 3: Catell's scree test.

An additional method introduced by Horn's parallel analysis (Horn, 1965) involves contrasting the eigenvalue sizes with those previously acquired from an identically sized random data set. Table 7 shows that only the eigenvalues above the similar values from the random data set are retained. The exact number of components that should be kept might be determined and shown to be the most accurate using this method. In the meantime, Hubbard and Allen (1987) report that Kaiser's criterion and Catell's screen test tend to permit a higher number of components than necessary.

Table 7: Monte Carlo PCA by Marley Watkins for parallel analysis.

Eigenvalue	Random Eigenvalue	Standard Dev.
1	1.9206	.0891
2	1.7500	.0634
3	1.6274	.0568
4	1.5231	.0502
5	1.4303	.0446

As indicated in Table 8, only three factors for principal component analysis with Kaiser's criterion are bigger than those for parallel analysis.

Table 8: Comparison of actual eigenvalues of Kaiser's criterion to parallel analysis.

Component number	Actual eigenvalue from PCA	Criterion value from parallel analysis	Decision
1	10.042	1.9206	Accept
2	1.849	1.7500	Accept
3	1.799	1.6274	Accept
4	1.144	1.5231	reject

The three-component solution explained 58.3% of the variation, with Component 1 accounting for 42.73%, Component 2 accounting for 7.87%, and Component 3 accounting for 7.66% (Table 9).



Table 9: Relative importance of factors with three components retained.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	10.042	42.728	42.728	10.042	42.728	42.728
2	1.849	7.867	50.596	1.849	7.867	50.596
3	1.799	7.655	58.250	1.799	7.655	58.250

The Rotated Component Matrix (Table 10) provides a clearer view of the component loadings onto the three factors in Table 9. Principal Component Analysis with a Varimax rotation was utilized.

Table 10: Rotated component matrix with varimax method.

Variable (s)	Component		
	1	2	3
Poor project planning	.739		
Insufficient working capital	.716	.401	
Inadequate monitoring and/or poorly carried out inspections	.698		
Increase in contract sums	.641		
Specification of costly imported materials	.554		.510
Contractor's incompetency leading to low performance	.552	.313	.487
Plans not used correctly	.499	.455	
Haphazard award of contract without reference to funds availability	.474	.352	.405
Unrealistic expectation		.763	
Major challenges in the project requirement		.686	.373
Haphazard completion of technically unsound project	.382	.674	
Incorrect use of project methodology	.325	.620	
Poor project finances	.402	.567	
Escalation in total cost of project	.388	.535	
Changing requirements and specifications	.398	.488	
Inadequate resources	.456	.462	
Initial cost and schedule not revised	.335	.456	.354
Challenges of delay in payment to contractors resulting from govt. Bureaucracy			.757
Frequent change in government			.749
Selection and award of contract based on lowest bidder	.442		.718
Increase in the scope of work		.367	.635
Poor or shoddy work by building professionals, consultants, etc.	.407		.566
Change in pre-contract consultants		.444	.564

Table 11 shows that Factor 1 accounts for 42.7% of the total variance loads. Factor 1 includes variables like inadequate working capital, inadequate monitoring, improperly performed inspections, increased contract sums, expensive imported material specifications, contractor incompetence resulting in substandard performance, improper use of plans, and haphazard contract award without consideration for available funds. This is named misalignment of project success. 7.9% of the variance can be attributed to factor 2, which shows high positive loadings on irrational expectations, significant challenges with the project requirements, haphazard completion of a technically unsound project, improper application of the project methodology, poor project finances, an increase in the project's overall cost, evolving requirements and specifications, a lack of resources, and an original cost and schedule that was not revised. They are referred to as unanticipated project problems. Moreover, Factor 3 represents 7.7% of the overall variance and indicates high positive loadings on challenges like government bureaucracy-caused delays in contractor payments, frequent government changes, lowest bidder selection and award, an expansion of the work scope, subpar or substandard work by consultants, building professionals, etc., and a change in pre-contract consultants. This might be called



the too bureaucratic roadblocks from project initiators. Based on twenty-three variables that have previously affected project success rates and have been categorised accordingly, this analysis revealed three crucial factors: project misalignment, unforeseen project challenges, and excessive bureaucratic hiccups from the project initiator.

Table 11: Substantial factor loadings (varimax).

Factor	Variables	Description	Factor Loadings
1	X13	Poor project planning	0.739
	X16	Insufficient working capital	0.716
	X12	Inadequate monitoring and /or poorly carried out inspections	0.698
	X19	Increase in contract sums	0.641
	X2	Specification of costly imported materials	0.554
	X17	Contractor's incompetency leads to low performance	0.552
	X15	Plans not used correctly	0.499
	X21	Haphazard award of contract without reference to funds availability	0.474
2	X11	Unrealistic expectation	0.763
	X7	Major challenges in the project requirement	0.686
	X18	Haphazard completion of a technically unsound project	0.674
	X22	Incorrect use of project methodology	0.62
	X8	Poor project finances	0.567
	X5	Escalation in the total cost of the project	0.535
	X3	Changing requirements and specifications	0.488
	X20	Inadequate resources	0.462
3	X4	Initial cost and schedule not revised	0.456
	X6	Challenges of delay in payment to contractors resulting from government bureaucracy	0.757
	X14	Frequent changes in government	0.749
	X9	Selection and award of contract based on the lowest bidder	0.718
	X1	Increase in the scope of work	0.635
	X10	Poor or shoddy work by building professionals, consultants, etc.	0.566
	X23	Change in pre-contract consultants	0.564

5. Discussion

One of the most important factors affecting a building's occupants' well-being is the interior environment. Windows and other building components affect airflow in naturally ventilated residential buildings. A few aspects of residential dwelling design have been linked to CO₂ accumulation and the health of the occupants in the homes studied for this study. High quantities of particulate matter were found indoors, and the energy sources that the households chose for cooking—wood, charcoal, and kerosene—may have contributed to the problem. Another important source of particles could have been the absence of landscaping close to the buildings and candlelight used in the buildings. The primary building orientation was shown to be strongly related to the occurrence of numerous diseases mentioned by respondents, including tuberculosis, meningitis, measles, and malaria. The findings support Givoni's (1994) assertion that the efficacy of appropriate and optimised design in relation to its environment, such as optimal building orientation, can contribute in boosting the health and well-being of its occupants. Meningitis was significantly associated with window type and bedroom number. This could be owing to insufficient cross-ventilation in the bedrooms caused by an improper kind and restricted number of windows, which may have reduced the ventilation threshold and, as a result, resulted in poor pollutant disposal within the bedrooms. This is congruent with the findings of Al-Tamimi *et al.*, (2011); Akande *et al.*, 2023), who observed that architectural characteristics such as building position and orientation, as well as the type and positioning of windows, have a significant influence on air movements inside a building. Furthermore, their research found that windows that are



not correctly positioned to take advantage of the prevailing wind direction result in an overall insufficient design for airflow, compromising the residents' well-being, comfort, and health. Other findings in this study confirm the findings of Gao *et al.* (2016), who discovered that poor indoor air quality is one of the most important causes of health problems and is responsible for diseases spreading swiftly in the indoor environment via the airborne route.

The quality of housing projects in the studied areas is influenced by various factors, including project money, building materials, and project management skills, as revealed by the data from BEPs. These results corroborate the findings of Civelek (2018), who discovered that the low success rate of housing project schemes is a result of various issues including inadequate funding, bureaucracy, politics surrounding housing programmes, a lack of suitable organisations, and a lack of transparency in housing programme management. The third significant component, bureaucratic hiccups, demonstrates the influence of the project initiators on the project outcome, based on the factorial analysis results. Project managers should prioritise flexibility and financial adequacy since they are necessary for the effective completion of projects. This aligns with and bolsters the perspective of Ibem and Aduwo (2012), who argued that the construction of housing projects requires current and suitable financial planning in addition to a solid financial package as a means of constructing a stable financial system. This might not be the case if the management of the organisation in charge of carrying out the project does not receive a clear and prompt response from the project initiators, the government. Due to a lack of project finance, project executors, or BEPs, are unable to proceed with the project. This leads to the compromise of crucial project elements and subpar project completion. The analysis indicates that the biggest obstacle to the success of public housing projects is misalignment with project objectives. Effective project results depend on an understanding of how important strategic project planning is to averting project failure and increasing project success from the outset. This is in line with the findings of Ahmed and Sipan (2020), who found that public-private partnerships can be leveraged to create affordable housing in Nigeria and are essential project success elements for affordable housing in Abuja. The Nigerian government should support the public-private partnership by providing alternate sources of finance, the authors added, emphasising the importance of project funding. The researchers promoted the creation of more financial organisations, such as federal mortgage lenders, as well as the necessity of controlling or lowering high-interest rates and providing subsidies to assist in bringing down the cost of housing for those with low and moderate incomes.

6. Conclusions and Recommendations

This study looked into the interactions between many elements that impact Nigeria's ability to provide high-quality public housing developments. In an attempt to address the mounting housing shortages, it determined the components (i.e., housing quality) that are now absent from the delivery of housing, including housing functionality, sustainability, and habitability. When indoor air temperature and relative humidity exceed particular thresholds (for example, 28 °C and 70% RH), they can have an impact on indoor air quality. Based on this study, the design of public housing in Nigeria's hot and dry region would need to give more consideration to the hot and dry season of the year, which at times of the year may have high temperatures and relative humidity, deteriorating the air quality within the building. Furthermore, by diluting or eliminating interior air contaminants, building ventilation can improve indoor air quality. It is reasonable to suppose that the ventilation rate in Nigerian public housing design could be improved for improved indoor air quality, particularly at night. To create high-quality housing projects, stakeholders also need to focus on the following issues: (i) adequate project financing; (ii) appropriate building materials; and (iii) project management experience. There are two important aspects to the findings and their implications for practice and policy. Initially, it would enable those involved in the building industry, legislators, and academic institutions to assess the state of both new and old homes and offer suggestions or enhancements for the provision of housing. Secondly, it would help agents of the council, tenants, and homeowners make well-informed



judgements regarding the quality of housing. In conclusion, it is important and insufficient to consider only the number of houses required to accommodate Nigeria's growing urban population when providing public housing; rather, other factors such as appropriate design for improved air quality, high-quality and appropriate building materials, adequate project financing, and project management expertise would result in quality delivery of livable public housing in Nigeria.

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Conflicts of Interest

The author(s) declare(s) no conflicts of interest.

Data availability statement

The data that support the findings of this study are available from the corresponding author [O.K.A.], upon reasonable request.

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Original scientific paper

Assessing the Impact of Urbanization on Flood Risk by RS and GIS: A Case Study on Istanbul-Esenyurt

*¹ Buse ÖZER , ² Prof. Dr. Özge YALÇINER ERÇOŞKUN 

¹ Graduate School of Natural and Applied Sciences, Department of City and Regional Planning, Gazi University, Ankara, Türkiye

² Faculty of Architecture, Department of City and Regional Planning, Gazi University, Ankara, Türkiye

¹ E-mail: ozerbuse@outlook.com.tr, ² E-mail: ozgeyal@gazi.edu.tr

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Haramidere.

ABSTRACT



Floods, exacerbated by escalating urbanization, pose significant threats to life and property globally. Over the past decade, the Esenyurt district in Istanbul has witnessed a series of floods, highlighting existing flood risks. Rapid population growth in this area and dense urbanization caused by intensive construction increase flood risks. Given these factors, the study focuses on examining the historical impact of urbanization on flood risks, considering spatial and temporal changes. Landsat-8 satellite data, specifically examining NDVI, NDBI, and BU, was employed to detect building imprints and reveal their historical backgrounds for temporal risk calculations. The analysis showed a sudden increase in urbanization rates in 2016, 2017, and 2021. In the flood risk calculations, 2014 data for a return period of 100 years were used and flood inundation depth, economic damages, affected population and depth-damage function were taken into consideration. The results indicate that from 2014 to 2022, increasing urbanization led to a 32.9% increase in the population affected by floods, a 22.3% rise in potential economic damage, and a 13.6% increase in total flood risk. The relationship between flood risks, contemporary urbanization, and its economic dimensions has been evaluated to reduce risks and achieve sustainable cities.

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Highlights:

- Utilizes Landsat-8 satellite data within the HVE (Hazard, Vulnerability, Exposure) framework to evaluate the impact of urbanization on flood risk in Istanbul's Esenyurt district.
- Employs remote sensing and GIS technologies for a detailed historical analysis of urban development and its correlation with increased flood vulnerability.
- Highlights the critical role of urban planning in mitigating flood risks, emphasizing the need for sustainable urban development strategies.
- Provides a comprehensive data-driven approach, underlining the socio-economic consequences of rapid urbanization on flood risk management.

Contribution to the field statement:

The study uniquely combines remote sensing (RS) and geographic information systems (GIS) to explore the relationship between urbanization and flood risk in Istanbul's Esenyurt district. Using Landsat-8 satellite data within the HVE (Hazard, Vulnerability, Exposure) framework, it documents the significant impact of urban expansion on increasing flood risk, evidenced by a considerable rise in the affected population and potential economic damages between 2014 and 2022. This work not only sheds light on the historical development and flood vulnerability nexus but also serves as a critical reference for formulating urban planning and flood mitigation strategies, contributing significantly to the discourse on economic dimensions of sustainable urban development.

*Corresponding Author:

Graduate School of Natural and Applied Sciences, Department of City and Regional Planning, Gazi University, Ankara

Email address: ozerbuse@outlook.com.tr

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1. Introduction

Over time, the correlation between rainfall and water flow has undergone extensive changes, mainly due to the increase in urbanization. The effects of urbanization result in anomalies in the urban water cycle, influencing various factors and causing urban floods. The Emergency Events Database reveals that the averages for flood occurrences, loss of life, and economic damage from 2002 to 2021 were significantly lower than those recorded in 2022. This change suggests an increase in the frequency and severity of floods from 2022 onwards. The trend of rising flood incidence across the globe is notable, and Turkey is no exception to this trend. According to the 2017 data from the General Directorate of Water Management, Republic of Turkey Ministry of Agriculture and Forestry, the comparison between the periods 1975-2002 and 2003-2015 demonstrates a 1.5 times rise in flood incidences (General Directorate of Water Management, 2017:25).

Metropolitan areas with high population densities are particularly vulnerable to increased flood risk because floods have significant and complex consequences in terms of damage and loss of life. In this context, the increasing flood risk associated with expanding urbanization and rapid development has become a significant concern for cities. Therefore, this study aims to evaluate the flood risk due to urbanization historically. Thus, the effects of increasing urbanization on flood risk were evaluated in the framework of economic damage and population affected by floods.

Population growth in urban areas has led to an increase in natural disasters, with floods being the most frequent occurrence (Li et al., 2022). The primary cause of flood is a significant change in the water cycle within cities, which has been exacerbated by urban expansion, a rise in population density and the prevalence of artificial surfaces. This situation can lead to flood depending on various factors in the water cycle, which is a highly complex system.

Urbanization has a complex impact on a range of factors that influence the water cycle, resulting in intricate relationships. For example, a study conducted by Verbeiren et al. (2013) demonstrates that increased impervious surfaces lead to higher peak discharges. Additionally, Huang's (2019) study highlights that urbanization not only raises flow volume but also accelerates flow velocity, reaching its peak more rapidly. Impermeable surfaces have significant effects on crucial hydrological parameters including surface runoff velocity, magnitude, and volume as evidenced by the studies conducted by Salvadore et al. (2015), Walsh et al. (2005), and Dams et al. (2013).

Figure 1 shows a hydrograph that demonstrates changes in discharge over time as a result of urbanization. The process of urbanization involves a change in land use, in particular an increase in impervious surfaces such as built-up areas and asphalt roads. These surfaces replace natural and green spaces, leading to decreased permeability. Residential areas often have over 50% impermeable surface, whereas industrial areas can reach 70-80% (Salvadore et al., 2015). The composition and extent of such impermeable surfaces have a significant impact. This change leads to a decrease in evapotranspiration and an increase in soil infiltration, causing precipitation to convert into surface runoff. As a result, the runoff rates, volume of surface runoff (Salman and Li, 2018; Chen, Xie, and Xu, 2019), and peak flow due to urbanization intensify (Huang, 2019; Miller et al., 2014; Du et al., 2012; Li and Wang, 2009).

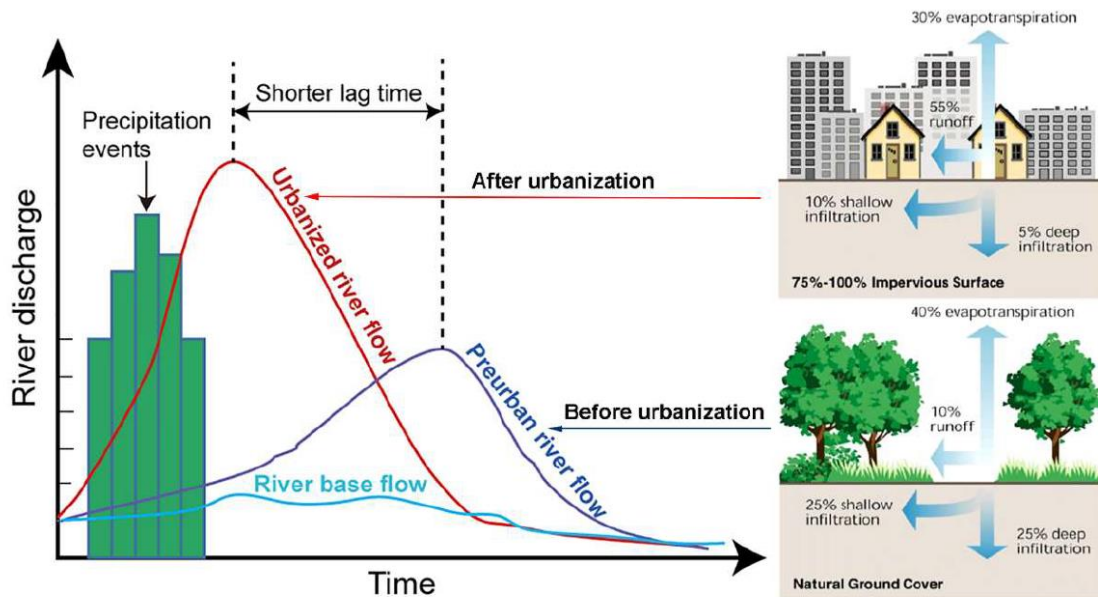


Figure 1. Impacts of urbanization on the surface on hydrological parameters (Ding, Wu, Tang, Chen, and Xu, 2022).

The imbalance created by all interrelated parameters causes a flood. Flood risk analysis is necessary to identify these relationships, but there are differences between flood risk analysis studies conducted in the context of urbanisation due to the framework, scale, method or components of flood risk.

Flood risk is generally expressed in the literature as "Risk = Hazard×Vulnerability×Exposure". Studies adopting the Hazard, Vulnerability and Exposure (HVE) framework highlight the significance of incorporating exposure into flood risk assessments (Aerts et al., 2018; Kron, 2005; Field et al., 2012). The main focus of exposure analysis is to evaluate individuals and property (Field et al., 2012), which have a critical impact on flood risk. Díez-Herrero and Garrote (2020) conducted a bibliometric analysis using the main keywords 'flood risk analysis and assessment' and showed that population and land use were the factors frequently considered in exposure analysis in the studies reviewed. This is because the effect on population and assets depends on land use trends. Therefore, exposure analysis is particularly important in urban areas with high population densities and rapid land use alterations. This framework provides a comprehensive and systematic approach to understanding and addressing flood-related issues, hence the use of the HVE framework in this study.

Flood risk analysis studies within the scope of urbanization were examined in the literature. The study by Luino et al. (2012) focused on the town of Alba in Italy, known for its industrial areas along a river. Despite structural measures, flood risk increased from 4% to 48% between 1852 and 1994, indicating a correlation between historical development, urbanization, and flood risk. Urbanization-induced changes in Land Use/Land Cover (LULC) were found to elevate flood risk, as shown by studies in Surat City, India, and East Ern Jeddah, Saudi Arabia (Waghwalwa & Agnihotri, 2019; Bahrawi et al., 2020). Changes in city density, LULC, and urban area alterations impact the water cycle, necessitating a combined assessment of hydrological processes and land use. Because the study concluded that changes in LULC caused by rapid urbanization increase the risk of flood. Studies, such as Nguyen et al. (2021), analysing the Tra Khuc River basin in Vietnam, integrated urban flood risk, land use, and hydraulic modelling. The Analytic Hierarchy Process method assisted in building-based flood risk evaluation, providing spatially detailed risk maps. Zope et al. (2016) observed a 6% increase in flood-prone areas in a Mumbai urban basin due to rapid urbanization between 1966, 2001 and 2009. Mustafa et al. (2018) projected a 5.5% to 11% increase in flood risk every decade from 2030 to 2100 in Belgium, factoring in 24 urbanization scenarios. In northern Vietnam, Do et al. (2022) used remote sensing and GIS to identify a 43% urban intensity increase over 35 years. Flood risk assessment demonstrated higher risk in intensely urbanized areas, emphasizing the importance of the extent and

intensity of urbanisation. Research in Istanbul's Esenler district by Nigussie and Altunkaynak (2019) utilized the SLEUTH (Slope, Landuse, Excluded area, Urban extent, Transportation and Hillshade) model for urbanization modelling. Dense development scenarios resulted in increased flood areas and, consequently, heightened risk. Yu et al. (2021) applied the HVE perspective to flood risk in Ulsan Metropolitan City, Korea. They conducted a high-resolution building-based flood risk assessment, emphasizing the importance of facility use and concentrations in risk calculations. It was determined that the risk is high especially when urban development is rapid around the river, but there is no risk in planned settlements. Handayani et al. (2020) highlighted that poorly planned urbanization contributes to increased flood-prone areas in Indonesia, emphasizing the need for urban plans considering flood risk amid population and infrastructure growth (Mustafa et al., 2018).

Changes in land use and rapid urbanisation have an impact on the water cycle, leading to research that examines both hydrological processes and urbanisation simultaneously. Diverse investigations conducted in Vietnam, India, Indonesia, and Belgium have examined the consequences of urbanization scenarios on flood risk, revealing a progressive rise in risk levels. Case studies in Northern Vietnam and Istanbul have demonstrated the manner in which the degree of urban expansion influences flood risk. The incorporation of remote sensing and geographic information technologies has provided valuable insights into evaluating flood risk in urban areas. In brief, urbanization without adequate attention to flood risk leads to the expansion of flood-vulnerable regions and emphasises the critical importance of urban planning in mitigating flood risks and economic damages.

Urbanization, flooding and the economic impact of flooding are three important interrelated factors. Understanding these relationships is critical for the creation of sustainable and resilient cities. Although the economic evaluations vary according to the aim, the damage to settlements in urban floods causes economic damage (Merz et al., 2010). This damage may occur in residential areas, commercial areas, infrastructure and other urban function areas. When urban planning is used effectively, loss of life, physical damage and economic damage arising from possible floods are minimized. In addition, after urban floods occur, improvement and risk reduction efforts for future floods have an economic impact. These efforts may include various measures such as infrastructure projects, water management plans and emergency preparations. Thus, ensuring the balance between urbanization and flood risk and managing the economic relationship is critical to ensure sustainable urban development.

In this study, a site-specific methodology was applied in order to present the flood risk historically. This methodology includes elements such as analyzing past flood events, determining economic damage, and analyzing the affected population. This process aims to show how flood risk evolves and increases in the process of urbanization, highlighting the importance of urban planning. The economic perspective emphasises that urban planning strategies should address not only the physical infrastructure but also the sustainability and resilience of the economy. The findings suggest that urban planning plays a critical role in determining strategies to cope with flood risk. Consequently, this study emphasises the importance of urban planning as a key component to understanding flood risk in urban areas from a historical perspective and to effectively mitigate these risks.

2. Materials and Methods

The research methodology comprises two interconnected components for calculating flood risk that centres around buildings over time (Figure 2). The first step is to identify buildings that have been affected by floods. The second step is to determine the flood risk by following the methodology used in Flood Management Plans using the identified buildings. These components are not isolated, but rather they are interlinked and reinforce each other. The two components of the methodology are described in detail in sections "2.1.2 Background Analysis of Buildings" and "2.1.3 Flood Risk Methodology".

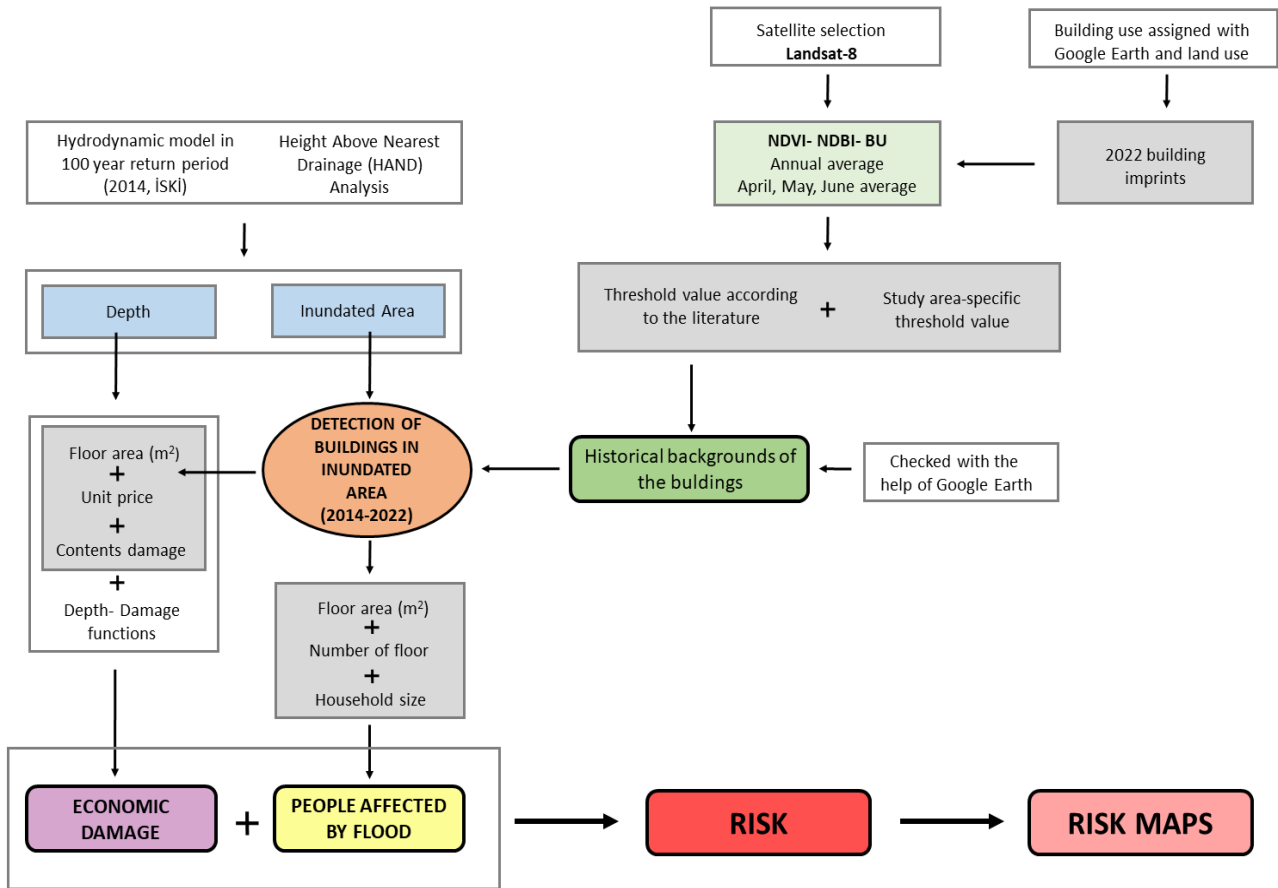


Figure 2. Study methodology flow diagram.

2.1.1 Study Area

The Esenyurt district of Istanbul province was chosen for the purpose of the study. The reasons for the selection of this study area are as follows:

- It is the most populous district of Turkey with a population of approximately 1 million.
- When the population changes in the past years are examined, rapid population increases have been observed.
- There is a dense coexistence of industrial and residential areas.
- In 2022, the flood disaster that occurred in Esenyurt caused a loss of life.

The study area, Esenyurt, is located on the European side of Istanbul and is bordered by the Trans-European Motorway (TEM) and D-100 highway, which are major transport arteries (Figure 3).

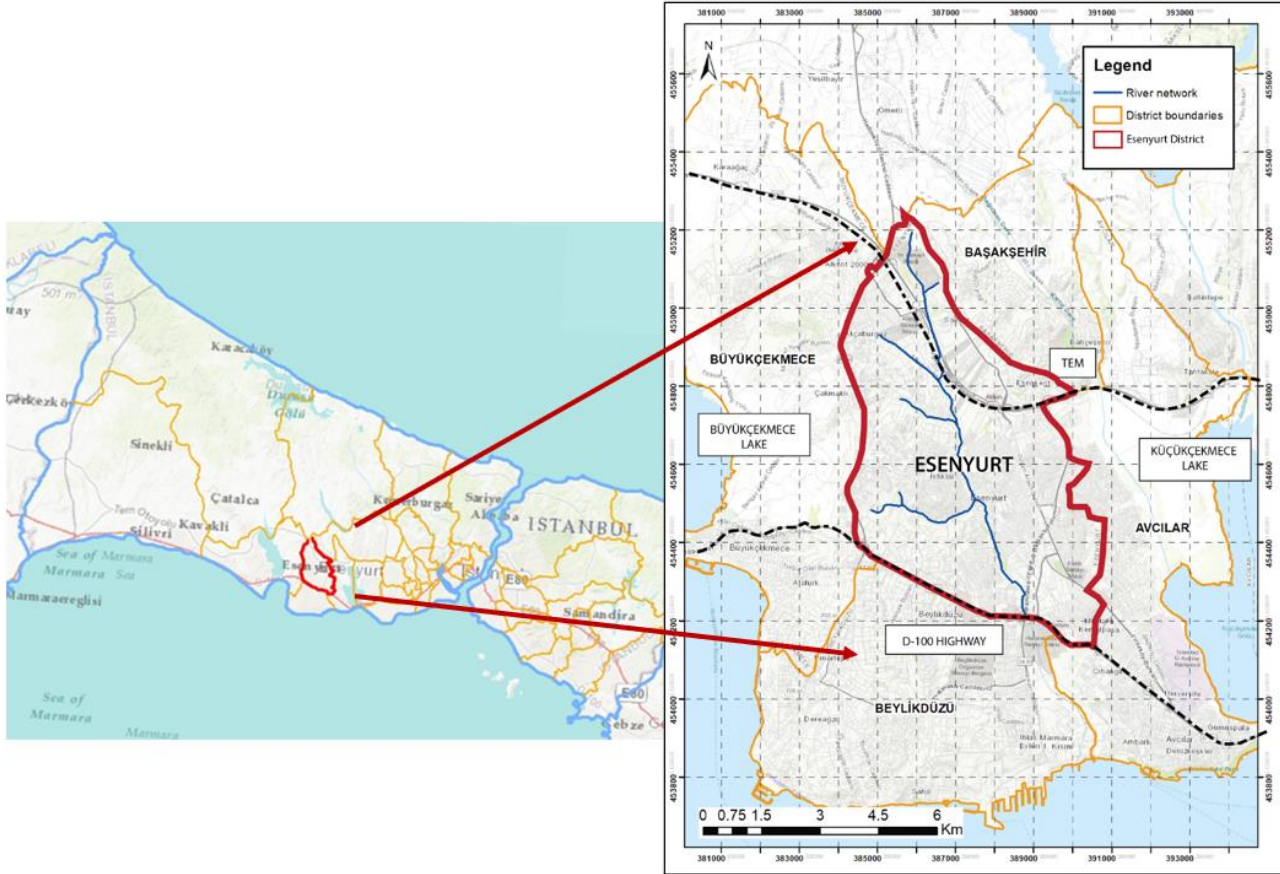


Figure 3. Esenyurt district in Istanbul.

In 1970, Esenyurt was a village with a population of 2,066, dominated by agriculture and livestock (URL-5). According to Ayhan's (2019) research into the population growth of Esenyurt, the strategic location of the area in Istanbul led to the development of industrial zones in the 1980s. Accordingly, the population increased and reached 7,180 in 1980 (URL-5). Within 10 years, mass housing constructions started, and the population of the district became 72,519 due to cheap land prices and the relocation of industrial facilities outside the city (URL-5). In the 2000s, rapid and unplanned settlement was experienced, and the population was 173,198 in 2000 (URL-5). In 2008, it gained district status, and in these years, both industrialisation and vertical construction accelerated. After 2008, although the population growth rate in the district varied, it continued to show a continuous upward trend. Today, it is the most populous district of Turkey and Istanbul with a population of approximately 1 million. The population of the district was 983,571 in 2022, constituting 6.18% of Istanbul's population (URL-2). While it was a village dominated by the agriculture and livestock sector with a population of 2,066 approximately 50 years ago, today it has turned into a district with high density consisting of industrial and residential areas.

Another important feature of Esenyurt district is the Haramidere River passing through the centre of the district. Haramidere is a river that originates in Esenyurt district and forms a catchment of approximately 47.5 km². The river passes through important main arteries (TEM and D-100 highway), densely populated residential areas and industrial zones. Esenyurt district constitutes the majority of the basin (74.1%) and when the floods occurring in this river were analysed, it was seen that all of them occurred in Esenyurt district. For these reasons, the part of the Esenyurt district affected by the Haramidere River was determined as the study area (Figure 4). In addition, the presence of both industrial and residential areas in the study area was useful in determining the risk change in areas with different characteristics.

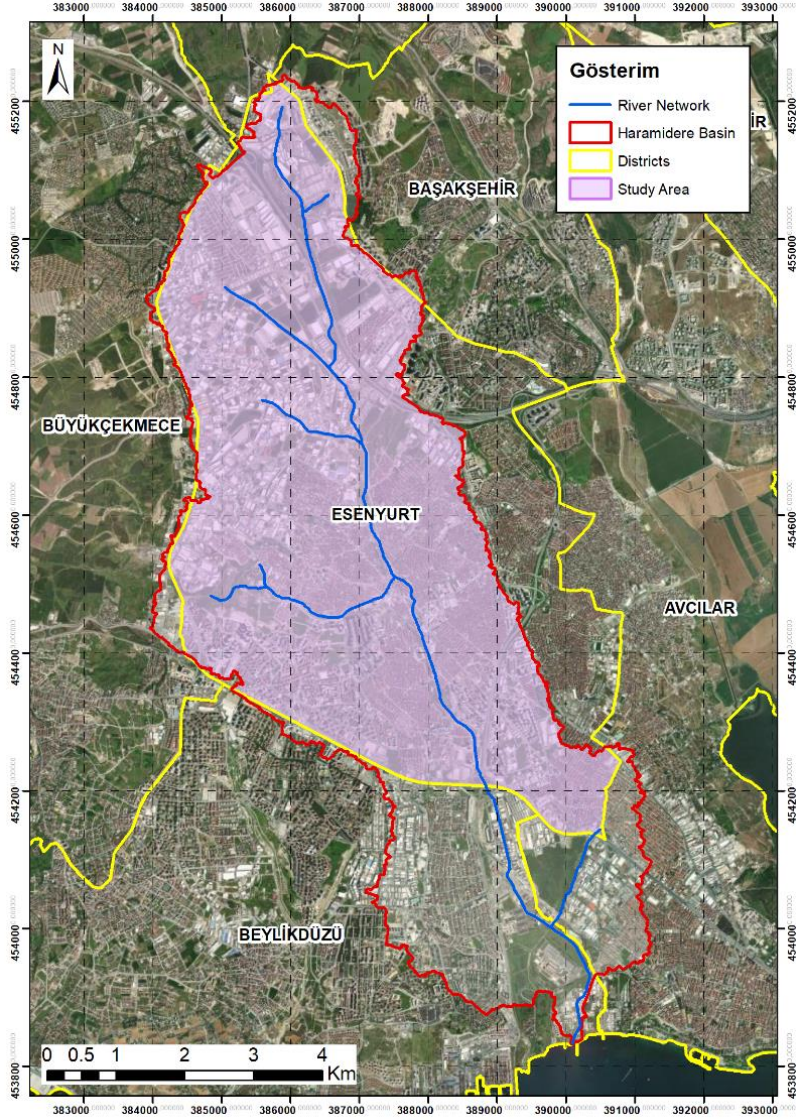


Figure 4. Study area.

2.1.2 Background Analysis of Buildings

To carry out the flood risk on a building-specific and historical basis, it is necessary to identify the buildings in different years. For this reason, in this study, the past conditions of the buildings were determined by remote sensing techniques. The following criteria were determined for the use of these techniques:

- Satellite data should be compatible with the historical time range (2014-2022).
- It should take measurements at least once a month in terms of temporal resolution.
- It should have bands that allow water, green areas, and soil to be distinguished.
- It should have the highest possible spatial resolution (<30m).

There are several methods in the literature to distinguish between water, vegetation and soil, which is one of the basic requirements. One of these methods is the separation of different wavelengths. The NDVI, NDBI and BU indices were used in this study to distinguish wavelengths from each other and to distinguish buildings from other components. NDVI is assumed to decrease when a previously vegetated area becomes a built-up area, while the other two indices, NDBI and BU, are assumed to increase in the opposite way. In order to calculate the indices, satellites with bands for Visible Red, Near Infrared (NIR) and Short-Wave Infrared (SWIR) wavelengths are needed. The selection of satellites was made according to the criteria established for the indices, and as a result of the comparison of satellites, the Landsat-8 satellite was considered to be the most suitable satellite.



The vegetation and construction of the buildings in the flooded area were analysed. The aim was to retrospectively determine the years of construction of the buildings. The aim was to determine the values used in the classification of these indices in relation to the years of construction of the buildings. For this purpose, the thresholds of the indices were determined that would distinguish the buildings from the ground and green areas.

Google Earth Engine (GEE) scripts were used to process the Landsat-8 library in this study. Instead of downloading each data individually, all analyses were conducted on the GEE platform. The dataset used is specifically named "LANDSAT/LC08/C02/T1_L2" and provides atmospherically corrected surface reflectance and land surface temperature derived from Landsat 8 OLI/TIRS sensors (Google-GEE, 2023). Images with more than 20% cloud cover were excluded from the study. In addition to annual averages, three-month averages for April, May and June, representing periods of dense vegetation, were examined to eliminate the influence of snow or ice. NDVI, NDBI and BU calculations were performed on 1,051 building polygons within the 2022 flood zone. For each building, both annual and three-month (April, May, June) averages of NDVI, NDBI and BU were calculated for the years 2014-2022. The calculations were carried out in four basic stages:

1. Identification of the years with breaks in the index values using the cumulative percentage of the annual averages and the months covering April-May-June for the respective year in the time series.
2. Subsequently, thresholds for buildings based on the NDVI classification obtained from the literature were examined.
3. Considering possible variations in the dynamics of the study area, specific building thresholds for the area were determined. This involved taking the lower and upper index values (NDVI, NDBI and BU) calculated for all buildings in the study area since 2014 as the building threshold. The years outside these values were then identified for buildings constructed after 2014.
4. Validate the results for some buildings within the inundated area using historical Google Earth imagery and compare with the results from the first three steps to determine the most appropriate method.

As a result, years of construction were determined for buildings within the inundated area that were classified into three main categories: "residential, commercial and industrial". In this way, the buildings in the study area and the construction thresholds for each of these buildings were determined (Figure 5).

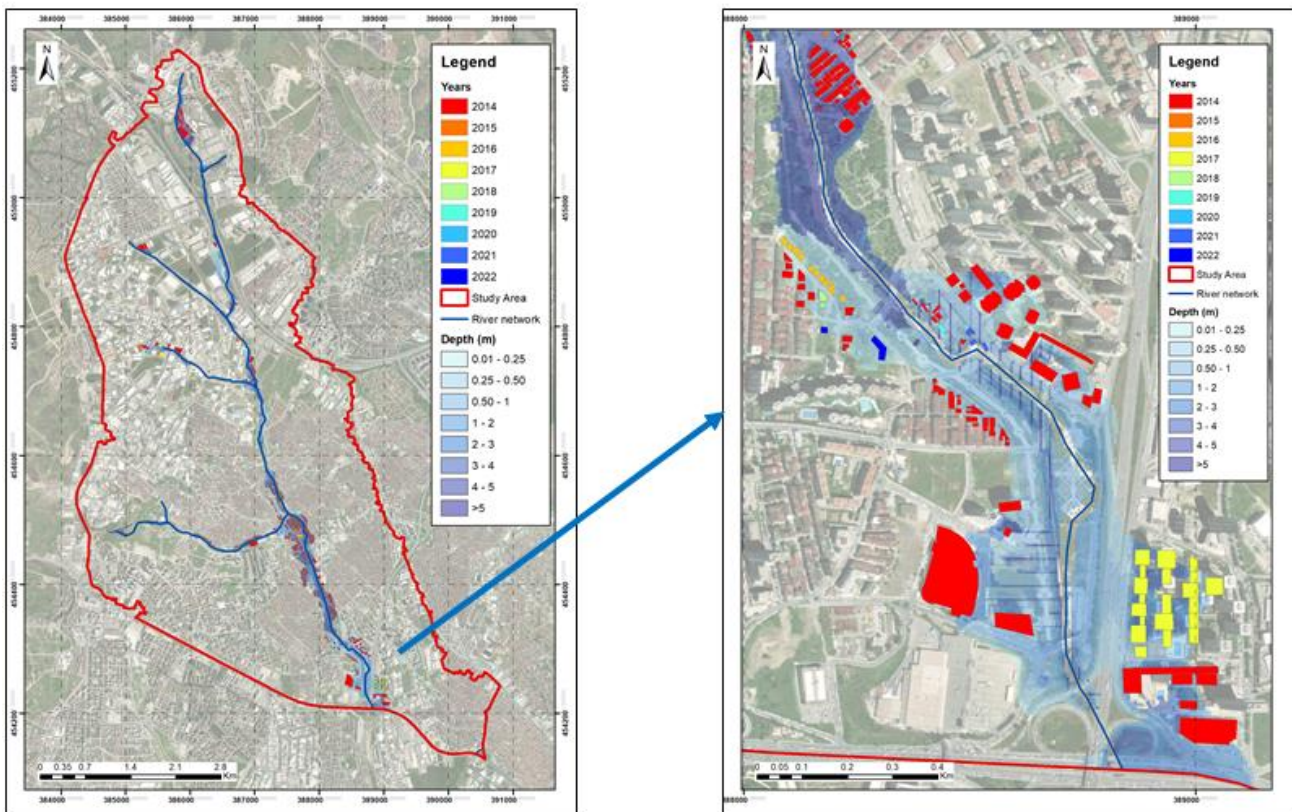


Figure 5. Construction years of the buildings.

2.1.3 Flood Risk Methodology

For flood risk assessment, the primary focus was on hazard analysis, determining the inundated area and inundation depth. The flood modelling project conducted by İSKİ (Istanbul Water and Sewerage Administration General Directorate) in 2014 in the Haramidere Basin served as the basis for identifying flood areas. This project used 1 and 2-dimensional hydrodynamic models for flood simulations. Hydrological and hydrodynamic studies were carried out for return periods of 25, 100, and 500 years, calculating the maximum discharge (Q_{max}) for each return period. The results of these studies provided information on flood-inundated areas and inundation depths for each return period. Inundation depth and inundated area results of the 100-year return period were used since the use of the 100-year return period would give more realistic results in risk calculations.

This study is based on the inundated area and inundation depth corresponding to the 100-year return period in the project carried out in 2014. It is assumed that no rehabilitation works have been carried out in the stream since 2014 and that the inundated areas and inundation depths have remained constant. The inundated areas (1.54 km² in total) and depths of inundation have been digitised for use in the risk calculation. For these reasons, historical risk assessments were made from 2014 to 2020.

In this study, the methodology applied in the Flood Management Plans by the General Directorate of Water Management, Republic of Turkey Ministry of Agriculture and Forestry was used for risk analyses.

The number of people affected by the flood was calculated based on the buildings identified in the "Background analysis of buildings" section. One of the important assumptions is that everyone in the inundation area will be affected regardless of the water depth. While calculating the affected population risk, household size of 3.43 people and night population were taken as basis (URL-10). When economic damage is analysed, it is seen that the methodology emphasises that economic damage has a linear relationship with depth damage. Traditionally in the literature, damage is associated with the depth of flood. It is based on the linear relationship between depth and damage (Chinh, Dung,



Gain, & Kreibich, 2017; Pistrika, 2010). It is assumed that damage is greater in areas with greater depth. In this sense, the methodology and literature are compatible with each other.

To determine the economic damage, the following formula was calculated separately for each building.

$$Z = DR \times A \times BF \times 0.6 \times 0.5 \times 1.18 \dots\dots\dots(i)$$

Z: Economic damage value (TL)

DR: Depth- damage function value

A: Floor area of building (m²)

BF: Unit price of building (TL/m²)

To compute flood risk using the provided formula, the initial step involves establishing the depth-damage relationship. This relationship is derived from flood data, specifically inundation depth, and economic damage data from historical events. However, due to the limited availability of comprehensive flood-related data in Turkey, the methodology referred to as "Global flood depth-damage functions," outlined by the Joint Research Center (JRC) in 2017, was adopted (Huizinga et al., 2017). These depth-damage functions were formulated separately for each continent, and the values designated for Europe were applied within the methodology. Consequently, the value of damage function value was determined for each building type and corresponding depth.

In the formula, the parameter called "BF", which represents the building unit cost, plays a crucial role in determining economic damages. This signifies the economic valuation of one square meter of building. The building costs used were taken from the publication "Announcement on Building Approximate Unit Costs to be Used in the Calculation of Architecture and Engineering Service Fees for the Year 2022/3", issued by the Ministry of Environment, Urbanization and Climate Change. The values have been specifically chosen to suit the context of our country (URL-11). This document was used to determine construction costs, which vary according to factors such as the type of residential building, the number of floors, the height of the building, the number of floors in industrial buildings and the type of production. In order to prevent the risk value from being affected by inflation, the values for 2022 are taken as fixed for the cost of each year.

The majority of depth-damage curves are reported to approach a value of 0.60. Irrespective of the water height, 40% of structures remain undamaged by the flood, and this portion should be excluded from maximum damage calculations (Huizinga et al., 2017: 55). Consequently, the undamaged segment of buildings was taken into account in damage calculations and adjusted by a factor of 0.60.

It is recommended to include a depreciation factor in damage assessments, considering the reduction in the value of buildings over time (Huizinga et al., 2017: 54). Different countries have modified the maximum damage value of buildings by introducing coefficients ranging from 0.50 to 0.63 in these assessments. In the methodology used, this coefficient is fixed at 0.50. In the methodology used, this coefficient is fixed at 0.50. As the approximate unit cost of buildings does not include VAT, the calculated damage value has been adjusted by multiplying it by 1.18.

The economic damage values discussed earlier specifically concern damage to buildings and do not encompass damage to contents. The computation of contents damage adheres to the approach outlined by Huizinga et al. (2017), linking contents damage to building damage. To be precise, contents damage is calculated as 50% of building damage for residential areas, 100% for commercial areas, and 150% for industrial areas.

In accordance with the methodology, the calculation of the total flood risk is based on normalized values for economic damages and affected population. The provided formula was used to normalize the data. As a result, the economic damage and affected population values for each building were transformed to be in the range of 0 to 1.

$$\text{Total Risk} = 0.5 \times \text{Economic Risk (0-1)} + 0.5 \times \text{Population Risk (0-1)} \dots\dots\dots(ii)$$

Once the calculation has been performed, the final flood risk is determined for each building. The overall risk assessment takes into account both economic and population factors. As a result, the resulting risk assessments provide a holistic result by considering not only physical damage but also the population.



3. Results and Discussion

The building-based risk analysis under high urbanization was carried out in two steps: background analysis and risk analysis of buildings from satellite imagery. Together with the background analysis of buildings, buildings were analysed historically according to their type of use (Table 1). When analysing the change from 2014 to 2022, the number of buildings increased continuously; residential buildings increased by 12.9%, commercial buildings by 8.6%, industrial buildings by 32.2% and total buildings by 13.9%.

Table 1. Buildings in the flood-inundated area.

Years	Number of buildings						
	Residential		Commercial		Industrial		Total Building
	Building	%	Building	%	Building	%	
2022	935	89.0	78	7.4	38	3.6	1,051
2021	929	88.4	75	7.1	38	3.6	1,042
2020	929	88.4	71	6.8	38	3.6	1,038
2019	927	88.2	71	6.8	38	3.6	1,036
2018	927	88.2	70	6.7	38	3.6	1,035
2017	918	87.3	69	6.6	38	3.6	1,025
2016	867	82.5	65	6.2	36	3.4	968
2015	835	79.4	61	5.8	36	3.4	932
2014	828	78.8	59	5.6	35	3.3	922

The economic damage and the population affected by the flood were calculated for each building. The population affected was calculated on the basis of the use of the building, the number of floors and the floor area of the buildings, determined by years. Based on the results, the number of individuals affected in 2022 is 50,407 (Table 2). This represents an increase of 12,471 people and an increase of 32.9% compared to the 2014 figures. Although there is a steady increase in the number of people affected by floods until 2022, it is seen that the growth rate decreases when compared to the total population of Esenyurt district. This is due to the significantly higher population growth rate in the Esenyurt district.

Table 2. People affected by flood.

Years	People affected by flood	Population of Esenyurt district	The ratio of the population affected by the flood to the district population (%)
2022	50,407	983,571	5.1
2021	49,646	977,489	5.1
2020	49,646	957,398	5.2
2019	48,521	954,579	5.1
2018	48,521	891,120	5.4
2017	48,198	846,492	5.7
2016	40,282	795,010	5.1
2015	38,677	742,810	5.2
2014	37,936	686,968	5.5



At the end of the applied process, the economic loss of each building was calculated by taking into account the number of floors, building height, floor area and unit cost according to the building use. These calculations for all years are given in Table 3. Between 2014 and 2022, there was a significant increase in economic damage to residential buildings, reaching around 90 million TL and contributing 11.6% more to the total damage. Commercial buildings experienced an increase in economic damages of around 30 million TL, increasing their share of total damages by 4.2%. For industrial buildings, it increased by approximately 18 million TL, up by 2.4%. The total damage during the period 2014-2022 showed an increase of approximately 143 million TL. Specifically, the economic damage in 2022 showed a notable increase of 22.3% compared to the figures recorded in 2014. It was found that the majority of the economic damage occurred in residential buildings. The reasons for the damage to houses are as follows:

- Increased urbanization and the establishment of residential areas close to riverbeds.
- Increase in the density of residential areas in existing settlements.
- High-rise buildings and therefore high unit costs of residential buildings constructed in recent years.

Although the number of industrial buildings is high, the economic damage caused by them is less than that caused by commercial buildings. The reason for this is that industrial buildings tend to be single-storey and have relatively low approximate unit costs, whereas commercial buildings tend to be multi-storey and have high approximate unit costs.

Table 3. Economic damage values (2014 - 2022).

Years	Economic Damage (TL)						Total
	Residential		Commercial		Industrial		
	TL	%	TL	%	TL	%	
2022	434,488,988	55.6	202,981,662	26.0	144,573,498	18.5	782,044,148
2021	431,715,832	55.2	202,981,662	26.0	142,358,106	18.2	777,055,600
2020	431,715,832	55.2	202,981,662	26.0	140,802,139	18.0	775,499,633
2019	427,128,864	54.6	202,981,662	26.0	140,802,139	18.0	770,912,665
2018	427,128,864	54.6	202,981,662	26.0	140,288,118	17.9	770,398,644
2017	422,935,273	54.1	202,981,662	26.0	135,598,661	17.3	761,515,596
2016	370,137,872	47.3	182,956,149	23.4	133,669,714	17.1	686,763,735
2015	352,077,976	45.0	182,956,149	23.4	130,919,358	16.7	665,953,484
2014	343,124,144	43.9	170,183,638	21.8	126,089,445	16.1	639,397,227

For each building, flood risk from both damage and population was calculated and risk maps were created at five risk levels (very low, low, low, medium, high and very high) in ArcGIS program. Within the scope of the study, the risk of all buildings was calculated and divided into zones (Figure 6). Maps of prominent examples within these zones were given (Figure 7, Figure 8, Figure 9, Figure 10).

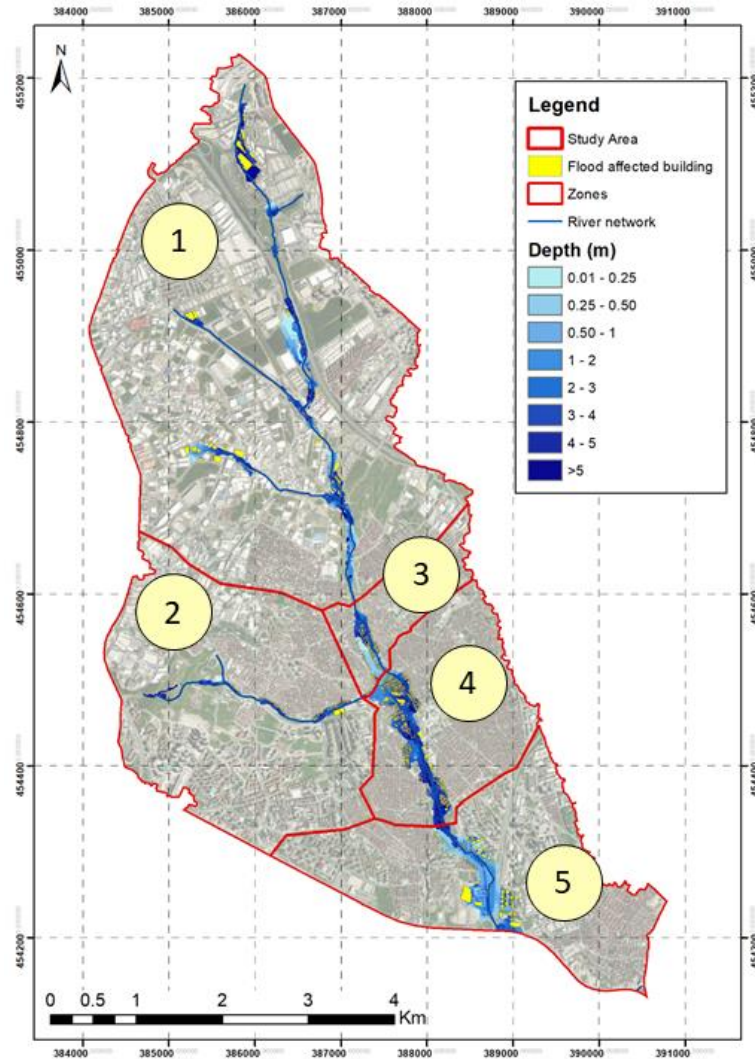


Figure 6. Study area zones.

According to the given maps, in Zone-2 (Figure 7 and Figure 8) residential buildings were constructed after 2014 at a distance of about 20 meters from the river and are classified in the "medium" risk category. In Figure 7 and Figure 8, there are 2 industrial buildings in the "high" risk category and both of them are single-storey buildings. Except for these industrial buildings, all other buildings are residential and categorised as "low" and "very low" risk. Therefore, depending on the depth of the risk classes, the importance of floor area, number of storeys and building use in risk classification becomes prominent. It also occurred in Zone-4 given in Figure 9 and Figure 10. After 2014, residential buildings were constructed approximately 50 meters from the river and were categorised as "very high" risk depending on the number of storeys and floor area of the building.

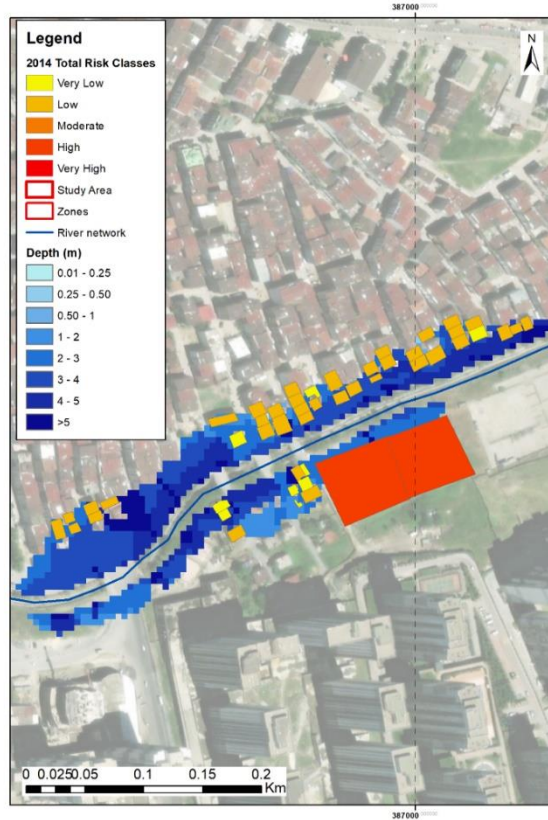


Figure 7. Flood risk map for Zone-2, 2014.

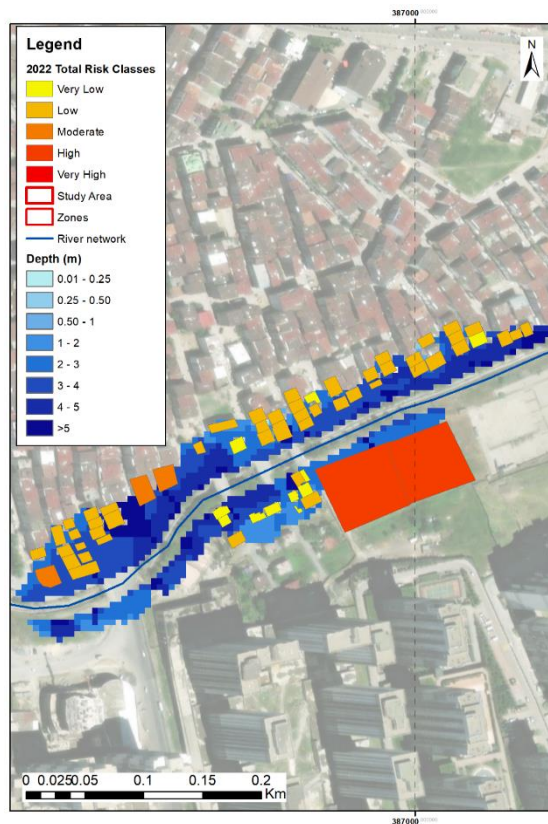


Figure 8. Flood risk map for Zone-2, 2022.

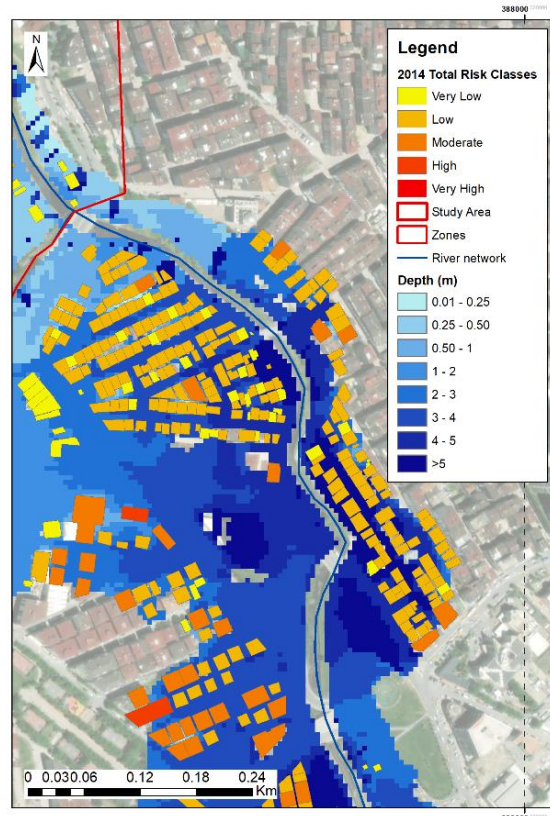


Figure 9. Flood risk map for Zone-4, 2014.

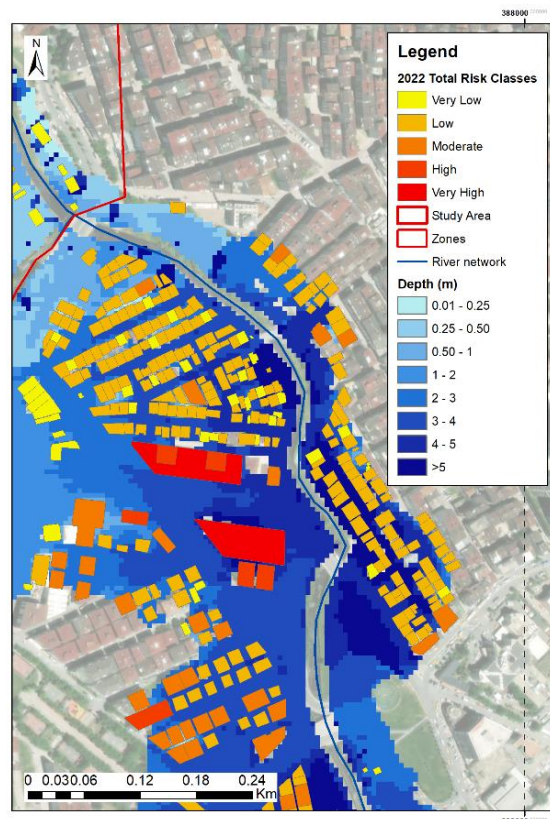


Figure 10. Flood risk map for Zone-4, 2022.

The results of the building-specific risk analysis were examined. The risk for residential buildings increased by 16.6%, the risk for commercial buildings increased by 9.9% and the risk for



industrial buildings decreased by 13.3% (Table 4). The reduction in the average floor area of industrial buildings towards 2022 was identified as the main factor contributing to the decrease in their risk. After a comprehensive examination of the entire study area, there was a 13.7% increase in the average total risk from 2014 to 2022.

Table 4. Risk averages of building use by years.

Years	Residential Risk	Industrial Risk	Commercial Risk	Total Risk
2014	0.0314	0.0319	0.0728	0.0330
2015	0.0318	0.0321	0.0760	0.0335
2016	0.0319	0.0307	0.0760	0.0335
2017	0.0358	0.0293	0.0799	0.0370
2018	0.0357	0.0299	0.0799	0.0369
2019	0.0357	0.0296	0.0799	0.0369
2020	0.0364	0.0296	0.0799	0.0375
2021	0.0364	0.0283	0.0799	0.0374
2022	0.0366	0.0277	0.0799	0.0375

When analysing all the results together, it was determined that the increase in the number of buildings, particularly in 2017, had an impact on the overall risk. In addition, it was found that the general trend of "number of floors" and "building area" is compatible with the change in risk. However, it should not be forgotten that the water depth in which the buildings are located is the most important factor in determining the risk.

In 2019, there was an above-trend increase in the population, which led to an increase in residential risk and total risk in the subsequent years. As a result, high urbanization has increased the number of people affected by flood by 32.9%, the economic damage in case of flood by 22.3% and the total flood risk by 13.6% from 2014 to 2022. In this case, 5,1% of the population of Esenyurt became vulnerable to the flood. All results show that the flood risk has increased significantly over the last 9 years. The most effective reasons for the increase in risk are:

- sudden population growth,
- increase in urbanization and settlements close to riverbeds,
- increase in settlement density in existing settlement areas
- increase in storey height of residential buildings constructed in recent years (Özer, 2023).

The main reason for their occurrence is that urban planning is not carried out effectively and in accordance with the study area.

Urban planning emerges as a key tool for flood risk reduction, facilitating the implementation of strategies, especially for current and future flood scenarios. In new settlements, the distance to riverbeds needs to be considered and in existing settlements, structural measures can be implemented where there is a risk of flooding. These measures are designed to divert flow away from flood-prone areas during flood events. Examples include the construction of reservoirs to mitigate downstream flows, the widening of canals to increase capacity, the implementation of diversions to reduce flows in main channels, and the construction of embankments to protect areas adjacent to canals (de Andrade Cruz et al., 2023). In 2020, the Istanbul Metropolitan Municipality initiated infrastructure and rehabilitation efforts for the study area. Infrastructure and rehabilitation works, including widening the channel section and strengthening the infrastructure to separate rainwater and wastewater, have not yet



been completed. However, these measures remain incomplete and successive floods, particularly in 2022, have continued during these efforts.

Complementing structural measures are non-structural and nature-based solutions aimed at flood prevention and mitigation (Conitz et al., 2021). Non-structural measures aim to minimise flood risks, reduce damage and increase community resilience without relying on physical alterations. Examples include urban planning and its enforcement, the formulation of flood management and mitigation plans, the establishment of floodplain zoning regulations to limit development in high-risk areas, the implementation of flood early warning systems, and public education on flood risks and preparedness measures.

The lack of adequate urbanization planning and the non-implementation of non-structural measures have led to an escalation of risk levels over time. As a result, changes in flood-risk areas have increased the potential losses in terms of human life and property (Şenol Balaban, 2016). In addition to the economic damages quantified in this study, the structural measures commonly used in Turkey to prevent floods entail additional costs. Embankments, rehabilitation, and other structural measures may not be sufficient to address various parameters such as flood frequency, velocity, and depth (Bruwier et al., 2015).

In this case, effective solutions include model-based approaches like Green Infrastructures, such as rain gardens, green roofs, permeable pavements, and rainwater harvesting, alongside Sustainable Urban Drainage Systems (SUDS), Low Impact Development (LID), Sponge Cities, and Nature Based Solutions (NbS) (Qi et al., 2021). These approaches share the same objectives. Nature-based solutions are a concept inspired by nature, aiming to preserve the natural balance and include actions towards this (Cohen-Shacham, Walters, Janzen, and Maginnis, 2016; Huang et al., 2020). The objective of this approach to flood is to improve water retention capacity and minimise flood risk by addressing the ecosystem holistically. To realise these objectives, the following actions can be implemented in the study area:

- Rainwater harvesting, green roofs to slow down the flow processes in Haramidere River,
- Permeable pavements, infiltration trenches to increase the permeability of rainwater,
- Bioswales to increase the permeability of rainwater and provide ecological benefits,
- Retention ponds to reduce surface runoff.

These measures allow for water recycling, efficient utilization, economic advantages, and decreased flood risk. The prevention of flood risk is achievable through the reduction of numerous parameters that contribute to the formation of floods by implementing these measures. Previous research has extensively examined the efficacy of Nature-based Solutions (NbS) in mitigating flood risks. These studies primarily concentrate on various aspects, including decreasing peak flow (Jackisch and Weiler, 2017), minimizing runoff (Dreelin, Fowler, and Carroll, 2006), reducing flood volume (Mei et al., 2018), and decreasing flood inundated area and inundation depth (Costa et al., 2021). Investigating the suitability of these parameters for the specific study area is essential to effectively reduce flood risk. Consequently, spatial planning plays a crucial role, particularly during the implementation phase. Combining nature-based solutions with urban planning is a recommended approach to reduce flood risk in Esenyurt. Considering the historical floods in Esenyurt, it is concluded that more emphasis should be placed on urban planning and model-based approaches such as NbS rather than structural solutions for flood-resilient cities.

The study's findings highlight the complicated connection between urbanization, population growth, and flood risk. In Esenyurt, risk levels have increased significantly over time due to ineffective urban planning and a lack of implementation of non-structural measures. This study emphasizes the importance of structural measures while also highlighting limitations in addressing parameters such as flood frequency, velocity, and depth.

To address these limitations, a holistic approach that combines nature-based solutions (NbS) is advocated. These approaches aim to increase water retention capacity, minimize flood risk, and provide economic benefits. Additionally, they offer more sustainable economic contributions compared to structural solutions.



The proposed implementation of nature-based solutions for reducing flood risk in Esenyurt gains further significance when integrated with effective spatial planning and considering the urban economy. This study concludes that it is crucial to place greater emphasis on model-based approaches, such as urban planning and Nature-based Solutions (NbS), particularly in the face of increasing urbanization, to establish a sustainable and flood-resilient economic structure.

4. Conclusion

Floods are a widespread natural disaster causing significant economic damages and human losses. These losses are linked to rapid population growth and urbanization. Therefore, it is essential to assess flood risk and urbanization together. Accordingly, the flood risk caused by the frequently-flooded Haramidere River in the İstanbul district was analysed concerning urbanization. Esenyurt district was chosen due to its population of approximately 1 million and its dense construction in both industrial and residential areas.

The most important feature of this study is the combination of remote sensing and GIS in flood risk assessment and analysis. Using remote sensing, background analysis of buildings and their evolution over time were obtained. These data were processed with GIS and the areas exposed to flood risk were mapped by spatialising the degree of risk. These risk maps played a critical role in identifying high-risk areas, assessing potential flood impacts on the population, and informing urban planning decisions. While RS data provides temporal continuity of the data used in the study, GIS spatialises these data. GIS determines trends with analyses for temporal and spatial differences of the data provided by GIS and RS. The integration of RS and GIS creates a powerful whole for analysing and understanding spatial data. In summary, the research has provided a comprehensive and data-driven approach to understanding the complex interactions between urbanization and flood risks by developing remote sensing and GIS applications in flood risk assessment. Another important feature of this study is the introduction and comprehensive application of the HVE (Hazard, Vulnerability, Exposure) framework. With this framework, it has addressed multiple dimensions such as risk, economic damage (TL in 2023) and the number of people who will be affected by flood risk. It was determined that the flood risk has increased over the years, and this increase was caused by the rapid population growth and urbanization in the risky areas. It is concluded that population and risk increases are in parallel on an annual basis. In addition to its important features, it provides the information necessary to effectively target risk reduction and adaptation measures by identifying flood risk hotspots where hazards, vulnerabilities and exposures converge. Based on this information, it should be recommended to determine urban planning and model-based flood prevention and mitigation strategies such as nature-based solutions by analysing the basin in detail. While determining these solutions, urban density, population, and socio-economic status should be taken into consideration. The district is categorised as arid-semi-humid, but due to the decrease in precipitation in recent years, there is a possibility of transition to semi-arid status. For this reason, nature-based solutions such as plant-based green corridors, green roofs, bioswales, etc. cannot be implemented due to the characteristics of the area. Therefore, the study area should be investigated in detail and appropriate nature-based solutions should be implemented with the help of urban planning.

After the completion of the ongoing rehabilitation works in Esenyurt, it is predicted that the flood risk will decrease when the recommendations determined within the scope of the study are implemented. GIS plays a crucial role in assessing and managing flood risk, providing a versatile tool for analysis and implementation. It facilitates the simulation of a variety of scenarios related to the planning of nature-based solutions (NbS), including determining their location, size, and form. GIS helps urban planning by identifying the enduring consequences of climate change and urban development, improving adaptability to changing conditions. Before and after the implementation of Nature-based Solutions (NbS), Geographic Information Systems (GIS) assist in sustainable initiatives by facilitating the evaluation of possible consequences and tracking the efficiency of green infrastructure. By conducting consistent data collection and analysis, GIS guarantees the continued



success of such features in mitigating the threat of floods. When GIS is combined with urban planning, it plays a crucial role in reducing flood risk through site-specific applications.

The study offered a practical solution to a serious problem related to the disclosure of flood risk associated with the rapid urbanization in Istanbul-Esenyurt. This study conducted an analysis of the historical flood risks between the years 2014 and 2022. It identified the susceptible areas and quantified the economic damages and the population affected by the flood. Furthermore, it provided a preliminary preparation for the potential applications to mitigate the flood risks and established a basis by assessing these risks. This study demonstrates that urbanization policies implemented without effective planning can result in economic losses. Settlements in high-risk areas and urbanization processes increase the impact of floods, leading to potential losses of infrastructure, property, and other economic assets. Therefore, it is important to have strict regulations on buildings in high-risk areas and to integrate contemporary planning processes to minimise the economic losses caused by floods. Urban planning has been proposed as a solution to the flood risk arising from urbanization and population growth. It is important to consider urban resilience to flooding and risk mitigation strategies in the design and implementation of urbanization policies. As a result, the study suggests that urban planning can be used to reduce flood risk and that local governments should consider the interaction between urbanization and flood risk when developing urban planning policies.

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Conflict of interests

The authors declared that there was no conflict of interest relating to the conduct, outcome, and publication of this study.

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 authors.

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 are presented in this study.

Institutional Review Board Statement

Not applicable.

CRedit author statement:

Buse Özer led the conceptualization, methodology, and investigation of the study, playing a crucial role in the formulation, planning, and execution of research activities. She was primarily responsible for writing the original draft of the manuscript and creating the visual materials to effectively represent the study's findings. Prof. Dr. Özge Yalçiner Ercoşkun provided critical supervision, contributing to the conceptual framework of the research and ensuring the project's direction and methodology were robust and reliable. She also played a key role in the validation of results, guaranteeing the accuracy and reliability of the findings, and was instrumental in reviewing and editing the manuscript, significantly enhancing its clarity and quality. Furthermore, Prof. Ercoşkun was responsible for acquiring the funding that supported the project, securing the necessary resources and materials for the research. Together, their combined efforts have significantly contributed to the advancement of the study, demonstrating a collaborative and comprehensive approach to research. All authors have read and agreed to the published version of the manuscript.



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Original scientific paper

Analysing the Social Impacts of Urbanization on Traditional and Contemporary Trading Environments: The Case of Bahrain

*1 Noor Saleh Alalawi , 2 Prof. Dr. Islam Hamdi Elghonaimy

¹ & ² Department of Architecture and Interior Design, College of Engineering, University of Bahrain, Bahrain

¹ E-mail: nalalawi@uob.edu.bh, ² E-mail: eelghonaimy@uob.edu.bh

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ABSTRACT

The trade sector is among the top four growing sectors contributing to Bahrain's GDP. Despite the successful impact of trade on the local economy, there is an apparent disconnect between individuals engaged in trading activities and their physical urban spaces, posing a significant threat to preserving Bahrain's vibrant social trading culture. The research hypothesis is that effective urban design can significantly improve trading activities in the old city of Manama. Consequently, the research aims to define the role of physical urban design in influencing trade, outline the social impacts of urbanization on traditional and contemporary trading environments, and identify urban principles that affect the physical act of trade. The methodology follows a theoretical study that considers the history of urbanization and its contemporary theories, the impacts of urbanization, and the trading development impacts of urbanization on trading environments in Bahrain. An analytical study is then adopted to analyse the problem, using the "fishbone diagram", questionnaires and photographic analysis of the area. The findings highlight the importance of utilizing outdoor space, diverse building typologies, organic circulation routes, spatial layout, interior design, landscaping, adaptable design, interaction spaces and intimate spaces within the design of traditional and contemporary trading environments. The research concludes with recommendations to sustainably revive the trading streets in Bahrain. The results provide valuable insights for stakeholders, such as Bahrain Authority for Culture and Antiquities, and those working in architecture, urban and interior design, to reignite informal social trading experiences from the past. The results stress the importance of people's participation in design.



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Highlights:

- Effective urban design principles can enhance socio-economic vitality by fostering vibrant trading environments in Bahrain.
- Urbanization poses socioeconomic challenges by disrupting traditional trading practices and social interactions.
- An adaptable spatial layout, incorporating diverse building typologies, enhances commercial street functionality.

Contribution to the field statement:

This study contributes to the academic field by providing in-depth insights to stakeholders and experts into the impact of urban design and architecture in enhancing commercial activities in trading environments. The findings highlight the significance of the spatial layout, interior design, landscaping, adaptable design, interaction spaces, diversity of building typologies, and circulation, which should be prioritized in the design of commercial streets.

*Noor Saleh Alalawi:

Department of Architecture and Interior Design, College of Engineering, University of Bahrain, Bahrain.

Email address: nalalawi@uob.edu.bh

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1. Introduction

1.1 Background and Context

Bahrain is an archipelago, located in the Arabian Gulf, at 50.85 east and 26.24 north. The majority of the population resides in cities, and mainly in Manama. The rest of the population lives in older parts of the island, rich with traditional Bahraini architecture and identity (Eldardiry & Konbr, 2022). Manama (Figure 1) became the capital of Bahrain in 1921 and was known as a prominent trading centre in the region (Aljazi, 2020). It is home to a diverse population and individuals of different faiths. Bahrain has a strong, respectable history of urbanization, witnessing significant transformations in its built environments. Bab Al Bahrain Avenue is among the busiest streets in the capital, filled with residents and tourists. It has the significance of being both a destination and a transitional space. Most government buildings are located there and designed in a modern style. The characteristics of Bahrain's cities have been crucial to its urban development throughout history. Due to globalization, the city's primary economic drivers have been the tourist industries and trade, which have contributed significantly to its status as a central hub for commerce (El-Ghonaimy, 2020).



Figure 1. Manama's location in Bahrain (Adapted from (UPDA, 2024)).

1.2 Statement of Problem and Research Gap

Urbanization impacts commercial activities in traditional and contemporary trading environments in Bahrain. It is home to some of the world's most forward-thinking heritage preservation specialists, because of the professional guidance that it received from the government of Bahrain in the late 1960s (Hamouche, 2004). Globalization has radically altered the urban morphology of Bahraini cities, distorting the city's trading centre, even though early modern planning practices took into account the city's trading, social cohesiveness and historical significance. Hamouche (2004) claims that two concrete measures must mitigate the adverse effects of global planning practices on cities with heritage significance:

- a. The first strategy is to force non-native players to adapt to local conditions (climate, moral standards, cultural norms, etc.) in an authentic metropolis such as Muharraq.

b. The second strategy involves nurturing local human resources via knowledge-based networks. Moreover, in the older areas of Bahraini cities, the type of trading that facilitates tourists buying souvenirs, crafts and handmade trade has driven the city's economy, making it a central commercial hub. Unfortunately, globalization has dramatically changed the older section of the city's urban morphology, distorting its historical core despite the meticulous consideration of social coherence and historical significance in early modern planning. Most projects in such areas lack appropriate designs to attract visitors, which was a different case in the past, respecting both traditions and heritage issues and the vital commercial operations and needs of the users in the historical zones. Due to the significance of the heritage component in the city development plans, the designs of open spaces need to be re-examined, and streetscape conditions reflecting local identities need to be improved to enhance the trading ambience. Moreover, the designs should align with the strategic masterplan of Bahrain 2023, Bahrain's Authority for Culture and Antiquities (BACA) vision and the local municipality goals. To ensure that this paper achieves its aim, it is important to understand numerous key factors. The trade sector, which includes wholesale, retail sale and any service related to the sale of any type of goods in Bahrain, is among the top four growing contributors to the country's GDP (MOFNE, 2023). In the same context, it should be noted that the contribution of trade to Bahrain's real GDP increased from 11.8% in 2019 to 13.1% in the second quarter of 2023 (MOFNE, 2023). This demonstrates the successful impact of trade within the local economy. However, despite this rise in numbers, there is an apparent disconnect among individuals engaged in trading activities in Bahrain. There is an observed decline in social activities across the country, as individuals are attracted to global brands and shopping at malls and online, for a variety of reasons, including ease, fast transactions and convenience. This brings us to the main research problem, which addresses the disconnect in trade, posing a significant threat to preserving Bahrain's vibrant social trading culture, which its people have long celebrated.

1.3 Objectives and Hypotheses

The overarching aim of the research is to explore the dynamics of different trading environments in Bahrain to revive commercial activities. The objectives of the study include: 1) outlining the social impacts of urbanization on trade; 2) assessing the perceptions of commercial activities in traditional trading environments (Old Manama); and 3) identifying the architectural principles that influence the physical act of trade (Old Manama and Souq Al Baraha). The findings will help in the proposal of recommendations to reignite social trading experiences from the past. This can be achieved through a mixed-method approach.

- a. A "fishbone diagram" will be used to pinpoint the fundamental causes of disconnect in trade in Bahrain.
- b. A questionnaire (quantitative) will be adopted to explore the dynamics of trade from the personal perspectives of both shoppers and residents, and to outline the social impacts of urbanization on trade.
- c. A photographic analysis (qualitative) will be used to identify architectural principles that affect trade.

1.4 Significance and Structure of the Paper

The paper is structured in five sections. The first consists of an extensive literature review on urbanization and its impacts on trading environments, along with background information about Bahrain. Subsequently, the materials and methods section discusses the mixed methodology employed. The third section presents the results, while the fourth presents the discussion and the final section highlights the conclusions and recommendations for reviving the commercial streets of old areas in Bahrain (Figure 2). The research seeks to investigate the physical urban design and architectural elements that can significantly improve trading activities in the old city of Manama.

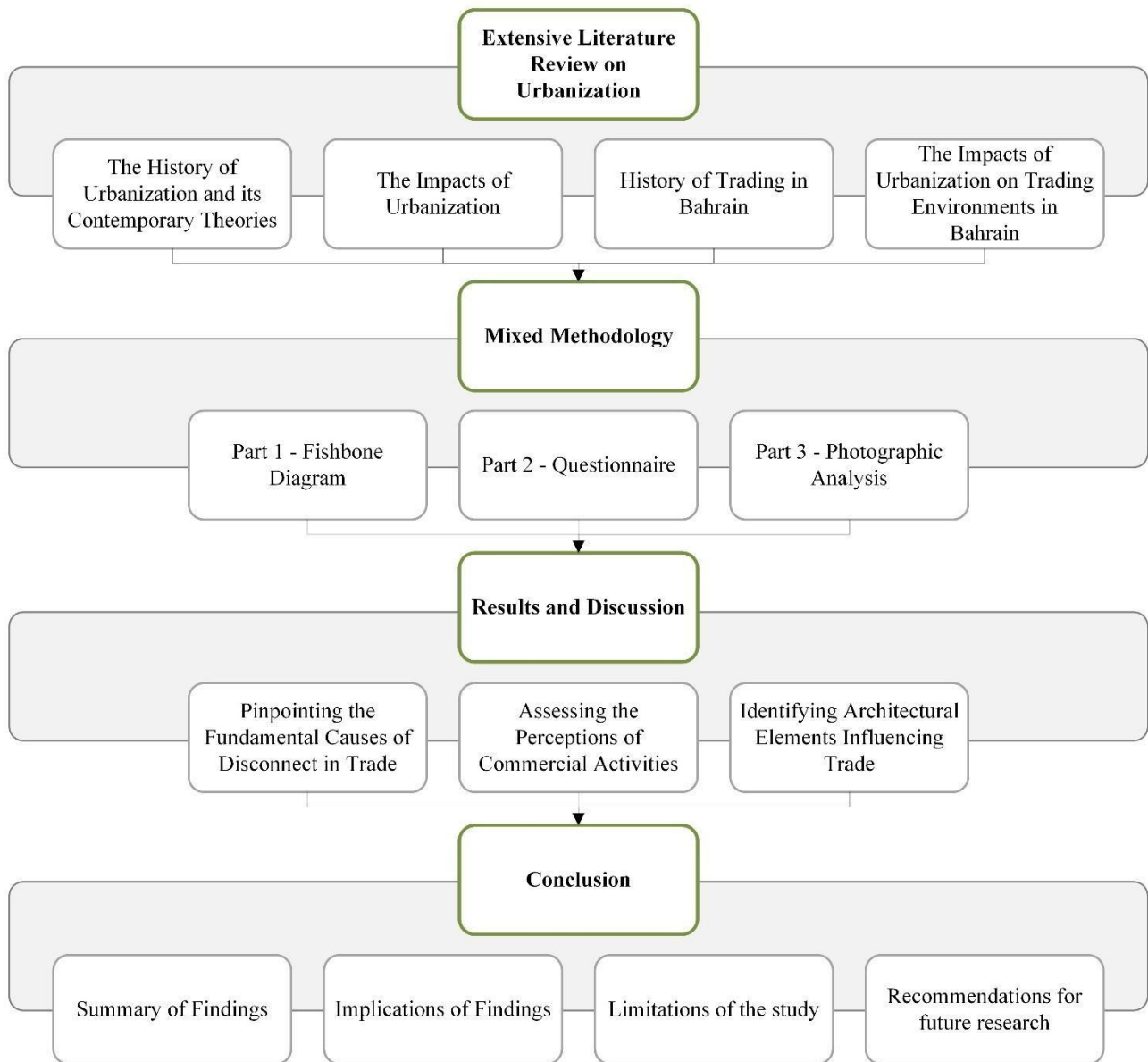


Figure 2. The research structure (Developed by the Authors).

2. Literature Review

2.1 The History of Urbanization and its Contemporary Theories

Urbanization is a global phenomenon; however, the absence of a fixed definition stems from the fact that urban aspects vary among different researchers and professionals in the field (Dijkstra et al., 2020). Many academics agree that urbanization is generally defined as the migration and relocation of populations from rural regions to urban areas, resulting in the subsequent alteration of the physical environment within urban settings (Kuddus et al., 2020). Throughout history, the attraction of cities as focal points for trade, culture, education and economic opportunities has consistently motivated the migration of people. This trend became even more pronounced following the advent of the Industrial Revolution in the eighteenth and nineteenth centuries (Friedlander & Okun, 2022). Over time, numerous urban theories surfaced to enhance our comprehension of cities and urban life. These theories adopt an interdisciplinary approach that garners interest from various disciplines, including



architecture. Due to substantial transformations in the scale, scope and characteristics of settlements, the clear distinction between urban and rural areas has become increasingly blurred (Hugo, 2016).

During the twentieth century, many influential contemporary schools of urban theory emerged, such as the Chicago School, the Frankfurt School, New Urbanism and Placemaking, among others. Each theory made distinctive contributions to the field of urban planning. The Chicago School focused on micro-sociology, urban sociology, social dynamics and urban ecologies within cities. The Frankfurt School aimed to enhance the understanding of social change (Jayne & Ward, 2016). Influenced by both schools, philosopher Henri Lefebvre focused on the “social production of space” and the “right to the city” (Kuttler, 2023). New Urbanism aimed to foster a sense of community among residents and counteract a sense of placelessness; however, further research is necessary to examine its advantages within the context of contemporary development, particularly post-COVID-19 (Garde, 2020). Placemaking emerged to enhance community engagement and people’s quality of life (Ellery et al., 2020). Ellery et al. highlight its importance in economically, socially and environmentally responsible design (2021). Placemaking also has the ability to give a sense of place, which can improve social communication and coherence in a community (Dash & Thilagam, 2022). Numerous researchers and theorists examining urban theories in the twenty-first century highlight the diversity and intricacy of urban life, focusing on social aspects and promoting cultural expression and cultural identity. They concur that cities are no longer confined within discrete boundaries, and the essence of urban life is now defined by the interplay of flows, juxtapositions, permeability and relational connectivity (Jayne & Ward, 2016). They are also widely recognized for their incorporation of diverse approaches, methods and theoretical perspectives, resulting in a range of both positive and negative impacts on societies.

2.2 The Impacts of Urbanization

The process of urbanization brings about numerous benefits to society by improving the social and economic aspects of people’s livelihoods (Murayama & Estoque, 2017). Table 1 illustrates the positive and negative impacts of urbanization, categorizing them based on their effect on the pillars of sustainability.

Table 1: Positive and negative impacts of urbanization on economic, social and environmental aspects (adapted from Murayama & Estoque, 2017; Lynam et al., 2023; Thaweeppworadej & Evans, 2023):

	Impact	Affected Sustainability Pillar(s)	Forms of Impact
(+) Positive Impacts of Urbanization	Economic opportunities & trade	Economic, Social	Increase in trade; increased GDP
	Infrastructure services and	Economic, Environmental	Improved infrastructure; enhanced utilities; increased investments; tech advancements
	Social and cultural diversity	Social	Cultural exchange; community building; interaction
	Knowledge innovation and	Economic, Social	Knowledge exchange; collaboration; entrepreneurship
(-) Negative Impacts of Urbanization	Overcrowding	Economic, Environmental	Population density; housing shortage; strain on infrastructure/resources; decrease in prosocial behaviours



Environmental degradation	Environmental		Effect on air, water and land; depletion of biodiversity; climate change
Social inequality	Social		Housing and employment disparities; segregation; access to services
Traffic congestion	Economic, Environmental	Social,	Increased vehicles; limited road infrastructure; parking challenges
Loss of agricultural land	Economic, Environmental	Social,	Decreased food production; displacement of rural communities
Urban poverty and crime	Economic, Social		Rising cost of living; concentration of disadvantaged populations
Social fragmentation	Social		Spatial segregation; loss of social networks; communication technology
Health challenges	Environmental		Air and noise pollution; inadequate sanitation

Urban centres epitomize the fusion of creativity and imagination, showcasing humanity’s immense potential for innovation and the generation of knowledge. They serve as vibrant hubs for socio-cultural transformations and act as engines of economic growth. However, urbanization brings with it negative environmental and socioeconomic impacts on individuals, communities and the natural environment. These include the urban heat island effect, air pollution flooding, traffic congestion, urban poverty and crime (Bodo, 2019). Additionally, it leads to overcrowding, social inequality, social fragmentation and loss of agricultural land, which itself leads to decreased food production (Thaweeproradej & Evans, 2023; Lynam et al., 2023). Overload theory claims that overcrowded environments, characterized by a wealth of stimuli, can affect individual cognitive abilities and exhaust cognitive resources. Consequently, individuals can show indifference to others and a decrease in their tendency to engage in prosocial behaviour (Liu et al., 2023). This is especially relevant in trade, where social interaction plays a key role.

It is evident that urbanization impacts all pillars of sustainability except environmental degradation, which is mostly concerned with the Environmental pillar. Urbanization exerts a noteworthy influence on social dynamics, shaping how people interact with each other and with their urban environment. Urbanization plays a vital role in fostering economic growth and development socially, particularly through trade. While it encompasses many economic and environmental impacts, the social impacts hold particular importance for trade, which is the primary focus of this study (El-Kholei et al., 2019). The next section delves into the background of Bahrain, setting the scene for the research.

2.3 History of Trading in Bahrain

Bahrain has been renowned as the epicentre of maritime trade in the Arabian Gulf for over four millennia (Figure 3), due to its strategic position (Laursen & Al-Otaibi, 2022). Situated along the historic Mesopotamia–Indus trade route, the island swiftly evolved into a vital port of call for vessels transporting valuable commodities between the two coastlines. Throughout history, trade has thrived in Bahrain, demanding extensive interaction with diverse individuals to facilitate business transactions.



Figure 3. Historical trade routes, with Bahrain as a pivotal nexus within the region (Laursen & Al-Otaibi, 2022).

Consequently, in the past, social engagement held paramount importance among the inhabitants of Bahrain. The majority of the population engaged in domestic and international trade. The streets of Old Manama were buzzing with people and commercial activities in the 1960s. They were full of life. The city was run by the people and trade was at its peak, with Manama the trading hub for pearls in the region. Among the items commonly traded, local pearls, dates, textiles, spices, handicrafts and livestock were some of the most popular commodities exchanged. The majority of residents were attracted to the coast and relocated to the old cities of Manama and Muharraq, which served as bustling pearl-trading centres (Salama & Wiedmann, 2016). These cities were characterized by a blend of residential structures, mosques, educational institutions and traditional commercial streets, adorned with vibrant souqs (El-Kholei et al., 2019). The age-old trading practices in Bahrain instilled important ethical values among its people, fostering a strong sense of trust within the community. Shop owners relied on verbal agreements rather than formal payment systems, emphasizing the power of word-of-mouth transactions. They had many traditions, including placing a chair outside their shops, which would then be brought inside once the first sale of the day was made. This practice aimed to inform potential customers that they had already made a sale and encouraged them to visit neighbouring shops, promoting mutual benefit among traders (Gui, 2021).

Urbanization and the subsequent rise in population density introduced a risk to this dynamic. The island now faces the challenge of overcrowding, threatening to undermine the essential social interactions that have long been integral to its economic vitality. An increasing number of individuals are residing in densely populated urban settings (Liu et al., 2023). The population density increased by 80% in 20 years, from 1,029 people per km² of land in 2001 to 1,852 people per km² of land in 2021. Bahrain ranks as the sixth most densely populated country globally, with Macau in China holding the top position in terms of population density (UN, 2024). Overcrowding has an impact on the urban heat

island effect, increasing temperatures within cities and decreasing social relationships between individuals. Although the impact of overcrowding extends to various sectors, the focus of this study is on the commercial sector and trade, which is discussed in the following section.

2.4 The Impacts of Urbanization on Trading Environments in Bahrain

Throughout history, the trade landscape in Bahrain has experienced significant transformations (see Figure 4), influenced by a range of factors, with urbanization standing out as a prominent catalyst (Shubbar & Furlan, 2019). Manama in particular has gone through multiple stages of development, including autonomous, bureaucratic and global urbanism (El-Kholei et al., 2019). Due to the influence of urbanization, globalization, technological advancements and rapid architectural progress, local residents gradually shifted away from trade centres. This resulted in the emergence of larger air-conditioned shopping centres and a notable transformation in the urban design of commercial areas (Sarkar et al., 2020). Locals moved out of the capital and have been replaced by Asian workers, leading to overcrowding and posing a threat to Bahrain's social trading culture. Relations between buyers and sellers have become very systematic, if they exist at all, as people are leaning more towards convenient shopping options and environments, such as going to the mall or using e-commerce.

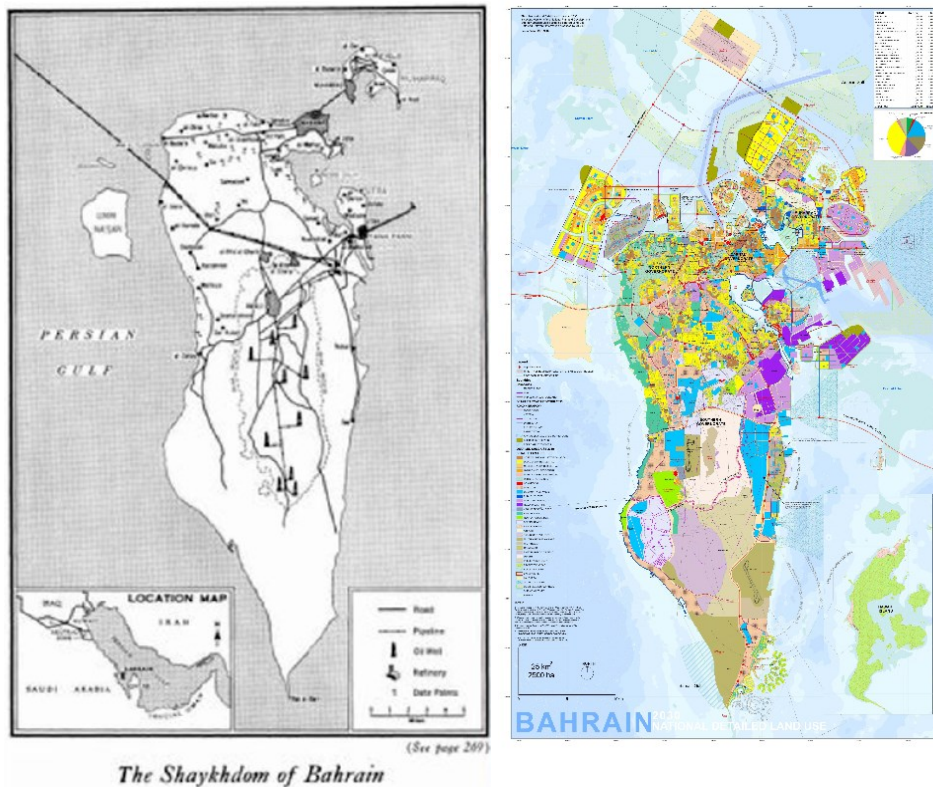


Figure 4. The transformation of Bahrain from 1955 to its vision for 2030 (Shubbar & Furlan, 2019).

The COVID-19 pandemic significantly impacted the dynamics of commercial spaces. In response to social distancing regulations, outdoor shopping districts began to emerge, catering to the desire of people to spend more time outdoors because of being confined to their homes during the pandemic (Gordon-Rawlings & Russo, 2023). Additionally, e-commerce witnessed a surge in popularity, driven by the seamless connection between buyers and sellers and its heightened level of ease and convenience. The transition from traditional commercial streets to contemporary open-air shopping districts brings benefits, but it also carries a cost. Despite the improved comfort provided by technological advancements in controlling indoor climate and the increased space, a social gap has emerged between shoppers and shop owners. Architectural environments have shifted from cosy,



intimate and natural indoor and outdoor spaces, fostering trade built on loyalty and trust, to colder, more formal shopping experiences, characterized by limited interaction with sellers and a controlled movement of people (Iqbal et al., 2022).

Shopping malls have hence become essential components of many cities across the world (Olla et al., 2023). The physical, psychological and social attributes of the mall highlight place attachment as the bond between people and places (Lee & Jeong, 2021). This bond is described as cognitive or affective (Widya et al., 2019), or even as a cognitive-emotional construct (Reese et al., 2019).

In addition to the changing landscape of the trading environments, the insufficient infrastructure in Bahrain, lack of public parks, limited alternatives to transportation and lack of pavements have resulted in a strong dependence on cars. This leads to congestion, pollution, lack of space and overcrowding, factors that have an important impact on the trading environment (AlKhalifa, 2018). Furthermore, the large number of low-wage workers unable to work remotely further exacerbates urban overpopulation. These workers are heavily dependent on public facilities and services in densely populated urban areas, which increases overcrowding (Champlin et al., 2023). Overpopulation also generates health and safety concerns, including increased noise levels, excessive waste beyond cleaning capabilities, the impaired ability of security personnel to maintain order, increased conflicts due to limited mobility and, most importantly, barriers to the access of emergency vehicles (Silva, 2020). It also poses difficulties in accessing stores in outdoor commercial areas, as entrances to stores may become congested, making it challenging for shoppers to navigate freely.

The transportation infrastructure plays an important role in managing the population and reducing crowding. The numbers of registered vehicles continue to increase, causing traffic congestion, which leads to overcrowding (Gazder et al., 2018). It also increases air pollution, affecting people's health and vulnerability to disease, and is a critical issue that needs to be addressed. In today's consumer landscape, customers prioritize transactions that demand minimal time and effort, as they perceive such purchases to be more advantageous. Consequently, traffic congestion is a hindrance, affecting route selection, shopping location selection and shopping trip rate frequency, causing customers to alter their shopping destinations or to choose to stay at home and opt for online ordering instead (Hawkins-Mofokeng et al., 2022). Kanyepe's study confirms a positive relationship between travel behaviour and traffic congestion (Kanyepe, 2023), while another study also emphasizes the significant connection between traffic congestion and land use, specifically in urban areas (Kanyepe et al., 2021). Existing research demonstrates that locals play an important role in reviving the essence of old areas, and BACA is constantly working on reviving these old areas of Bahrain to preserve the traditions of the people and the essence of Old Manama.

3. Materials and Methods

Manama, the capital of Bahrain, was selected as the study area. The reason behind this selection was that most of Bahrain's population is concentrated in Manama. Urbanization greatly impacts trade in both traditional and contemporary trading environments in Bahrain, and in Manama in particular, since most of the commercial and trade hubs are located there. Old Manama was selected as the traditional trading environment, while Souq Al Baraha was selected as the contemporary trading environment. A mixed-method approach was utilized to enhance the credibility and generalizability of the findings. The methodology was divided into three parts (Figure 5). The first part presents a "fishbone diagram" to pinpoint the fundamental causes of disconnect in trade in Bahrain. The second part is a questionnaire to assess the perception of commercial activities in traditional trading environments. The third part consists of a photographic examination of buildings and outdoor spaces to analyse how urban design influences trade, by investigating the elements that have an impact on the physical interactions between merchants and customers.

This mixed method provides a comprehensive understanding of the social impacts of trade and the interactions between different parties in traditional and contemporary settings. It also provides valuable insights into how to approach the design of future trading environments in order to enhance the dynamics of contemporary trade. Further, it redefines the relationship between shoppers and shop owners, to give stakeholders and industry experts the opportunity to reignite the informal trading experiences from the past.

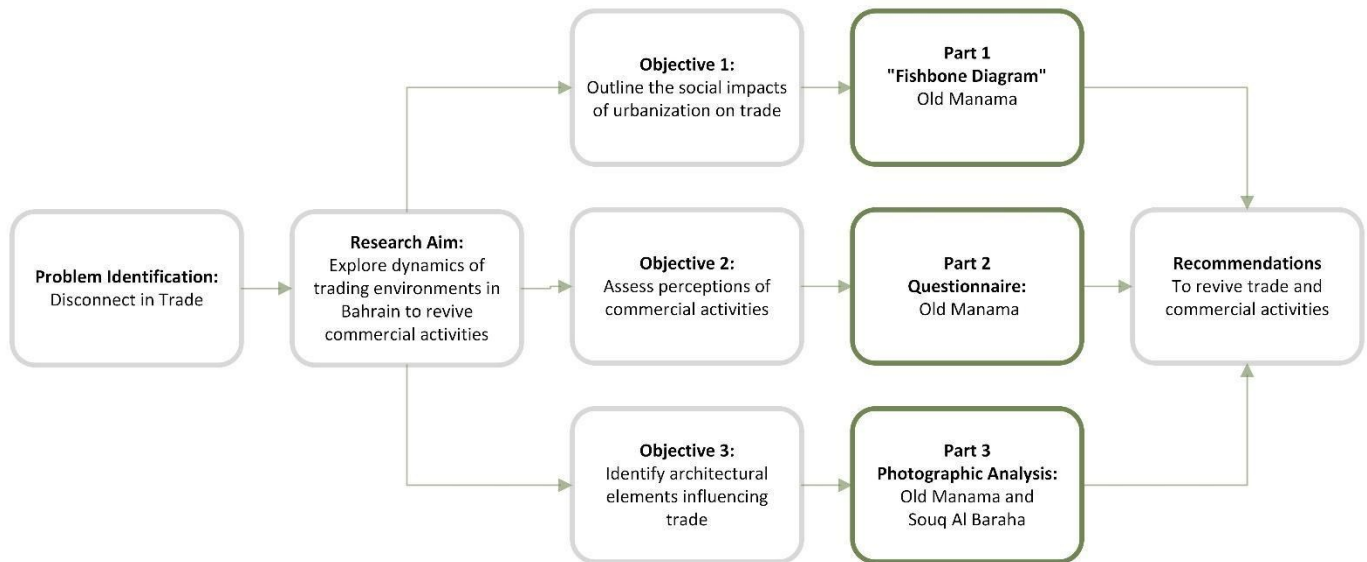


Figure 5. The mixed-methodological approach of the study.

3.1 “Fishbone Diagram”

Based on the aforementioned examination of the literature, a fishbone diagram was utilized as a valuable instrument with which to pinpoint the fundamental causes of disconnect in trade. To provide a comprehensive understanding of the potential factors, the diagram presents a detailed breakdown of the categories and their associated underlying causes. It is used to help to identify the root causes of a problem or effect and to assess the interplay between the cause-and-effect dynamics that contribute to areas in need of improvement (Plenert & Plenert, 2018; Coccia, 2017). Overall, it enhances understanding, promotes collaboration, simplifies complex issues and provides a structured framework for organizing and analysing qualitative data and determining the essence through phenomena (Jawwad, 2020).

3.2 Questionnaire

To facilitate the active participation of people in reviving commercial activities in Old Manama, a questionnaire was distributed using SurveyLegend to gather insights from residents of and visitors to the area. Table 2 outlines the demographic characteristics in more detail. The objective was to collect opinions and ideas that could play a significant role in revitalizing trade in Old Manama. Data was gathered in both English and Arabic, and the Arabic responses were subsequently translated and merged with the English data to create a comprehensive dataset. The questionnaire was distributed in both languages, as the majority of residents in Old Manama find it more comfortable and convenient to express their concerns in their native language. The initial set of questions consisted of demographic-related inquiries. The research team included detailed information about the study’s purpose and a digital consent form at the beginning of the questionnaire, to ensure that all participants were aware of the research and their voluntary participation. The questionnaire was designed to ensure anonymity, and the collected data was stored securely, with access only to the research team. By addressing these ethical considerations, the research team aimed to protect the rights and privacy of all the participants.



A convenience sampling method was employed to distribute the questionnaire via different social media platforms. This allowed the researchers to reach a broad audience quickly and efficiently. To mitigate potential bias, the link was shared across multiple platforms, to reach a diverse audience, enhance the representativeness of the sample and ensure the robustness of the findings. To ensure the validity and reliability of the data-collection instruments, the questionnaire was developed based on a comprehensive review of the literature, and a pilot test was conducted to identify any issues with the questions. With a population of approximately 1.5 million, at a 95% confidence level and 5% margin of error, the sample size for the study was calculated as 385. A total of 762 individuals participated in the study.

Table 2: Demographic characteristics of the sample.

Variable	Category	n	%
Gender	Male	134	18
	Female	475	62
	Not answered	153	20
Age group	0–18	63	8
	18+	547	72
	Blank	152	20
Relation to Old Manama	Ex-resident of Old Manama	213	28
	Current resident of Old Manama	14	2
	Visitor to Old Manama	183	24
	Descendant of ex-residents of Old Manama	187	25
	None of the above	80	10
Residency in Old Manama	Unknown	85	11
	Less than a year	12	2
	1–5 years	30	4
	5–10 years	32	4
	10+ years	223	29
	None of the above	288	38
Frequency of visits to Old Manama	Unknown	177	23
	Never	99	13
	1–2 times a month	257	34
	3–4 times a month	84	11
	5+ times a month	128	17
Nature of visits to Old Manama	Unknown	194	25
	Clothes shopping	264	21
	Gold and jewellery shopping	328	26
	Cultural events	144	12
	Visiting family or friends	217	18
	Eating out	210	17
	Other	69	6

The questionnaire findings were subjected to descriptive statistical analysis using the Statistical Package for Social Science (SPSS version 29.0 for Windows). The frequency distribution was used to summarize the responses for the categorical variables. Cronbach’s Alpha was used to assess the internal consistency of the questionnaire items to ensure reliability.

3.3 Photographic Analysis

A photographic analysis of buildings and outdoor spaces was conducted to understand how urban design influences trade. Old Manama was selected as a traditional trading environment, due to its history as a central trading hub in Bahrain. Souq Al Baraha was selected as the contemporary example, due to its recent date of construction. The data-collection process took place during March 2024. To

ensure the validity and reliability of photographic analysis, a standardized protocol for capturing and analysing the photographs was developed. The analysis aimed to understand the impacts of architectural elements on commercial activities in Old Manama and Souq Al Baraha. The findings were subjected to qualitative analysis to emphasize trends and draw conclusions regarding commercial activities. Lazar and Chithra's indicators of culture were utilized in the analysis to identify urban design elements that influence trading activities. They emphasize the importance of integrating cultural components in architecture and urban design, as they promote interactions and create a sense of belonging. These components include the use of local materiality, traditional elements, interior spatial layout, landscaping, flexibility and interactive spaces (Lazar & Chithra, 2022).

4. Results

4.1 “Fishbone Diagram”: Pinpointing the Fundamental Causes of Disconnect in Trade

Eight factors were categorized to encompass all the possible causes of the disconnect in trade: urbanization, economy, environment, petroleum, migration, cultural change, the Great Recession and COVID-19 (Figure 6). This diagram offers a comprehensive overview of the various causes that contribute to the observed disconnect in social trading activities.

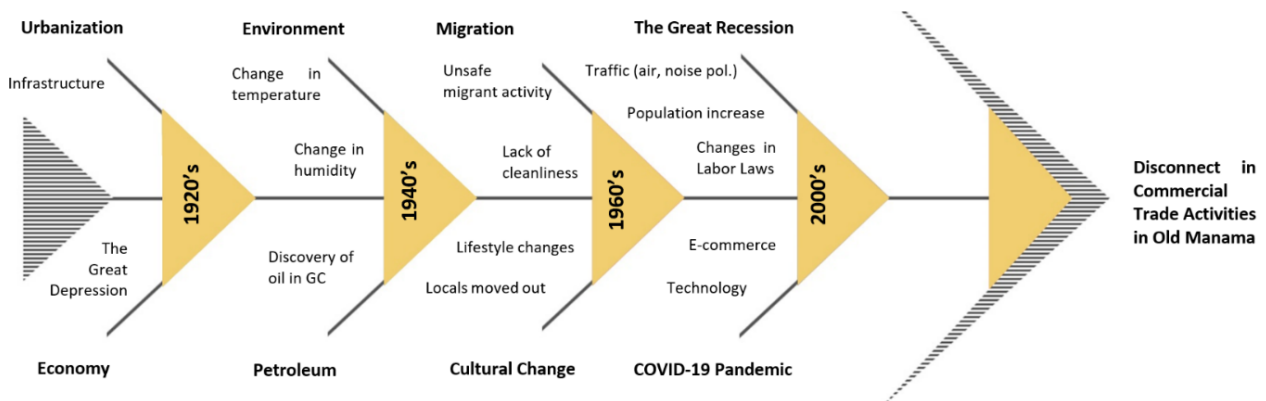


Figure 6. Fishbone diagram outlining categories and causes that contribute to the observed disconnect in social trading activities in Old Manama.

4.2 Questionnaire: Assessing the Perception of Commercial Activities in Old Manama

Among the participants, 63% identified as female, 18% as male and 19% as unknown (Figure 7). A total of 28% of the participants were ex-residents of Old Manama, 2% were current residents, 24% were visitors, 25% were descendants of ex-residents of Old Manama and 21% were none of these or did not select anything. Out of the entire sample, 29% had resided in Old Manama for more than ten years. The majority of the sample (34%) reported that they visit Old Manama once to twice a month. The types of visits differed among the sample, but the most popular choice was shopping for gold and jewellery. Attending cultural events was the least preferred choice.

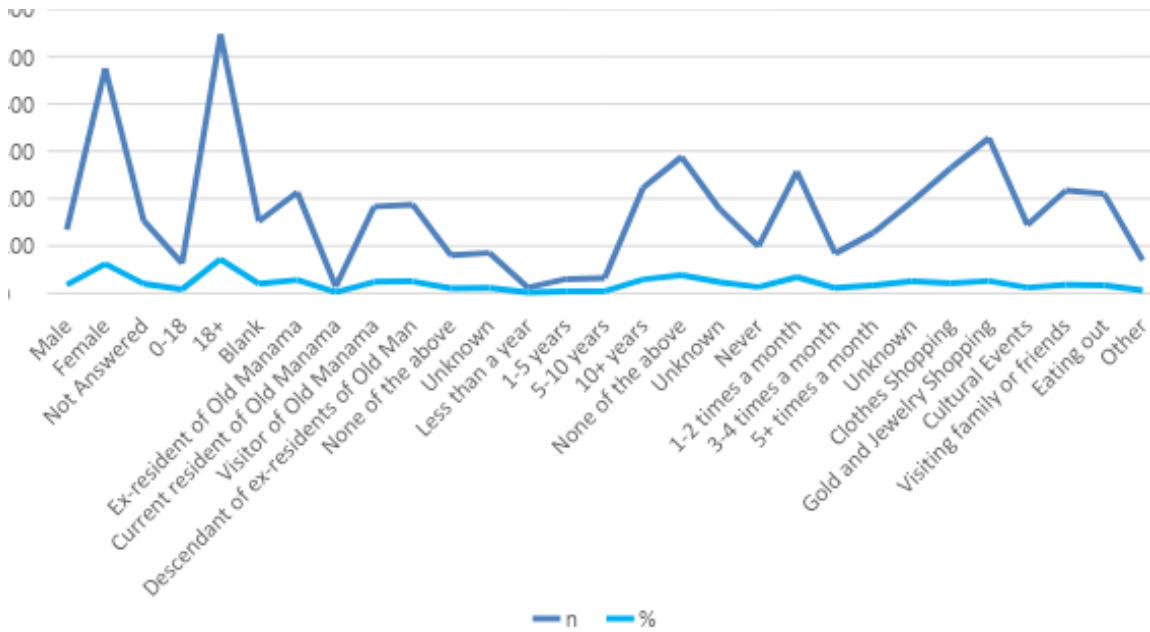


Figure 7. Visual representation of demographics.

Participants who selected the “other” option shared a wide array of reasons for visiting Manama. These included activities such as leisurely strolls, commuting to work in the town centre, people-watching, attending religious events (particularly during the month of Muharram), savouring local cuisine like Bahraini chickpeas and *mattay*, purchasing sewing supplies and having suits tailored. Interestingly, former residents of Old Manama mentioned more personal motivations, such as strolling through the alleyways to reminisce about their past experiences in Old Manama, visiting their childhood homes, attending funerals and paying respects at the graves of their family members. This exemplifies the strong bond that they have with Manama, evident in their consistent return to the area, while their extensive knowledge of the locality makes them valuable sources of insight, and thus it is worthwhile learning from them (Bobbio, 2018).

The perception of Old Manama was assessed through various questions in the questionnaire. A significant majority of participants (73%) concurred that Old Manama offers a diverse range of cafes and restaurants, while an even larger majority (79%) believed that the area provides everything that they seek in terms of shopping. Participants who indicated that they could not find all the items that they needed specifically mentioned certain products, such as branded clothing, fashionable modern clothing items, furniture, perfumes and make-up. The majority (75%) agreed that the area is family-friendly, and 83% felt safe during their visit to Old Manama. Participants who chose “not feeling safe” as their reason mentioned that this was primarily due to the increasing presence of unmarried Asian migrant workers who have recently relocated to the area. Additionally, there is a general concern about the lack of cleanliness, poorly lit streets at night and the potential for alcohol-related incidents where the workers do not adhere to the area’s policies. These factors have an impact on local commerce, as the public, feeling unsafe, may choose alternative shopping destinations such as malls instead. Furthermore, this finding emphasizes the necessity of implementing security measures to enhance the sense of safety among the public.

An overwhelming majority (98%) of the study participants expressed the view that infrastructure enhancements are crucial for the revitalization of Old Manama. The participants also expressed their opinions regarding the challenges of commercial activities in Old Manama: 38% believed that challenges in trading activities are due to the lack of infrastructure development, 25% believed that they are due to the decline in historical and cultural assets, 21% said that they were due to limited



business opportunities, and 11% selected the lack of community involvement. A small portion (5%) of respondents who selected “other” provided a range of reasons for their choice. These included concerns about the lack of maintenance of existing facilities, the migration of the local community being replaced by external subcommunities, traffic congestion, limited investment, insufficient parking, the exclusion of local residents from event planning, inadequate circulation and unfavourable climatic conditions. They also mentioned the increased competition with the availability of more convenient shopping destinations, the government’s negligence in promoting it as a tourist attraction compared to other old areas in Bahrain, and inadequate restroom facilities. Following the examination of the public’s perception of commercial activities in Old Manama, the final section of the questionnaire focused on soliciting suggestions from the public regarding potential measures to revive trade in the area. To encourage more family visits, 28% of the participants suggested increasing the availability of restroom amenities, 46% suggested providing outdoor and children’s play areas and 16% suggested offering baby changing facilities. Among the “other” (10%) responses, the majority suggested the need for additional parking facilities suitable for families. Some also emphasized the importance of wider pedestrian roads that are stroller-friendly, the provision of shaded areas to combat the summer heat and the inclusion of more public furniture to provide resting spots for visitors.

When asked what suggestions could attract more visitors to Old Manama, 29% proposed additional parking spaces, and the remainder of the answers were equally divided between the restoration of old buildings, the development of recreational spaces and providing landscaped rest areas with seating. Additional recommendations encompassed the implementation of various measures to enhance the restorative ambiance of the area, such as augmenting greenery through increased tree planting, ensuring regular street cleaning, providing additional waste bins and establishing air-conditioned spaces. Notably, a significant proportion (32%) of surveyed individuals underscored the pivotal role of tourism and hospitality in revitalizing trade within Old Manama. This was closely followed by the recognition of the potential of food and beverage establishments, art and cultural venues, and retail and souvenir shops. Some participants proposed the conversion of old houses into boutique hotels as an attractive proposition for tourists. Furthermore, promoting traditional handicraft workshops and activities that embody ancestral heritage emerged as a means with which to infuse authenticity into the area. Suggestions also included organizing traditional music events, comedy nights, photography tours, religious and national tours, and local culinary tours. Moreover, a considerable number of participants expressed the opinion that local businesses could benefit from marketing assistance and tax exemptions. Finally, the questionnaire emphasizes that the local community plays a vital role in the revival of trade in Old Manama by supporting local businesses, participating in cultural events and promoting Old Manama through social media and word of mouth.

4.3 Photographic Analysis: Identifying Architectural Elements Influencing Trade

The traditional marketplace in old Manama is a cultural hub, dating back to the 1920s. The traditional buildings previously incorporated sustainable practices with minimal impact on the environment (Figure 8).

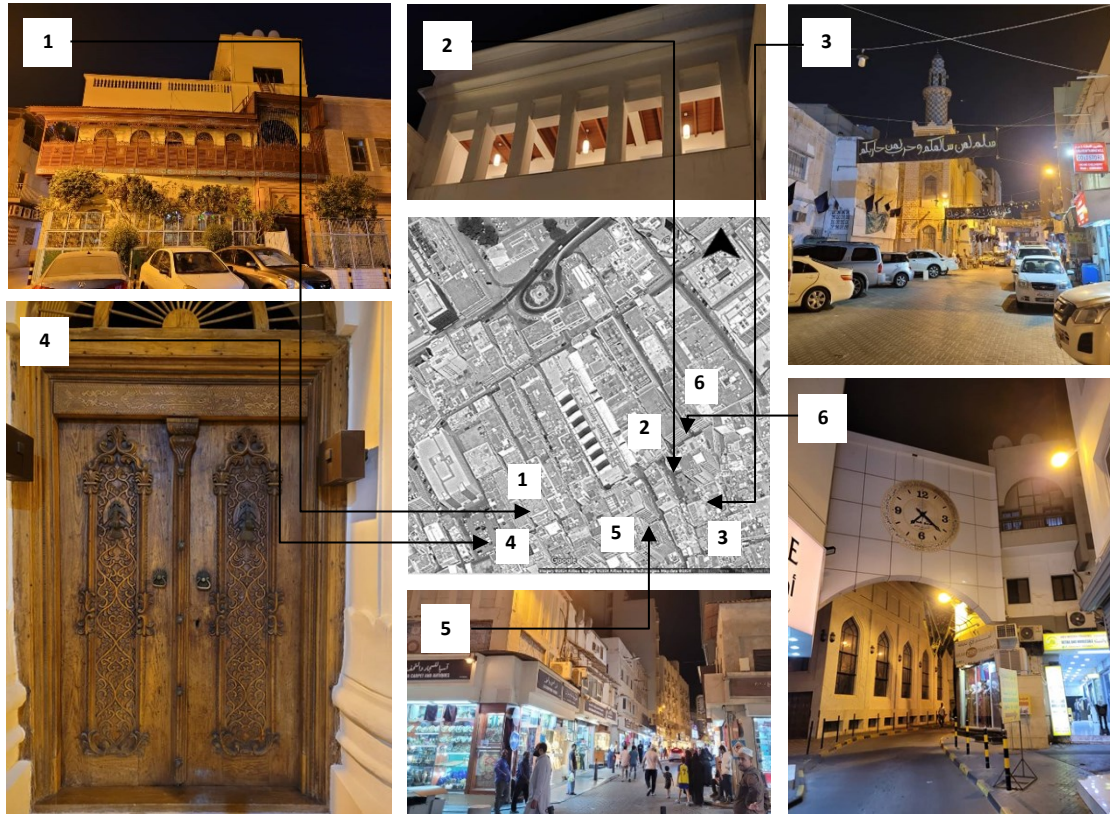


Figure 8. Photographs highlighting the narrow streets of old Manama.

They were built to reduce heat gain and maximize thermal comfort. Clay, palm leaves, limestone and timber were locally sourced for the construction of the geometrically dense buildings. Various elements, such as arches, projected mashrabiya and wooden craftsmanship, were integrated into the buildings. The narrow alleyways connected neighbourhoods where people used to trade (Figure 8). The public halls were designed to be flexible to house religious and social events.

In contrast, meticulous photographic documentation was conducted to capture the architectural elements at Souq Al Baraha, encompassing diverse spatial areas (Figure 9). The project recreates the traditional layout of a souq by arranging its building structures around courtyards. Designed in a contemporary manner, the souq blends traditional and modern elements. The project aims to enhance connectivity by linking districts through a central gathering space. Organic streets are designed to resemble old Bahraini neighbourhoods.

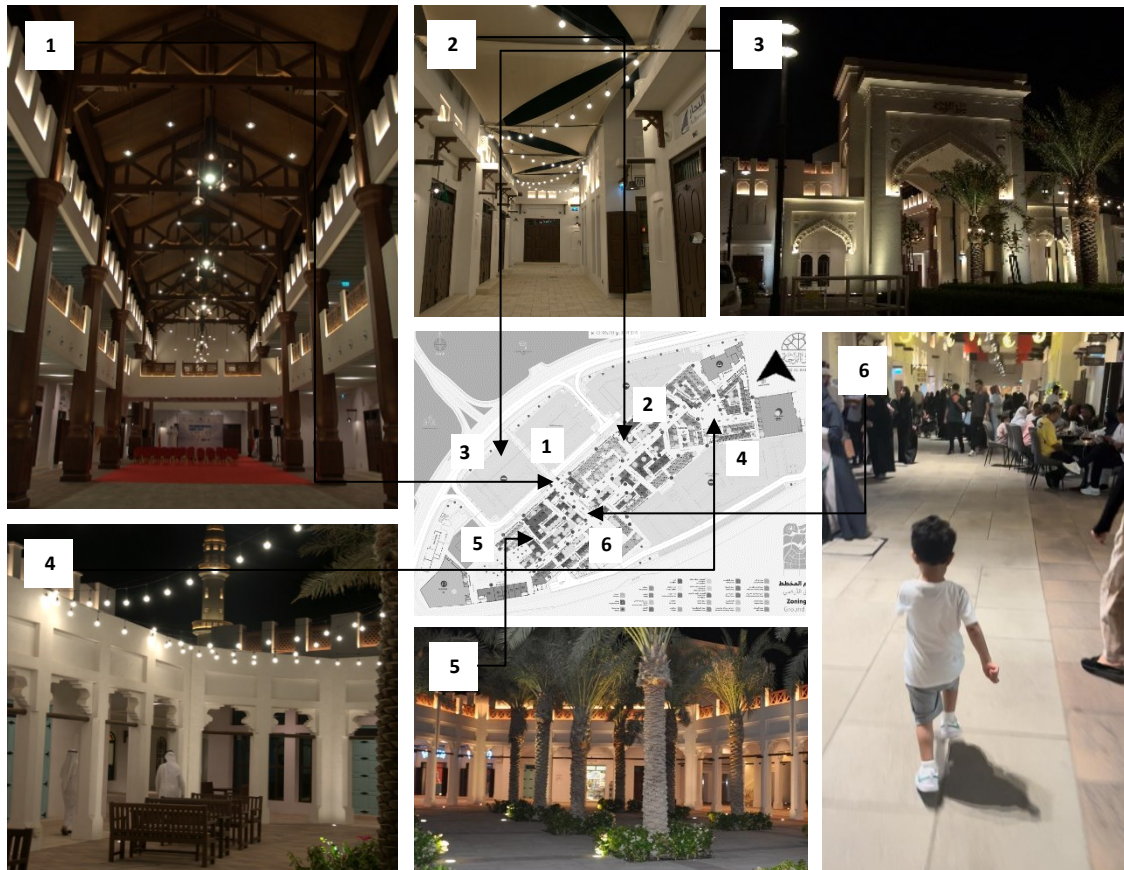


Figure 9. Photographs of traditional architectural elements at Souq Al Baraha.

The photographic analysis adeptly portrayed the visual architectural elements present within each space, revealing the unique characteristics and distinct conditions of five key areas. These areas encompass the entrance foyer, circulation area, retail shops, courtyards, and food and beverage (F&B) establishments. Figure 9 showcases a collection of these photographs, offering a visual depiction of the distinct spatial environments and their architectural nuances.

The entrance foyer is a grand double-height space, while the circulation areas and retail shops are more intimate and controlled. Additionally, the courtyards are large open spaces with vegetation and promenades of columns. The F&B shops are located adjacently, with traditional artistic openings and elements. Several outdoor courtyards are strategically placed to invite children to play in a safe environment. The integration of street furniture fosters a platform for social activities. Arches such as those found in old Bahraini houses are integrated within the façade and different wall openings. Shaded corridors and arcades also direct the visitors between different zones.

Palm trees and street furniture provide shaded rest areas. The use of natural colours and raw textures creates a unique tactile experience as users pass by, representing natural elements such as the sand and limestone. The overall design retains a distinct Bahraini essence and identity, fostering a strong sense of belonging, despite the use of contemporary materials. The sizes of the shop units range from 4 m² to 1,445 m² to accommodate a diversity of spaces to represent the old souq. The integration of cultural elements at Souq Al Baraha promotes interactions, creates a sense of belonging and improves sustainable behavioural change.

5. Discussion

The photographic analyses of both Old Manama and Souq Al Baraha emphasize the importance of outdoor spaces, diverse typologies of space, organic circulation and intimate spaces in enhancing commercial activities. These findings are in line with Lazar and Chithra’s (2022) findings of elements that emphasize culture. The results highlight how the commercial streets integrating elements of culture have a strong positive impact on commercial activities. Table 3 highlights the impacts of architectural elements on commercial activities in Souq Al Manama and Souq Al Baraha. Materiality and façade treatment displayed no impact on the commercial activities.

Table 3: The impact of architectural elements on commercial activities.

Architectural Elements	Traditional (Souq Al Manama)	Contemporary (Souq Al Baraha)	Impact on Trade Activities
Materiality	Mud; wood; palm fronds	Partial – aesthetic but not fully local	No impact
Traditional architectural elements	Arches; mashrabiyyas; balconies	projected Arches; repetition; placemaking	Minimal impact
Spatial layout	Narrow; organic circulation; geometrical volumes; furniture layout	Organic diverse spaces; circulation; architectural	Significant impact
Façade treatment	Light colours; minimal glazing	Light colours; repetition; openings	No impact
Interior design	Traditional elements; intimate, small spaces	Intimate, small spaces; minimal seating	Significant impact
Landscape	Communal; courtyards; local vegetation; indoor–outdoor spaces	Courtyards; local vegetation	Significant impact
Adaptable design	Flexible, from private and intimate to public; diverse typologies	Flexible outdoor furniture; multi-purpose courtyards	Significant impact
Interaction spaces	Courtyards; furniture layout	Courtyards; indoor/outdoor shops	Significant impact

The questionnaire gathered insights from residents of and visitors to Old Manama to assess their perception of commercial activities. People’s participation in design is very important, as seen in the existing literature, and it remains a challenge for architects to facilitate it. The engagement of individuals is driven by their interests, sense of empowerment and desire for transformative change (Zhang & Zurlo, 2020). Another study highlighted people’s participation as one of five criteria with which to transform commercial streets. The study emphasized the importance of understanding the opinions of users and shop owners in the revival process (Mehanna & Mehanna, 2019). These characteristics resonate strongly with the people of Manama, who are eager to bring about meaningful transformations in their community. The study’s findings illuminate the concerns voiced by both residents and visitors in Manama, predominantly stemming from the rapid urbanization and the diminishing social activities associated with trade. The original people of Manama, descendants of ex-residents of Manama and residents of Bahrain in general feel closely connected to Manama, as it represents the old origin of the country. Due to their strong emotional connection, they possess a deep passion for revitalizing the area. Hence, actively involving both visitors and residents of Old Manama, to acknowledge their issues and consider their suggested strategies, is essential for reviving the locality. Additionally, the study participants experienced a sense of empowerment with the opportunity to voice their perspectives on the ongoing developments within their community. This active engagement instilled a sense of hope among the participants, as they acknowledged that their input was being thoroughly examined and that their valuable contributions had the potential to bring about positive transformations.

Based on the findings from the “fishbone diagram”, questionnaire and photographic analysis of Old Manama and Souq Al Baraha, Figure 10 illustrates a wide range of recommendations to breathe new life into the area, categorizing them into three primary groups: minor adjustments, structural modifications and public support.

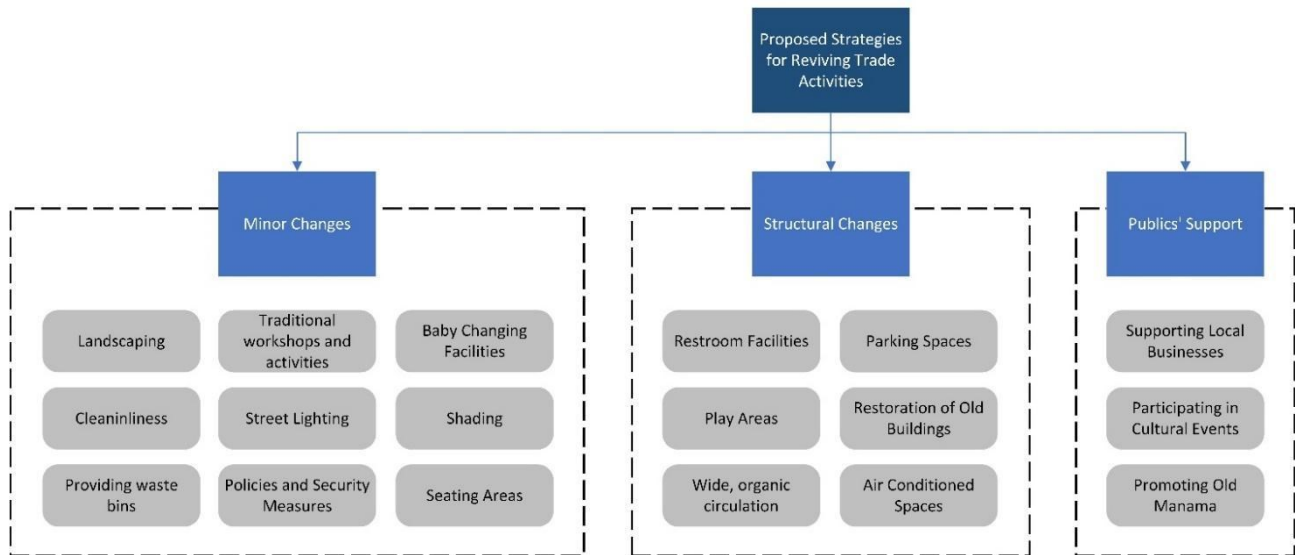


Figure 10. Summary of proposed strategies, highlighting minor adjustments, structural modifications and public support as the three main categories for reviving commercial activities in Old Manama.

The minor solutions require less time to integrate and encompass the combination of softscape elements, which include more landscaped areas and planting shrubs and trees, and the provision of hardscape elements, such as public furniture for relaxation, the creation of shaded spaces and improvements in street lighting. Additionally, there should be more clarity regarding the implementation of stricter policies regarding alcohol consumption and hygiene, the integration of enhanced security measures and the introduction of traditional tours and workshops that celebrate the local culture. On the other hand, structural solutions involve implementing long-term changes to the area’s infrastructure, such as expanding parking facilities, widening pathways and restoring old buildings. Support from the public includes backing local businesses, engaging in cultural gatherings and advocating for Old Manama using social media and personal recommendations. The insights derived from this data are of significant importance to both the planning authorities and BACA, and can act as a starting point from which to rejuvenate the area. BACA is continuously working on developing historic areas in Bahrain and could include the recommendations in the rejuvenation scheme for Old Manama. The planning authorities could also consider the findings and recommendations in future urban policy changes. The authors acknowledge that contextual factors such as cultural shifts or economic changes over time may influence the findings, as these dynamic elements can significantly impact commercial activities and experiences within trading environments.

6. Conclusion

This study explored the dynamics of traditional and contemporary trading environments in Bahrain. It successfully addressed the three objectives, namely outlining the social impacts of urbanization on trade, assessing the perceptions of the public regarding commercial activities in traditional trading environments (Old Manama), and identifying important architectural elements that influence trade in both traditional and contemporary trading environments. The findings highlight infrastructure, social and cultural diversity, overcrowding and economic opportunities as the most significant social impacts resulting from urbanization that have an effect on trade. The questionnaire results stressed the



importance of people's participation in design and the close relationship that the people of Bahrain have with Old Manama.

This study contributes to the academic field by providing in-depth insights for stakeholders and experts into the impact of urban design and architecture in enhancing commercial activities in trading environments. The findings highlight the significance of spatial layout, interior design, landscaping, adaptable design, interaction spaces, diversity of building typologies and circulation, all of which should be prioritized in the design of commercial streets. The findings of the study aid in proposing recommendations for changes to revive trade, and offer valuable insights for stakeholders and experts to inform and guide the development of urban design policies and the design of successful commercial streets.

The study is constrained by using two specific case studies in Bahrain. While the in-depth analysis allows for a comprehensive understanding, the research team is aware of the higher risk of bias associated with the two locations, which may influence the results. Future research could include additional commercial streets in other traditional and contemporary areas in Muharraq. The questionnaire administered as part of this research focused mainly on perceptions of Old Manama; therefore, further research could also address the perceptions of commercial activities in contemporary souqs and developments, such as Souq Al Baraha, Al Liwan and Sa'ada seafront. In addition, shop owners in traditional and contemporary souqs, as well as those with experience in both environments, could be interviewed to understand commercial activities from their perspective and add further insight, as this study only focused on the perceptions of visitors. Future research could also adopt further statistical analysis techniques, such as an ANOVA analysis to compare the means of perceptions between different groups of participants or a multiple regression analysis to determine the extent to which different independent variables predict the perceptions of commercial activities. The findings from this study are vital to reignite trading activities from the past within the Kingdom of Bahrain, through minor changes, structural changes and the public's support.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

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

CRedit Author Statement:

Conceptualization, N.S.A. and I.H.E.; methodology, N.S.A. and I.H.E.; software, N.S.A. and I.H.E.; validation, N.S.A. and I.H.E.; formal analysis, N.S.A. and I.H.E.; investigation, N.S.A. and I.H.E.; resources, N.S.A. and I.H.E.; data curation, N.S.A. and I.H.E.; writing – original draft preparation, N.S.A. and I.H.E.; writing – review and editing, N.S.A. and I.H.E.; visualization, N.S.A. and I.H.E.;



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Original scientific paper

The Relationship Between Sense of Place and Nature-Based Architectural Beauty: A Comparative Case Study

*¹ Sana Al-azzawi , ² Prof. Dr. Göksenin İnalhan , ³ Nada Al-azzawi

¹ & ² Department of Architectural Design, Faculty of Architecture, Istanbul Technical University, Turkey

³ Department of Computer Engineering, Faculty of Electric-Electronic Engineering, Istanbul Technical University, Turkey

¹ E-mail: al-azzawis16@itu.edu.tr, ² E-mail: inalhang@itu.edu.tr, ³ E-mail: al-azzawi16@itu.edu.tr

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ABSTRACT



Biophilic design, which integrates nature into the built environment, has shown positive impacts on human well-being. However, the benefits of indirect experiences of nature remain less explored, particularly in relation to the sense of place (SoP). This study investigates the relationship between nature-based architectural beauty and SoP through a comparative case study of two educational buildings with different aesthetic qualities: one classical and naturalistic, the other modernist and mechanistic. Using a quasi-experimental design, the study employs a survey-based quantitative analysis, measuring 1) SoP among users, 2) perceptions of naturalness through image-based judgments, and 3) objective measures of naturalistic beauty using image analysis. Findings indicate that users of the naturalistic building report a significantly higher sense of place, supported by perceptions of naturalness and objective measures. This suggests that environments embodying naturalistic beauty foster positive connections and place attachment. The study contributes to architectural and urban design strategies by highlighting the socio-economic benefits of nature-inspired aesthetics. By enhancing emotional and psychological well-being, such designs can lead to increased productivity, reduced stress, and stronger community ties, ultimately contributing to socio-economic development through improved quality of life and sustainable urban planning.

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Highlights:

- Biophilic design principles, when applied to architectural aesthetics, can lead to improved well-being and socio-economic benefits.
- Architectural environments with naturalistic properties can be objectively measured and subjectively perceived to assess their aesthetic and psychological impact.
- Naturalistic buildings foster a higher sense of place by enhancing place identity, attachment, and dependence.
- The study employs a novel combination of survey-based data with low-level image analysis to evaluate naturalistic qualities in architecture.

Contribution to the field statement:

This study enriches place theories by demonstrating the critical role of naturalistic visual properties in fostering a sense of place, and advances biophilic design by empirically validating the psychological impact of indirect nature interpretations. By linking architectural beauty with place attachment, the research offers novel insights into design strategies that enhance well-being and socio-economic development.

***Sana Al-azzawi:**

Department of Architectural Design, Faculty of Architecture, Istanbul Technical University, Turkey

Email address: al-azzawis16@itu.edu.tr

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1. Introduction

In recent years, there has been an increasing focus on integrating the built environment with nature, spurring the development of the biophilic design movement. Biophilia, a term coined by Wilson (1986), describes an inherent human tendency to seek connections with nature and the living world. The biophilic design movement aims to enhance this connection by emphasizing design strategies that promote human emotional and physical well-being (Almusaed, 2010; Kellert, 1993; Kellert et al., 2011). Although the core objectives of biophilic design are clear and intuitive, the concept encompasses a broad range of interpretations and methodologies related to how 'nature' is understood and experienced in the built environment. Ryan et al. (2014) categorizes biophilic patterns into three groups: (1) 'nature in space,' which focuses on incorporating visual and climatic elements of nature; (2) 'nature of space,' which involves spatial properties such as refuge, prospect, mystery, and peril; and (3) 'natural analogues,' which include biomorphic forms, materiality, and the complexity and order of natural patterns.

Similarly, Kellert (2018) identifies three categories of nature experiences: (1) direct experiences, which involve physical contact with natural elements like vegetation, water, and climatic conditions; (2) indirect experiences, where the built environment simulates natural elements through imagery, materials, and geometries; and (3) spatial experiences, focusing on organizational aspects of space that evoke natural qualities, such as prospect, refuge, and integrated complexity.

Recent developments in the biophilic design literature, particularly around natural analogues and space/place experiences, have extended the theory by incorporating elements of form and spatial design, which are central to the architectural and urban disciplines. This newer interpretation frames nature as a dynamic process that generates harmonious, integrated structures through geometric transformation and place-making.

Evidence suggests that implementing biophilic design principles can significantly enhance human well-being (Gillis & Gatersleben, 2015; Hung & Chang, 2021; Soderlund & Newman, 2015; Zhong et al., 2022). Research has shown that direct experiences of nature in built environments positively influence various health outcomes, including improved workplace conditions (Nieuwenhuis et al., 2014), enhanced attention and memory (Lee et al., 2015; Berman et al., 2012), faster stress recovery (Ratcliffe et al., 2013), and increased physical activity and healing (Sari et al., 2023).

Indirect nature experiences, such as simulated natural environments and nature imagery, have also been linked to psychological benefits. For example, exposure to simulated office settings with natural views has been associated with reduced anxiety (Chang & Chen, 2005), while viewing natural scenes accelerates recovery from acute stress compared to urban scenes (Brown et al., 2013). Additionally, interior environments featuring fractal light patterns are shown to enhance visual preference and mood (Abboushi et al., 2019). Spatial configurations that resemble natural environments, like prospect-refuge spaces and organic visual patterns, are also found to support psychological restoration and preference (Akcelik et al., 2024; Coburn et al., 2019; Herzog & Bryce, 2007).

While aspects of space, place, and natural analogues have been extensively explored in aesthetic and landscape studies (Kaplan & Kaplan, 1989; Kuper, 2017; Liu et al., 2021; Ode et al., 2009), their connections to psychosocial theories of place are still inadequately defined (Zhong et al., 2022). The concept of 'place experience' is a central theme in theories of sense of place (SoP) or place attachment, which focus on the meanings, emotions, and behaviors that shape human interactions with their environment (Altman & Low, 1992; Lewicka, 2011a; Manzo & Devine-Wright, 2013). According to Lewicka (2011), research on SoP has predominantly highlighted social factors over physical ones, even though natural elements are frequently cited as key contributors to place attachment (Han et al., 2023; Ojalampi & Koskinen-Koivisto, 2023). The impact of the natural complexity, spatial configuration, and geometry of the physical environment on SoP, however, remains underexplored.

Addressing this gap can help evolve biophilic design from a superficial application of natural features to a more profound interpretation of nature as a dynamic, generative process that creates organic qualities with significant psychological impacts (Figure 1). This study seeks to establish a link between

biophilia and place theory by exploring whether the modeled naturalness of built environments influences our sense of place.

Definitions of Natural (Biophilic) Architecture

			
	Explicit nature	Nature as image	Nature as process
Definitions of nature	Nature as an addition to the built environment	Nature as formalistic inspiration	Nature as a generative process (order and complexity)
Experience of nature	Direct experience of nature	Indirect experience of nature	Indirect experience of nature
Design strategies	Vegetation, natural lighting, Water, landscape Natural building materials	Use of organic shapes and forms, imitation of natural imagery	Form evolution, adaptation, naturalistic geometric properties
Examples	Changi Airport, Singapore	Lotus Temple, Delhi	Alhambra Palace, Granada

Figure 1. The different approaches and interpretations of biophilic design (Developed by the Authors).

1.2 Naturalness and Living Structures

The built environment can be naturalized by modelling generative processes typically found in nature and characteristic of timeless architecture and city planning. Architect and mathematician Christopher Alexander proposed a theory describing how this process creates ‘living’ or nature-like structures. In the “*Nature of Order*” (2002), he argued that we experience buildings and cities as ‘living’ due to a pervasive structure of interrelated parts forming integrated wholes. Here, ‘life’ is defined through complex orders rather than the typical biological sense. This deep structure endows any region of space with coherence, order, and beauty. *Living structures* in nature and the built environment are hypothesized to be the underlying forces inseparable from our experience of beauty, sense of well-being, relatedness, and belonging. (Alexander, 2002).

Alexander identified 15 *geometric properties* of living structures found in almost all natural and biological systems, as well as in timeless works of art and architecture. These properties outline how parts of a whole are organized to support each other, resulting in higher degrees of life, coherence, beauty, and naturalness. For example, the most fundamental property pertains to the organization of structures in proportionally related and organized *levels of scale*, favouring *local symmetries* over general symmetry and creating *contrast* between sub-structures through colour, shape, and other characteristics. These properties emerge from a generative process of step-by-step adaptation to the existing structure, where each step follows naturally from the previous one.

Such generative processes are evident in nature, from the growth of embryos to the crack patterns that form on dry land. When applied to architectural and urban design, they reflect an organic worldview that emphasizes orders of connecting and interdependent relationships, as opposed to the assembly of objects in space, which characterizes the mechanistic design approach of the modernist era.

Subsequent attempts have been made to quantify the concept of living structures. For example, Nikos Salingaros developed a method of quantification based on an analogy to thermodynamics (Salingaros, 1997). The latest mathematical model of living structures was introduced by Bin Jiang, which relies on two fundamental laws: *the scaling law*, which states that a living structure has far more small components than large ones across all scales, and *Tobler’s law*, which posits that everything is related to everything else, but near things are more related than distant things (Jiang, 2015). Structural beauty or ‘livingness’ is determined by the number of substructures and the hierarchy of these substructures



based on the head-tail/breaks, a method of iterative division according to their scale. Degree of life is formally defined by the formula $L = S \times H$, where S is the number of substructures, and H is the number of hierarchical levels of these substructures calculated by the head/tail breaks. This method was tested on architectural and city plans with units of analysis similar to the space syntax method, such as convex spaces and axial lines. It was also applied to pixels in image-processing algorithms (Jiang & de Rijke, 2023).

Another study by Coburn et al., (2019) experimented with low-level image features as proxy measures for two of the 15 fundamental properties: *Levels of scale* and *contrast*. The *Levels of scale* property is operationalized by 1) *edge density*, measuring the number of straight and curved edges in an image; 2) *fractal dimensions* capturing the visual complexity and scaling differentiation of the edge maps of architectural images; and 3) *entropy*, a statistical measure of randomness in a scene, calculated using the scene's intensity histogram. The *contrast* property is operationalized by calculating an image's standard hue, saturation, and brightness values along with their standard deviations. In their experimental work, low-level features calculated for a sample of exterior and interior architectural images significantly predicted participants' perception of naturalness and other psychological outcomes, such as comfort, which have implications for well-being studies.

The nature of order includes several hypotheses that have not been empirically tested. Measurement methods such as those described can facilitate this testing. The ongoing research focuses on the relationship between living structures and human experiences within a given place. According to *the nature of order*, environments that exhibit the properties of living structures contribute to experiences of beauty, support human life and well-being, provide emotional nourishment, and foster a sense of belonging.

1.3 Sense of Place

Seamon (2019) argued that the properties of living structures must be inherently related to the experience of place. Alexander's description of experiencing life and wholeness in architecture resonates with the concept of SoP, particularly in its phenomenological and philosophical formulations. In recent decades, there has been increased interest in place research across social sciences, psychology, environmental design, and geography. At its core, place is understood to be more than just physical space because of its meaningfulness to the individual and groups (Tuan, 1979). Edward Relph (1976), the pioneering humanistic geographer famously stated, "*Places are sensed in a chiaroscuro of setting, landscape, ritual, routine, other people, personal experience, care and concern for home and the context of other places.*" The meanings attributed to certain places tend to be multi-layered, complex, and depending on various factors. According to the phenomenological and psychological perspective, (Canter, 1997; Relph, 1976) SoP constitutes the following dimensions: 1) The physical characteristics of the environment, 2) The meanings and emotions attached to the place, and 3) The activities the place provides.

Due to the complexity of place processes and the multidisciplinary nature of the theory, place literature encompasses numerous concepts. One key term in environmental psychology is *place attachment*, which describes affective bonds to places. Place attachment is often defined through two concepts: *place dependence* and *place identity*. *Place identity*, a component of the self-system, refers to how individuals view themselves in relation to their environment (Proshansky, 1978). *Place dependence* relates to actions in place and refers to the degree of fit between what an environment offers in terms of usability and an individual's intended uses and competencies (Stokols & Shumaker, 1982).

Jorgensen and Stedman (2001) proposed an attitude-based interpretation of SoP, incorporating cognitive, affective, and conative (behavioural) components. They validated the measurement with data from a questionnaire survey of over 200 rural homeowners. The attitudinal components of the sense of place are defined as follows: 1) beliefs about the relationship between self and place (the cognitive component), 2) feelings towards the place (the affective component), and 3) the behavioural exclusivity of the place compared to alternatives (the conative component). This formulation serves as

the basis of the most widely used psychometric measures of SoP (Boley et al., 2021; Jorgensen & Stedman, 2001; Williams & Vaske, 2003).

SoP is defined through people, place, and process (Scannell & Gifford, 2010). It varies depending on factors related to the place itself (its physical characteristics, such as scale, land use, and building density) or factors related to the individual (such as duration of stay, ethnicity, age, economic status, and value system). Due to the social constructivist nature of the concept, social and personal factors have been more prominent in place studies (Lewicka, 2011). However, ecological psychology has emphasized the importance of considering both physical and social factors in place of attachment studies. Recent research has attempted to link restorative environments with SoP, finding that nature and aesthetic appeal positively predict attachment and identity (Ariannia et al., 2024; G. Brown & Raymond, 2007; Hur et al., 2010; Jayakody et al., 2024; Li et al., 2023; Olla et al., 2023). SoP is also linked to pro-environmental behaviour and influences perceptions of human/nature relationships (Feng et al., 2022; Schroeder, 2007). Most studies focus on the perception of physical environmental quality and values, often lacking a theoretical basis from design theories that apply objectively measurable variables.

Advances in biophilic design theories with reference to complexity science, objective beauty, and living structures open new avenues for addressing this knowledge gap. By investigating the attractive power of living structures and sustaining emotional engagement through repeated interaction, we can better understand the connection between biophilic patterns and SoP. Naturalistic environments, both in their explicit nature content and underlying order, can attract people based on their biological inclinations and aesthetic drives. Experiencing these places can support environmental awareness and conceptualization of identity through the lens of human/nature relationships (Schroeder, 2007). Additionally, naturalistic patterns offer affordances, such as mystery, which encourages exploration of the environment (Figure 2).

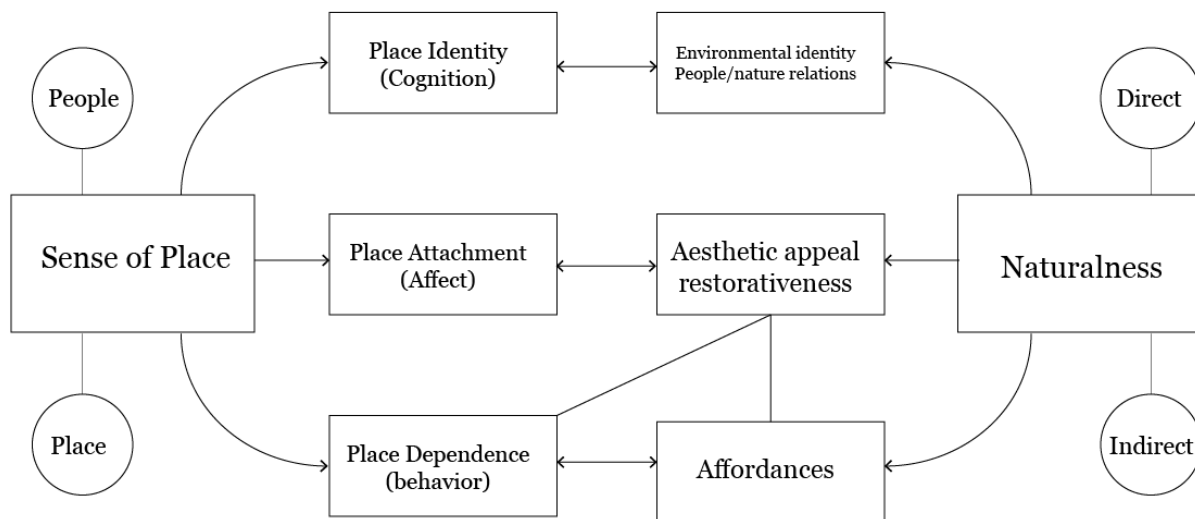


Figure 2. The different approaches and interpretations of biophilic design (Developed by the Authors).

Within this broader framework, this study explores one aspect of the relationship between naturalness and SoP by focusing on the properties of living structures and their impact on perceived naturalness and SoP. The findings could have significant implications for biophilic design, demonstrating how to reconnect people with nature beyond traditional greening schemes. They also encourage a reevaluation of the fundamental spatial and morphological aspects that are critical to design disciplines.

2. Materials and Methods

A pilot study was designed to explore the research question using existing measures and manageable settings within this more prominent research topic. The study aims to test the hypothesis that occupants of buildings with higher degrees of modelled naturalness experience higher levels of SoP than those in less naturalistic buildings.

A comparative quasi-experimental case methodology was utilized to test this hypothesis by comparing two settings. Variables of the physical environment and user responses regarding SoP were analyzed and compared. Although the researcher could not manipulate the variables, potential influences on the outcome were neutralized by selecting cases with similar features. The study focused on two buildings with a hypothesized difference in degree of life (naturalness) as the basis of comparison. The objective was to compare the occupants' judgments of livingness and SoP using simple descriptive and t-test statistical analyses. Figure 3 outlines the methodological procedure.

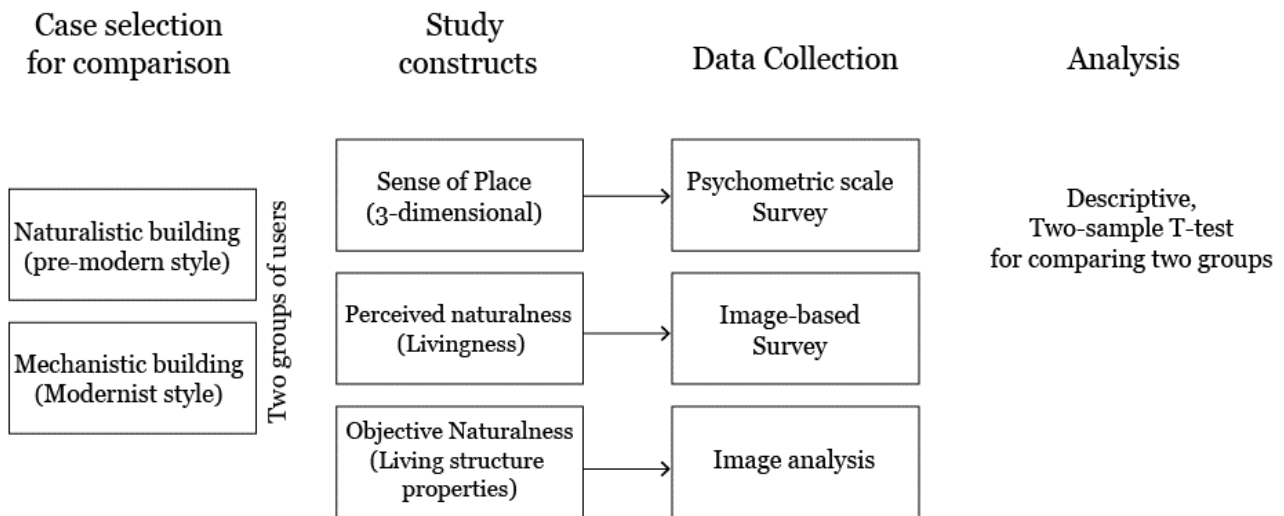


Figure 3. Research methodology and procedure (Developed by the Authors).

The selection criteria were developed to neutralize, as much as possible, the effect of common physical, social, and personal factors that can influence SoP. The criteria considered were:

- The two buildings must be similar in function and size.
- Users of the two buildings must have similar demographic backgrounds, such as age groups and occupations.
- The two buildings must have noticeable differences in their aesthetic character. One is expected to have naturalistic qualities, and the other is mechanistic.

The selected cases were two faculty buildings at Istanbul Technical University in Türkiye; the first building houses the Faculty of Architecture and is known as the *Taşkışla* building, located on a remote campus. The second building is the Electric-Electronic (EE) Engineering faculty on the main campus. Both buildings are similar in size, facilities, number of students, and typology; each features rectangular forms and internal courtyards. However, they are distinct in their form, language, and aesthetics, which form the basis of comparison.

Taşkışla is a restored and adapted neo-classical building, originally a military hospital and later a military barracks, constructed in the early 1850s. Its outstanding stylistic features include a detailed classical masonry façade, wide and spacious corridors, and hallways overlooking a central courtyard with a garden and fountain (Figure 4). An online search shows that the building is a cherished monument and historical architectural landmark in Istanbul, with many students sharing photographs of it on social media, especially its courtyard. The building has been used as a film location in many local productions.

In contrast, the EE building, built in the 1980s, is characterized by a mechanistic and utilitarian style, with a more recent addition featuring different materials and facade details while maintaining the

overall structure (Figure 4). Classically designed buildings are more likely to have higher naturalistic quality. Based on this and the general response to the buildings, it was hypothesized that the Taşkışla building has a higher degree of life and that its students experience a higher SoP than students in the EE building.



Figure 4. The two faculty buildings that were used for the comparative method.

The variables in the study are SoP and naturalness (degree of life). These constructs are operationalized through three types of measurements as follows:

1) **Measurements of sense of place for the two groups of building users:** A highly reliable and widely used 5-point Likert-type instrument developed by Jorgensen and Stedman (2001) was used to measure SoP. This attitude-based construct includes three dimensions: *place identity*, referring to the role of places in the process of self-identity; *place attachment*, which revolves around the emotional bonds that people have towards significant places; and *place dependence*, or the ability of places to support the needs and activities of their occupants.

2) **Measurements of the users' subjective judgement of degrees of life:** Using image pairs, the degree of life test, originally developed by Alexander (2002), was employed to test perceived livingness as an approximation of perceived naturalness.

3) **Objective measurements of naturalness or 'life' of the building:** Image analysis of interior and exterior images of the two buildings was conducted using two methods outlined in the literature review. The first method involves measuring low-level image features, which have been shown to correlate with perceptions of an image's naturalness and predict aesthetic preference (Coburn et al., 2019). The second method is a recursive calculation of an image's structural beauty according to the scaling law. (Jiang & de Rijke, 2023).



Data collection began by photographing the two buildings to create a pool of image pairs showing equivalent features and spaces for image analysis and the degree-of-life test. All photos were taken during the day using an iPhone 13 camera. The images were generally taken at eye level, with a few exceptions where the camera was tilted to show distant façade details. None of the images included people to avoid influencing subjective judgement and image analysis calculations. Additionally, natural features such as trees and the sky were kept roughly similar in area across comparable image pairs. Next, a set of 30 image pairs was decided and analyzed using open-source Python codes for the specified image analysis measures. Following this, a survey was administered to the buildings’ users. Survey participants were randomly assigned from two groups of students enrolled in the faculties housed by the two buildings. The students voluntarily participated in an online survey via the SurveyMonkey platform, with the link shared by faculty lecturers. The survey consisted of three sections:

1. The first five questions gathered personal information about the students, such as age, gender, level of education (bachelor's/ postgraduate), and the number of years spent studying in their faculty building.
2. The second section featured the SoP measuring instrument, containing 12 items grouped into three sets of four. Each set measured one of the three dimensions of SoP. Some items were modified from the original residential property scale to suit the study context.
3. The third section measured subjective judgments of an image's ‘livingness’. It contained 30 questions, each featuring an image pair. Each pair displayed two equivalent spaces from the two buildings side by side, and the participants were asked to select the one that felt more alive. The images included both interior and exterior views, and their order was randomized in the survey.

3. Results

In total, 23 responses were received from Taşkişla students and 29 from EE students. Table 1 presents the frequency of demographic information for the two surveyed groups.

Table 1: Demographic information for the two groups of surveyed students.

Demographic		Taşkişla students	EE students	
Age	20 and below	13.0	10.3	
	20-23	47.8	41.4	
	24-26	21.7	24.1	
	27-29	4.3	6.9	
	30 and above	13.0	17.2	
Gender	Male	70	37.9	
	Female	30	62.1	
Educational Level	Bachelor's Degree	61	51.7	
	Post-Graduate	39	48.3	
Period of study	1 year or less	56.5	20.7	
	2 years	30.4	10.3	
	3 years	4.3	17.2	
	4 years	0		
	5 years and above	8.7	13.8	
			37.9	
Major	Architecture	69.6	86.2	Computer engineering
	Landscape architecture	4.3	3.4	Electrical engineering
	urban planning	26.1	10.3	Other



The internal reliability of the SoP scale was calculated using Cronbach’s alpha, resulting in a score of .916 for the Taşkışla student survey and .896 for the EE students survey. Table 2 shows the mean score for each item of the Likert-type SoP scale. Additionally, the mean scores of place identity, place attachment, and place dependence were calculated for each group of students.

Table 2: Demographic information for the two groups of surveyed students.

Likert Scale Items	Taşkışla Students		EE Students	
	Mean	Std.Deviation	Mean	Std. Deviation
IDN 1 (I feel that X* is a reflection of me)	3.83	.984	2.00	.964
IDN 2 (Studying in X says much about who I am.)	3.87	1.100	1.97	.906
IDN 3 (I feel that I can be myself at X)	4.00	.853	2.34	1.078
IDN 4 (Studying at the X reflects the type of person I am.)	3.78	1.043	2.03	.823
ATTCH 1 (I feel relaxed when I am at X)	4.26	.964	3.31	1.072
ATTCH 2 (I feel happiest when I am at X)	3.35	1.229	1.97	1.085
ATTCH 3 (X is one of my favorite places to be.)	3.91	1.041	1.97	.823
ATTCH 4 (I will miss X when I graduate)	4.22	.795	2.34	1.233
DEP 1 (X is the best place for me to enjoy doing my studies)	3.74	1.214	2.03	1.052
DEP 2 (As a university facility, no other place can compare to X)	3.83	1.302	1.52	.738
DEP 3 (I wouldn’t substitute any other place for studying and things I do at X.)	3.17	.984	1.72	.922
DEP 4 (I wish I were studying at some other place than Taşkışla)	4.00	.905	2.48	1.153
	A total of 23 responses		A total of 29 responses	




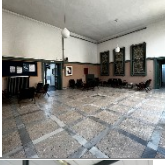


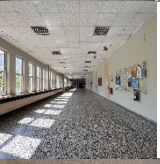
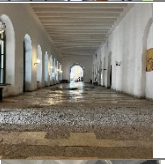







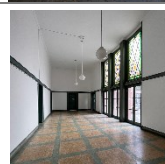

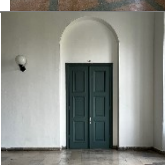

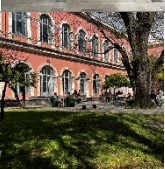
Comparing the two groups, students at Taşkışla reported a higher level of place identity, attachment, and dependence than those at the EE building. A 2-sample T-test was conducted to determine if the differences in these reported measures were statistically significant. Table 3 shows that Taşkışla students scored significantly higher on all three dimensions. Notably, students at Taşkışla reported a high SoP despite most having studied there for only one to two years. Additional statistical analyses revealed no significant correlation between the number of study years and any SoP constructs. Furthermore, there was no significant difference in the reported SoP between bachelor’s and postgraduate students for both groups.

Table 3: Demographic information for the two groups of surveyed students.



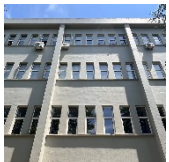

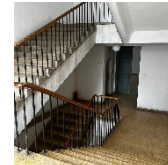




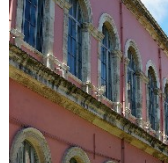

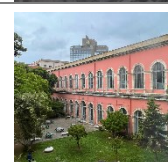
	Mean (Taşkışla)	Mean (EE)	t	Two-Sided p
IDN	3.8696	2.0862	7.860	<.001
ATTCH	3.9348	2.3966	6.877	<.001
DEP	3.6848	1.9397	7.769	<.001

The degree-of-life test showed a strong consensus between the two groups of students. Both Taşkışla and EE students rated images of the Taşkışla building as having more life than those of the EE building. Only out of the 30 image pairs had a majority preference for the EE images, which were of sitting areas and staircases. Table 4 presents the selection percentage for each image for both groups of students.


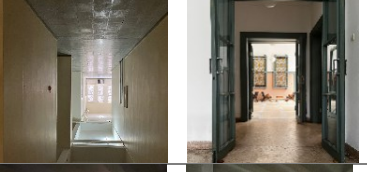
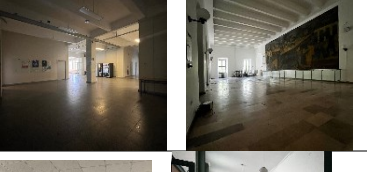
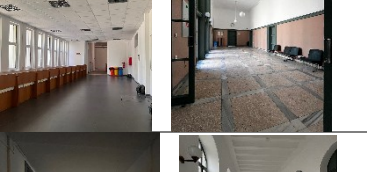

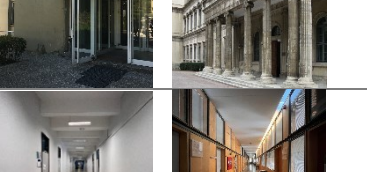

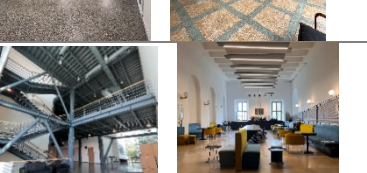
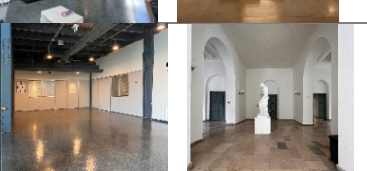
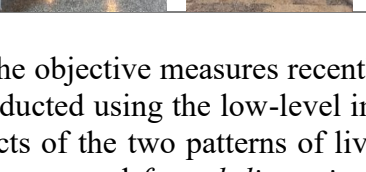
Table 4: The results of the degree-of-life test.

item	Responses					
	Taşkışla students		Image pairs		EE students	
1 Entrance Hall	14%	86%			31%	69%
2 Sitting Area	67%	33%			93%	7%
3 Lab/Studio	5%	95%			21%	79%
4 Corridor	5%	95%			14%	86%
5 Classroom	14%	86%			17%	82%
6 Hallway	5%	95%			10%	90%
7 Corridor	0%	100%			4%	96%
8 Hallway	24%	76%			24%	76%
9 Door	5%	95%			7%	93%
10 Courtyard	5%	95%			0%	100%



11 Façade	10%	90%			0%	100%
12 Façade Detail	0%	100%			0%	100%
13 Window	5%	95%			11%	90%
14 Stairway	62%	35%			93%	7%
15 Façade	0%	100%			21%	79%
16 Corridor	0%	100%			14%	86%
17 Façade Detail	5%	95%			21%	79%
18 Courtyard	10%	90%			18%	82%
19 Sitting Area	5%	95%			0%	100%
20 Courtyard	0%	100%			0%	100%



21 Cafeteria	45%	55%		15%	85%
22 Corridor	0%	100%		4%	96%
23 Hallway	10%	90%		15%	85%
24 Sitting Area	10%	90%		37%	63%
25 Corridor	0%	100%		11%	89%
26 Entrance	5%	95%		4%	96%
27 Corridor	10%	90%		11%	89%
28 Hallway	10%	90%		7%	93%
29 Sitting Area	20%	80%		11%	89%
30 Hallway	5%	95%		22%	78%

The third part of the analysis aimed to test the objective measures recently developed for the concept of living structures. Image analysis was conducted using the low-level image features method on the same set of images, approximating the effects of the two patterns of living structures: *level of scale* and *contrast*. Five measures were tested: *entropy* and *fractal dimension* to represent levels of scale, and the standard deviation of the image's *hue*, *saturation*, and *brightness* to describe the property of *contrast* (Coburn et al., 2019). A sixth measure applied is the scaling law method, which approximates



the degree of life based on structural hierarchies and the number of substructures (Jiang & de Rijke, 2023).

The analysis utilized open-source Python codes and built-in Python image analysis features. Most images from the Taskisla building scored higher on five of the six measures (Entropy 53%, Hue 63%, Saturation 63%, brightness 70%, scaling 60%). Conversely, 60% of EE images scored higher for the fractal dimension. Higher scores on all dimensions generally correspond with images containing more vegetation, fine textures, and architectural detail. In contrast, images of monotone and minimalist interior spaces score the lowest, aligning with the theoretical concepts of living structures. Figure 5 summarizes the result of the image analysis.

Fractal dimension*

image no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	mean
Taskisla	1.50	1.68	0.38	1.63	1.53	1.41	1.22	1.54	1.38	1.89	1.70	1.62	1.64	1.72	1.65	1.54
EE	1.57	1.57	1.63	1.82	1.55	1.45	1.27	1.51	1.62	1.82	1.69	1.54	1.62	1.63	1.79	1.59
image no.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	percentage
Taskisla	1.66	1.47	1.74	1.60	1.74	1.60	1.57	1.37	1.62	1.72	1.42	1.52	1.71	1.54	1.44	40%
EE	1.49	1.70	1.88	1.44	1.77	1.60	1.36	1.24	1.51	1.15	1.59	1.61	1.72	1.71	1.70	60%

*a measure of visual complexity, detecting repeated patterns across scales. Calculated using the Minkowski-Bouligand method (Coburn et al, 2019).

Entropy*

image no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	mean
Taskisla	7.53	7.72	7.77	7.32	7.77	7.64	7.75	7.61	7.75	7.67	7.67	7.15	7.44	7.87	7.31	7.52
EE	7.47	7.75	7.65	7.43	7.40	7.60	6.89	7.55	6.72	7.80	7.83	7.66	7.39	7.89	7.70	7.57
image no.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	percentage
Taskisla	7.84	7.14	7.51	7.47	7.66	7.39	7.70	7.56	7.89	7.50	7.35	7.66	7.56	7.53	7.43	53%
EE	7.68	7.65	7.71	7.51	7.71	7.42	7.15	7.33	7.63	7.45	7.32	7.18	7.48	7.88	7.77	47%

*statistical measure of randomness in a scene that is calculated using the scene's intensity histogram (Coburn et al, 2019)

Hue St. deviation*

image no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	mean
Taskisla	15.73	34.90	45.65	20.90	33.43	17.94	45.79	44.40	28.34	27.69	45.74	48.74	26.74	27.85	37.00	35.23
EE	39.65	35.64	41.32	38.53	32.84	36.05	17.11	22.85	33.64	26.74	34.40	37.53	22.74	44.09	12.88	32.00
image no.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	percentage
Taskisla	30.83	57.95	64.67	58.13	35.39	40.46	23.08	13.33	34.31	25.70	27.43	36.10	30.72	40.26	37.82	63%
EE	29.79	39.69	32.93	43.18	43.40	35.90	24.65	16.33	29.53	6.88	34.11	46.04	33.27	33.23	35.18	37%

*a measure of color hue variation in an image, calculated standard Python image HSV analysis (Coburn et al, 2019)

Saturation St. deviation*

image no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	mean
Taskisla	48.57	51.49	31.07	39.30	51.90	61.69	37.98	41.40	31.52	84.76	61.46	51.77	34.77	71.46	54.79	49.23
EE	27.90	53.75	44.51	25.69	50.78	27.26	22.96	44.29	26.41	87.89	60.93	39.52	58.19	48.44	66.42	43.15
image no.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	percentage
Taskisla	45.00	51.37	64.00	62.42	58.88	48.19	38.38	59.24	45.32	23.58	27.90	71.43	36.61	59.17	30.79	63%
EE	42.53	48.62	69.53	39.02	50.49	36.79	39.76	26.67	58.31	28.49	25.64	21.74	27.90	37.42	41.54	37%

*a measure of color saturation variation in an image, calculated standard Python image HSV analysis (Coburn et al, 2019)

Brightness St. deviation*

image no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	mean
Taskisla	48.47	62.12	65.13	41.72	58.65	48.78	54.46	53.56	56.21	76.8	57.51	45.3	59.37	68.45	48.68	56.62
EE	46.66	70.17	53.05	49.18	42.49	53.95	37.28	53.49	40.17	71.51	79.17	65.74	54.03	68.14	67.08	58.96
image no.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	percentage
Taskisla	68.85	43.51	80.38	66.65	70.73	55.62	73.3	52.41	68.12	50.37	67.08	63.58	54.82	52.27	45.41	70%
EE	65.45	65.51	64.74	66.28	66.07	47.61	42.04	51.46	52.18	50.51	47.59	38.98	48.36	67.89	61.74	30%

*a measure of brightness variation in an BW image, calculated standard Python image HSV analysis (Coburn et al, 2019)

scaling*

image no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	mean
Taskisla	13219	27357	3819	29395	13642	12866	13828	21999	5016	61312	30422	27312	3515	22259	25294	19692.16
EE	8059	7333	9322	59228	11423	13819	12251	7153	27377	43935	21394	13041	12591	Error	18243	19044.54
image no.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	percentage
Taskisla	19955	26382	50749	Error	34654	15428	7122	5292	16295	31168	16118	Error	13243	Error	17651	60%
EE	Error	15032	Error	5313	23553	37470	18915	12161	5985	6607	31007	30711	30698	18714	10472	40%

*a function of levels of structure hierarchy (pixels) and number of substructures (Jiang & de Rijke, 2023)

Figure 5. Results of the image analysis measuring objective naturalness.

4. Discussion

4.1 Naturalness/life in Architecture

Alexander (2002) argued that a consensus can often be reached by asking people to reflect on which scene feels more alive, attributing this to certain universal properties of living structures that resonate with our experience of the world. He also suggested that pre-modern buildings were more likely to possess those properties. Similarly, Kaplan's preference theory has demonstrated the impact of natural complexity and coherence on aesthetic appraisal through naturalistic patterns such as mystery,

prospect, and refuge (Kaplan & Kaplan, 1989). The cases in this study were chosen for their demonstrable differences in aesthetic quality and style, with one hypothesized to be more naturalistic. As predicted, participants assessing the livingness of these buildings showed a clear consensus in favour of the classical building, which was hypothesized to be more naturalistic in its visual quality. Objective measures of naturalness demonstrated close results when comparing the number of images scoring higher for the six measures and their mean score. Ranking the images according to these measures was generally consistent with their theoretical implications. For example, hallways with minimal geometry and little colour variation scored the lowest, while images with rich façade details or natural features scored the highest. Images with low L-score tended to feature less detail and overall blandness, such as the images of the EE building corridors. As expected, the detailed and aesthetically rich façade of the Taşkılla building scored higher than that of the EE building. Overall, some of these measures predicted perceived naturalness and preference in previous research. In this study, they were applied to real settings with building users, allowing for the examination of other psychological outcomes, such as the sense of place.

4.2 Naturalness and sense of place

The results from combining naturalness measures and SoP suggest that naturalistic buildings may foster a more positive place experience than mechanistic and utilitarian ones. The significantly higher level of SoP in naturalistic buildings confirms the research hypothesis. The demonstrable difference in perceptions of life indicates that variations in a building's naturalness likely influence the occupants' SoP.

Cole et al. (2021) have suggested that green buildings can support SoP by aligning common green building strategies with SoP dimensions. Similarly, naturalistic buildings can enhance SoP through the emotional dimension of forming attachments via attractive, nature-like features, identification with places based on environmental awareness and valuing nature, and dependence on places to perform desired actions. Previous research has shown that people tend to form attachments and identify with places due to the presence of nature. The perceived beauty of places also contributes to forming SoP. These results highlight the connection between nature and SoP, demonstrating that naturalistic patterns of order enhance this relationship.

4.3 Implications for theory and practice

This study has highlighted a theoretical link between SoP and the naturalistic properties of the built environment. Place theories have often been criticized for their ironic underemphasis on places and their objective physical properties (Lewicka, 2011). Exploring this link broadens our understanding of people/place relations, which are formed by a multitude of factors, including extended and repeated interactions, personal experiences and memories, social ties, and the attractive force of living structures that can evoke interest, aesthetic enjoyment, and emotional engagement.

On the other hand, the biophilic design theory should move beyond its focus on greening buildings and cities in order to explore the full potential of its goals. More empirical evidence is needed to examine the effects of indirect nature in place, such as prospect/refuge and mystery, as well as other properties of living structures, such as local symmetries and simplicity.

Nature and biology play a significant role in contemporary urban and architectural design thinking, whether through taking inspiration from natural forms, evolutionary and generative processes, or even for branding purposes. Designers can use this biological moment to make their designs more human-friendly and considerate of their emotional impact. To increase the naturalness of the environment, buildings and cities should be allowed to 'grow' organically through sensitive adaptive processes that fit new forms rather than impose them. Based on these findings, designers are encouraged to follow adaptive design processes that create highly integrated and aesthetically pleasing living structures. The theory of living structure and other advancements in biophilic design are promising in describing these processes and guiding designers to adopt this approach.



5. Conclusion

This study has demonstrated that architectural environments embodying naturalistic beauty significantly enhance the sense of place (SoP) experienced by their users. By comparing two educational buildings with distinct aesthetic qualities, it was found that the building with naturalistic elements, the Taşkışla, provided a stronger sense of attachment, identity, and dependence than its mechanistic counterpart. These findings suggest that environments designed with biophilic principles, which integrate nature and its analogues into the built form, can foster more profound emotional connections and promote psychological well-being.

The results also highlight the importance of objective measures of naturalistic beauty in understanding how architectural design influences human experience. The study's novel combination of survey-based data and image analysis revealed that features such as complexity, coherence, and detail are crucial in determining the perceived naturalness of a building. These findings support the argument that design strategies focused on enhancing naturalistic qualities, such as through the use of local symmetries, fractal patterns, and organic forms, can positively impact users' perceptions and experiences of their environment.

Overall, this research provides valuable insights into the interplay between architecture and human psychology, suggesting that biophilic design not only has aesthetic appeal but also contributes to socio-economic benefits by fostering environments that support well-being and community ties. Future studies should further explore the specific elements of naturalistic architecture that most effectively enhance SoP, using both qualitative and quantitative methods to build a more comprehensive understanding of the relationship between built environments and human experience.

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Conflicts of Interest

The authors declare no conflicts of interest.

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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Original scientific paper

Towards Biodiverse Urban Public Spaces: A Morphological Study in Milan

*¹ Assistant Prof. Dr. **Fabio Lepratto** , ² Assistant Prof. Dr. **Francesca Zanotto** 
^{1&2} National Biodiversity Future Center, Department of Architecture and Urban Studies, Politecnico di Milano, Italy
¹ E-mail: Fabio.lepratto@polimi.it, ² E-mail: Francesca.zanotto@polimi.it

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ABSTRACT



This study explores the role of architectural composition and urban design in enhancing urban biodiversity, which is crucial for improving ecosystem services and overall urban sustainability. It addresses a gap in the literature by providing empirical evidence on how specific morphological characteristics in urban regeneration projects can support biodiversity, emphasizing the overlooked potential of architectural morphologies in urban greening strategies. Focusing on five recent urban regeneration projects in Milan, the study conducts a detailed analysis of built volumes and green areas. Quantitative measurements, such as green area compactness, perimeter edge continuity, and building front permeability, were combined with qualitative assessments to identify correlations between urban morphology and biodiversity potential. The analysis revealed three distinct urban morphologies—"Central Park," "Fluid Park," and "Garden Between Houses"—each offering unique conditions for accessibility and biodiversity development. These morphologies demonstrate varying capacities for conserving, promoting, and implementing urban biodiversity, depending on their interaction with the surrounding urban fabric. By establishing a clear correlation between urban morphology and biodiversity potential, this research highlights the critical role that architects and urban designers play in addressing the emerging challenge of enhancing urban biodiversity. It provides valuable insights for future urban regeneration projects aimed at fostering sustainable and biodiverse urban environments.

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Highlights:

- Architectural composition in urban design can significantly enhance biodiversity in public spaces by optimizing morphological characteristics.
- Distinct urban morphologies, such as "Central Park," "Fluid Park," and "Garden Between Houses," influence biodiversity potential through their interaction with surrounding urban fabric.
- Urban regeneration projects with increased green area compactness and perimeter edge continuity foster higher biodiversity and ecological connectivity.
- Milan's urban regeneration efforts demonstrate that specific settlement forms can successfully integrate biodiversity with accessible, visible public spaces.

Contribution to the field statement:

By identifying the correlation between urban morphology and biodiversity potential, this research contributes to the field of urban studies and architectural studies by shedding light on the role that architectural composition and urban design – and therefore architects and urban designers - can play in the emerging challenge of designing urban spaces aimed at conserving and enhancing urban biodiversity, facilitating ecosystem services provision and creating accessible, safe and inclusive public spaces.

*Corresponding Author:

National Biodiversity Future Center, Department of Architecture and Urban Studies, Politecnico di Milano, Italy

Email address: Fabio.lepratto@polimi.it

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1. Introduction

1.1 Background and Context

The preservation and promotion of urban biodiversity are crucial for achieving the objectives outlined in the European Union's Biodiversity Strategy for 2030: ecosystem restoration, ecological balance, human well-being, and overall urban sustainability (European Commission, Directorate-General for Environment, 2021). With a population share of about 50% in 2020, projected to increase to 58% over the next 50 years, the responsibility for the majority of the world's carbon emissions (Moran, et al., 2018) and ongoing threatening dynamics as urban sprawl, irreversible land-use changes, resource and energy-intensive consumption patterns, urban areas are a critical field of study to understand how to conserve and improve biodiversity globally (Luederitz, et al., 2015) and, at the same time, learn how to intervene in the built environment to provide cities with ecosystems services: a range of benefits granted by natural ecosystems (Millennium Ecosystem Assessment, 2005) (Danley & Widmark, 2016), involving in cities the improvements in air quality and microclimate regulation, recreational opportunities for nature experience and sports activities, water regulation and stormwater runoff control (Ronchi & Salata, 2022). The enhancement of green infrastructure is also connected with multiple health benefits (Dipeolu, Akpa, & Fadamiro, 2020) and can also promote crucial investment and business opportunities to foster Europe's economic recovery following the COVID-19 crisis (European Commission, Directorate-General for Environment, 2021).

This research is situated within the scientific activity of the National Biodiversity Future Center (NBFC), one of the five centres supported by the Italian post-pandemic National Recovery and Resilience Plan, focusing on frontier research aligned with European research priorities. The NBFC's goal is to generate knowledge for conserving, restoring, monitoring, and enhancing Italian and Mediterranean biodiversity. NBFC's Spoke 5 focuses on the generation of knowledge regarding the conservation and improvement of urban biodiversity. Urban public spaces in Italy still exhibit a considerable lack of biodiversity. Nevertheless, documents such as Law No. 10 of January 14, 2013, "Regulations for the Development of Urban Green Spaces", the National Strategy for Public Green Areas¹ issued in 2018, and the integration of the EU's Biodiversity Strategy for 2030 into a national strategy², reveal a regulatory and cultural context where the role of urban biodiversity is acknowledged as crucial for creating sustainable and resilient urban environments. Therefore, the city of Milan serves as a significant context for the investigation presented in this paper: it boasts a high-quality, consolidated urban environment that has experienced rapid growth and densification over the last two decades, particularly in regeneration areas within and around the city centre. This growth has highlighted the prominent role of architecture in embodying the city's economic and cultural development. Simultaneously, both the municipality and the metropolitan city are committed to improving the quality of public spaces through forestation policies and naturalization programs.

1.2 Problem Statement and Research Gap

Several frameworks and disciplinary approaches have been developed globally in recent years to design greener and more biodiverse cities while ensuring their functionality and livability (Beatley & Newman, 2013; Garrard, et al., 2018; Kirk, et al., 2021; Dizdaroğlu, 2022). In such models, the architectural composition is often relegated to a peripheral role in favour of larger-scale, ecology-related tools and systemic approaches, which are believed to be more effective in addressing complex, multifaceted, and extensive issues related to the integration of nature in the built environment in a comprehensive manner. However, architectural composition can provide substantial contributions to the challenge of envisioning urban public spaces that conserve and implement biodiversity and, at the same time, are also beautiful, safe and accessible for citizens.

The paper explores the disciplinary contribution that architectural composition and urban design can provide to the conservation and enhancement of urban biodiversity. It investigates the possibility of

¹ See Ministero dell'Ambiente e della Tutela del Territorio e del Mare - Comitato per lo Sviluppo del Verde (2018). Strategia nazionale del verde urbano [National Strategy for Urban Green Areas].

² See Ministero dell'Ambiente e della Sicurezza Energetica (2023). Strategia Nazionale Biodiversità 2030 [National Biodiversity Strategy 2030].



morphological definition of open spaces and spatial conditions that are potentially conducive to the development of organic components, the increase of biodiversity, and the provision of ecosystem services while, at the same time, outlining highly accessible and visible public green spaces. Combining the tradition of morphological and typological studies (Muratori, 1963; Caniggia, 1979) with the more recent research on urban biodiversity is an interdisciplinary approach that remains underdeveloped yet holds great potential. In recent years, a relatively limited number of studies have attempted this combination. Among these, Ståhle (2005) and Marcus (2008) have explored the connections between urban form and its influence on environmental ecology. Marcus and Colding (2011) discuss how to shape urban development towards more sustainable directions. Benelli and Pellegrini (2013) propose a methodology to relate settlement forms to different climatic and environmental performances. Andersson and Colding (2014) delve into how built urban forms influence biodiversity by comparing different suburban residential patterns in relation to their surroundings. More recently, Palazzo (2022) reflected on the potential to bridge urban morphology and urban ecology, starting from conceptualising cities as urban landscapes (Andersson, 2006; Forman, 2008; Forman, 2014) to identify patterns that better support urban resilience within the historic city framework. Much like the present study, these studies share a common trait: the development of geometric descriptions of urban forms pertinent to ecosystem services and environmental issues. They all advocate for a more interdisciplinary approach, where each discipline must acknowledge its potential role and express its limits to foster collaboration. This investigation aims to further contribute to the relationship between urban form and biodiversity potential, particularly by closely examining newly constructed contexts in medium-to-high-density urban areas resulting from regeneration projects.

1.3 Objectives and Contribution to the Field

This research has multiple objectives: 1) define a new methodology for the morphological analysis of urban open spaces aimed at recognizing biodiverse potentials in urban morphologies; 2) identify urban and architectural morphologies that are more conducive to supporting the conservation and development of urban biodiversity, as well as the provision of ecosystem services, and to generating more favourable conditions for citizens' interaction with nature; 3) generate useful knowledge to enhance biodiversity in new constructions and interventions in the existing built environment as a basis for the future definition of design guidelines; 4) considering the multidisciplinary of this issue, raise questions that can be addressed collaboratively with other disciplines to proceed in the direction of defining design guidelines. The research focuses on five case studies selected from the Atlas of Urban Regeneration of the Municipality of Milan³, on which quantitative analysis was performed at the urban and architectural scale, combined with qualitative remarks.

This study's expected contribution to the field of architecture, and more broadly, to the challenge of designing more biodiverse urban public spaces, revolves around the generation of new knowledge on the role that architectural composition and urban design can play in conserving and enhancing urban biodiversity and in the facilitation of ecosystem services provision. Additionally, the present research aims to provide guidance for integrated design approaches beneficial to designers and public administrations dedicated to enhancing urban biodiversity and ecosystem services in their cities (especially aimed at contexts similar to Milan).

1.4 Significance and Structure of the Paper

This research paper is organized into six parts. Following an introduction, the second part emphasizes the marginal role that architectural composition still plays in initiatives to enhance biodiversity in urban spaces. The third part introduces the analysis methodology, covering also the choice of the case study of Milan, highlighting its importance as a highly significant research context due to the rapid expansion of

³ The Atlas is a periodically updated digital map developed by Comune di Milano - the Municipality of Milan - providing an overview of the ongoing urban regeneration projects (above 5000 sqm) and the most relevant public and private interventions.



buildings over the last two decades and the attention given to environmental performances of open spaces. The analysis methodology is based on a quantitative approach, combined with qualitative remarks, applied to five case studies within the city of Milan. Parts four and five present the findings and their discussion. Finally, the sixth part outlines conclusions regarding the main contribution of this paper to the field, presenting the limitations of the current study and the main perspectives for development towards a comprehensive and more robust research methodology.

2. Architectural Composition for Urban Biodiversity: An Overlooked Potential

In recent years, several frameworks and disciplinary approaches have been developed globally to design greener cities. Landscape Urbanism (Mostafavi & Najle, 2003) (Waldheim, 2006) proposes planning cities through the design of the landscape rather than buildings and infrastructure, imagining new relationships and possibilities among the elements involved, reasoning with horizontal alignments rather than vertical development and introducing an understanding of the dimension of time and the changing nature of environments into the planning process (Corner, 2006). Ecological Urbanism (Mostafavi & Doherty, 2010), stemming from Landscape Urbanism, bends the focus towards envisioning and planning cities not only as cultural constructs but also as artificial ecosystems, to be designed and organized based on their demand and supply of resources (Hagan, 2014).

Within these approaches, the architectural scale is often overlooked among the levels of intervention at which it is possible to make substantial contributions to envisioning biodiverse urban public spaces. Architecture is a critical field in the challenge to make cities more sustainable and biodiverse: the construction sector is responsible directly and indirectly for more than one-third of global energy and process-related CO₂ emissions (Aste, Del Pero, & Leonforte, 2022), and buildings play a crucial role in the formation of urban heat islands; furthermore, architectural design holds the potential to shape the built environment and therefore drive or support greening strategies and integrated and sustainable models for urban biodiversity. Several recent innovations in the practice show through prototype buildings the feasibility of integrating trees and greening in architecture, especially in the framework of NBS at the building scale (World Bank, 2021), entailing the construction of new green roofs and green façades on new buildings or existing buildings. Biophilic design, on the other hand, poses humans' innate connection to nature as the foundation of an approach aiming to incorporate natural elements and references into the built environment to improve physical and mental well-being, enhance productivity, and promote a sense of harmony (Kellert, Heerwagen, & Mador, 2008). However, as far as efficient systems, in most cases, these strategies are not involved in the compositive conceptualization of the building: they represent "applied" solutions that are integrated into the design process at a later stage than other fundamental disciplinary tools of architectural design. A similar issue exists with the framework known as Animal-Aided Design (Hauck & Weisser, 2019) which, despite looking at the urban environment as an integration of scales and dimensions, including architecture, this approach is more oriented towards applied strategies *on* and *around* buildings, rather than investigating the effect of their outlining, composition and massing towards biodiversity.

Apart from these innovations, there is a general lack of attention to integrating urban biodiversity targets among the main challenges in the field of architecture. Furthermore, urban greening plans or strategies rarely involve the architectural scale: research developed within Activity 3.1 of NBFC Spoke 5 reveals that urban Green Plans⁴ (Pastore & Lazzarini, 2024) in Italy have a scarce commitment to implementation (Lazzarini, Mahmoud, & Pastore, 2024), highlighting, among the rest, a weak ability of planning instruments to engage with the architectural and urban design scale and domain. Given the multidimensional nature of urban challenges, it is crucial to increase knowledge on the possible role of

⁴ In Italy, the Green Plan is a voluntary tool supplementary to general urban planning. It defines the city's profile in terms of fundamental natural ecosystems and collects strategies, guidelines and actions for developing and enhancing urban and peri-urban green spaces. The Green Plan serves as a strategic instrument directing local urban transformation policies and municipal decisions regarding public green spaces, establishing principles and criteria for their development, shaping the city's green landscape. See Pastore, M. C. & Lazzarini, L. (2024). Piani e strategie del verde per la biodiversità urbana. In *Urbanistica Informazioni*, 313, pp. 67-72.

architecture in better integrating design solutions at different scales for more sustainable and biodiverse urban environments. Architectural composition can make a key contribution to the challenge of designing biodiverse urban public spaces by employing disciplinary fundamentals such as morphological study and typological methods: it can integrate ecological and qualitative requirements of urban public spaces, creating the conditions for biodiversity to thrive while ensuring that these spaces are safe, allergy-free, easy to maintain, welcoming, and accessible, suitable for developing high-quality uses and fostering meaningful relationships.

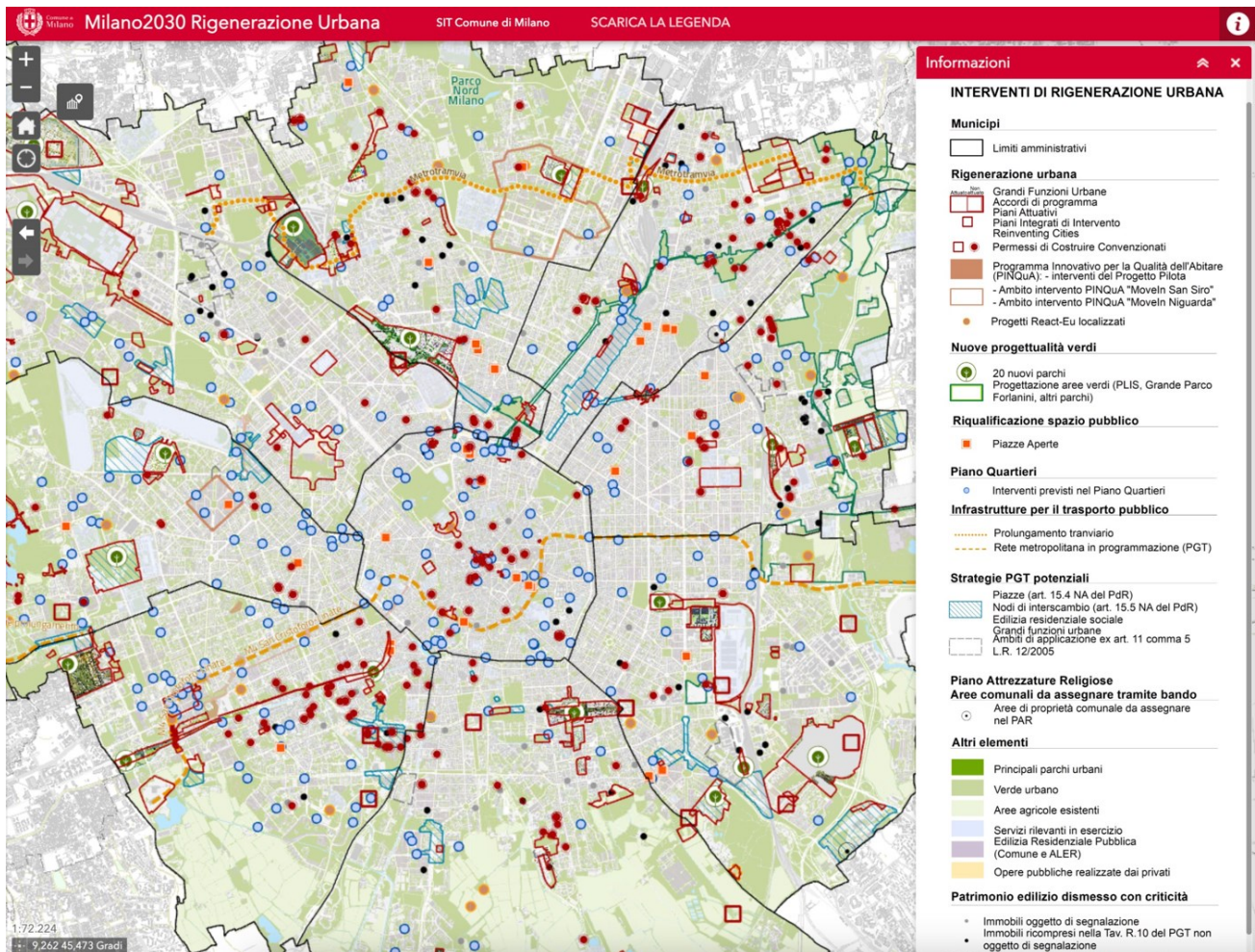


Figure 1. Extract from the Atlas of Urban Regeneration of the Municipality of Milan. The online Atlas map provides an overall and periodically updated view (Credits: Municipality of Milan).

3. Materials and Methods

3.1 Study Design and Setting

The methodology's first step involves choosing a context of study. The NBFC Spoke 5 research units are based in Milan (Politecnico di Milano, Università degli Studi di Milano-Bicocca), Florence (Università degli Studi di Firenze), Rome (Sapienza Università di Roma) Campobasso (Università degli Studi del Molise), and the different locations where Consiglio Nazionale delle Ricerche – CNR is based. Milan is the spatial context where the majority of Spoke 5 researchers are based, and the city has been chosen as the context of this study due to the potential usefulness of the results to further Milan-based research within Spoke 5. Furthermore, the city of Milan was chosen as it offers a compelling example for studying the role of urban open spaces in medium and large-scale developments, focusing on the existing relationships between biodiversity and different urban morphologies, for a large amount of land developed



or re-developed over the past 30 years, which amounts around 10 square kilometres⁵. Milan has undergone multiple large and medium-scale transformations, continuously following one another: a rare occurrence at the Italian national level and a prominent case also at the European level.

At the same time, the city of Milan is characterized by local regulations, such as the Piani di Governo del Territorio (territorial government plans) along with actions resulting from public-private negotiations (PRU - Urban Redevelopment Program, Programma di Riqualificazione Urbana - and PII - Integrated Intervention Program, Programma Integrato di Intervento), which have consistently considered the need to improve public green spaces and parks; initiatives such as “Nine Parks for Milan”⁶ (Comune di Milano, Laboratorio di progettazione urbana, 1995) (Marinoni, 2007) and, more recently, “20 Parks for Milan”⁷, the strategic policy document “Future Landscapes - Milan: open spaces in a metropolitan vision”⁸, the “Public Green Regulations of the Municipality of Milan”⁹, “Forestami”¹⁰ project, the “Guidelines for the design of the public space”¹¹ and many other initiatives demonstrate, together with a vibrant public debate, how urban planning and implementation tools for urban development have strengthened environmental parameters and, at the same time, have oriented public interest towards recognizing the benefits of urban nature and advocating for a more widespread presence of green spaces in the city of Milan. The rapid pace of building activity in Milan has transformed the city’s landscape within a few years. This speed also allows us to observe how, over a short period, the evolution of public discourse about the benefits of urban nature – both in Milan and at the European and global levels – has influenced, or failed to influence, architectural morphologies and settlement layouts.

With the aim of uncovering which urban morphologies are most conducive to creating space and conditions for biodiversity to thrive, as well as providing ecosystem services while ensuring high accessibility and visibility, the research focuses on five case studies of architectural and urban development in Milan conducted in the last three decades, chosen among a broader selection, to investigate how their building morphology influences their interactions between open and built spaces. A quantitative-qualitative analysis is conducted at the urban scale, involving tracing the perimeter of open space in each case study, examining their shape, compactness articulation, and continuity conditions that the perimeter edges can establish with the elements of the adjacent urban fabric. The quantitative investigation includes: 1) the connectivity established within each case with existing or potential ecological corridors and/or green infrastructures at the municipality level; 2) the connectivity established within each case with green areas at the neighbourhood level; 3) the extension of building fronts (intended also as windowed fronts, which allow for overlooking outside) generated by each case within the masterplan; 4) the extension of building fronts from the existing urban fabric with which each case establish connectivity; 5) the “compactness” of each open space. Qualitative remarks are then expressed to supplement the quantitative findings.

⁵ See Scenari Immobiliari (2023), Primo Rapporto Nazionale sulla Rigenerazione urbana [First National Report on Urban Regeneration].

⁶ The strategic project elaborated in 1995 on behalf of the City of Milan by the Urban Design Laboratory, with a concept by Pierluigi Nicolini, Cecchi & Lima and Pippo Traversi, envisages the definition of a broad strategy of restructuring the form of the city starting with the configuration of nine urban parks in peripheral areas, where buildings are structured around new central urban parks. See Comune di Milano, Laboratorio di progettazione urbana (1995). *Nove parchi per Milano* [Nine Parks for Milan]. Milano: Electa and Marinoni, G. (2007). Milan. An Evolving City. The changes in strategies of transformation from 1984 to 2007. In *Lotus navigator*, 131, pp. 132-141

⁷ “20 parks for Milan” is among the initiatives of the territorial government plan in force “Milan 2030” for a green, livable and resilient city.

⁸ See Bisconti, C. & Balducci, A. (2016). PAESAGGI FUTURI. Milano: spazi aperti in una visione metropolitana [Future Landscapes - Milan: open spaces in a metropolitan vision]. Comune di Milano.

⁹ See Comune di Milano (2017). Regolamento d’uso e tutela del verde pubblico e privato [Regulations for the use and protection of public and private green space].

¹⁰ “Forestami” is the project promoted by the Metropolitan City of Milan, Milan City Council, Regione Lombardia, Parco Nord Milano, Parco Agricolo Sud Milano, ERSAF e Fondazione di Comunità Milano, which plans to plant 3 million trees by 2030 to grow natural capital, clean the air, improve life in greater Milan and counter the effects of climate change. Born from research by Politecnico di Milano thanks to the support of Fondazione Falck and FS Sistemi Urbani.

¹¹ See Comune di Milano & AMAT Agenzia Mobilità Ambiente e Territorio (2021). Spazio pubblico. Linee guida di progettazione [Public space. Design guidelines].



Figure 2. Planimetric extract of the 15 urban-scale interventions detailed for this study. The park area is highlighted in red on the aerial photo. The projects, listed vertically from top left, are: Merezzate, Figino Borgo Sostenibile, Ex Macello, Ex Trotto, City Life, Cascina Merlata, Ex Scalo Porta Romana, Ex Scalo Farini, Porta Nuova, Ex OM, Adriano, Palizzi, Santa Giulia, Ex Calchi Taeggi, Ex Piazza d'Armi. (Aerial photos: Google Earth; edited by the authors with Michele Porcelluzzi).

3.2 Materials

Five case studies carried out in the last three decades were selected from the Atlas of Urban Regeneration of the Municipality of Milan (Figure 1). Among the regeneration areas listed in the Atlas, the selection criteria excluded transformation areas under 10.000 sqm, those under construction, those that did not involve an increase in the volume of residential use, those that did not provide substantial associated open spaces, and those presenting non-recurring morphologies deemed irrelevant for building a thesis due to their infrequency. The results of this initial selection identified 15 regeneration areas (Figure 2), from which 10 were excluded due to their unique characteristics (such as the presence of heavy infrastructure, the presence of a water body, the recreation of historical layouts), making them less comparable to the others. Consequently, five case studies were selected as they presented comparable spatial conditions. The five selected case studies are the districts named PII Santa Giulia, PII Cascina Merlata, PII CityLife, PII Garibaldi-Repubblica, PII Calchi Taeggi e Bisceglie. With the exception of Cascina Merlata, which was built on former agricultural land, the cases studied have in common that they are developed on land previously occupied by other functions, often called brownfields. These include former industrial areas released by relocations, as seen in the cases of Santa Giulia and Calchi Taeggi; former urban macro-functions, as in the case of City Life, which replaces the old pavilions of the Milan Trade Fair; and urban voids created by the transformation of the railway system, as in the case of Garibaldi-Repubblica. This means that, in most cases, the start of the transformation is preceded by land reclamation from polluting sources. In examining their location in relation to the more consolidated parts of the city, the selection includes areas located in densely built-up central areas, immediately adjacent to the consolidated city, and more rarefied peripheral contexts, as seen in the other three cases.

3.3 Procedures and Data Analysis

The cases were examined using publicly available project documents, orthophotos, and direct observations during visits. The perimeter of the open space in each area was traced using AutoCAD software (Figure 5). The Municipal Ecological Network map¹² of Comune di Milano (Figure 3) was superimposed onto each area to evaluate the compliance with existing or potential ecological corridors and the openings' width (Figure 6). Connectivity towards four elements (existing or potential ecological corridors and/or green infrastructures at the municipality level, green areas at the neighbourhood level, building fronts within the masterplan, and building fronts from the existing urban fabric) was visually represented in schemes using different lines and symbols, to aid in visualizing the conditions of each perimeter (Figure 7).

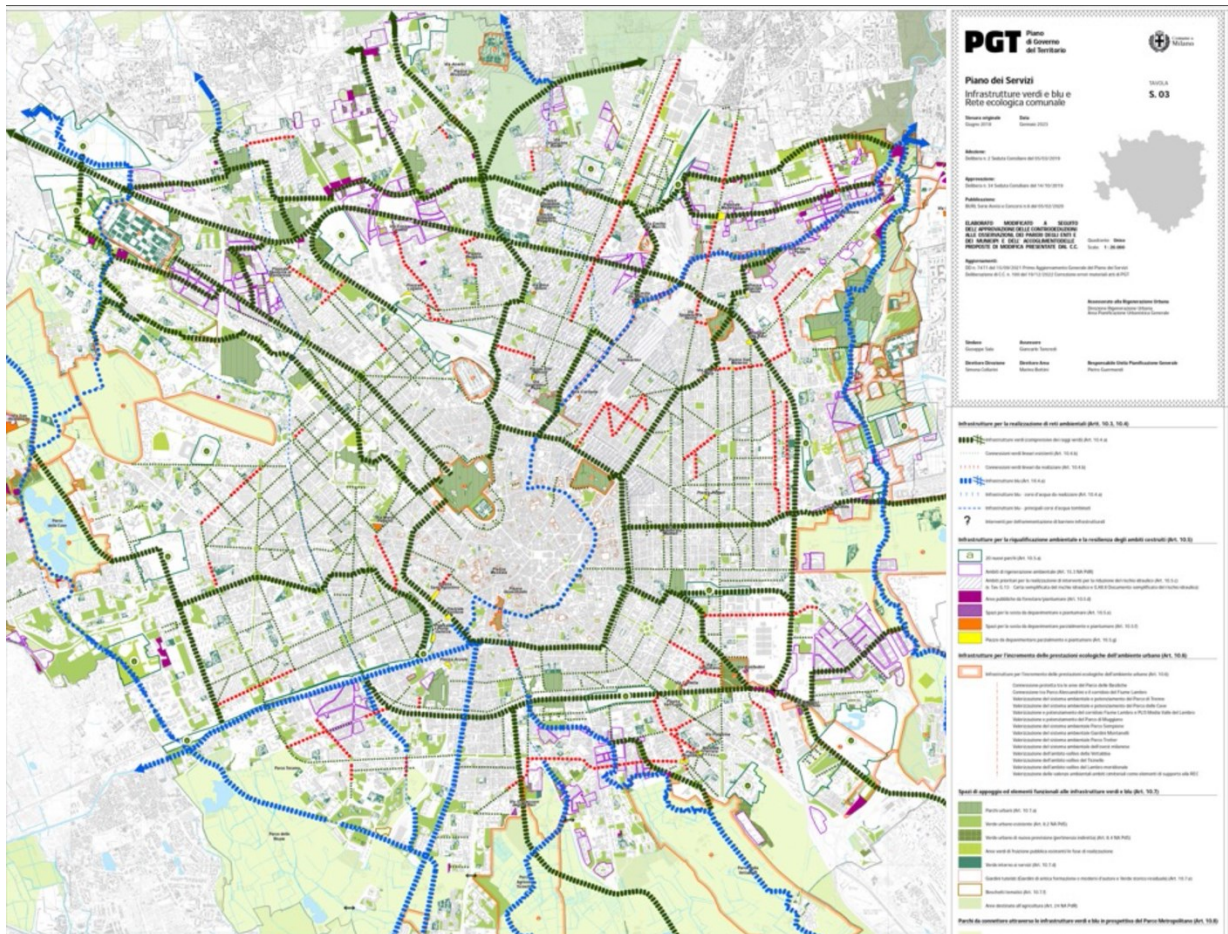


Figure 3. Extract of the ‘Municipal Ecological Network and Urban Green and Open Space System’ map. Territorial Governance Plan of Milan. (Map: Comune di Milano).

A “compactness” index was calculated by relating the perimeter and area to understand the relationship between the compactness of the open space outlines and their ability to provide a higher ratio of ecological connectivity and citizens’ accessibility as well as views from the architectural objects part of the same masterplan and those part of the existing urban fabric.

Perimeters and their connectivity conditions were compared visually to assess which case offered better conditions for the conservation and implementation of urban biodiversity. The results of this comparison were then coupled with the qualitative characteristics of such spaces and the potential biodiversity

¹² The Plan of Services – Piano dei Servizi (PdS) of the Territorial Management Plan of the city of Milan includes elaborates describing at the different territorial scales, regional, provincial and municipal, the ecological network of the city of Milan: its green endowment, ecological corridors and the system of green connecting rural and built-up territory, as well as between road works and urbanized areas and their rational distribution over the municipal territory to support settlement and planned functions.



conditions they may create, providing an opportunity to reflect on the possible interconnection between ecological connectivity and citizens’ accessibility and views. The diagrams (Figure 7) enable the interpretation of contexts, and their abstract nature makes them suitable for transferring the methodology and the emerging topic to other case studies. The study does not explicitly consider variables such as management, choice of plant species, or maintenance, nor does it measure actual biodiversity. The considerations primarily focus on spatial configuration.

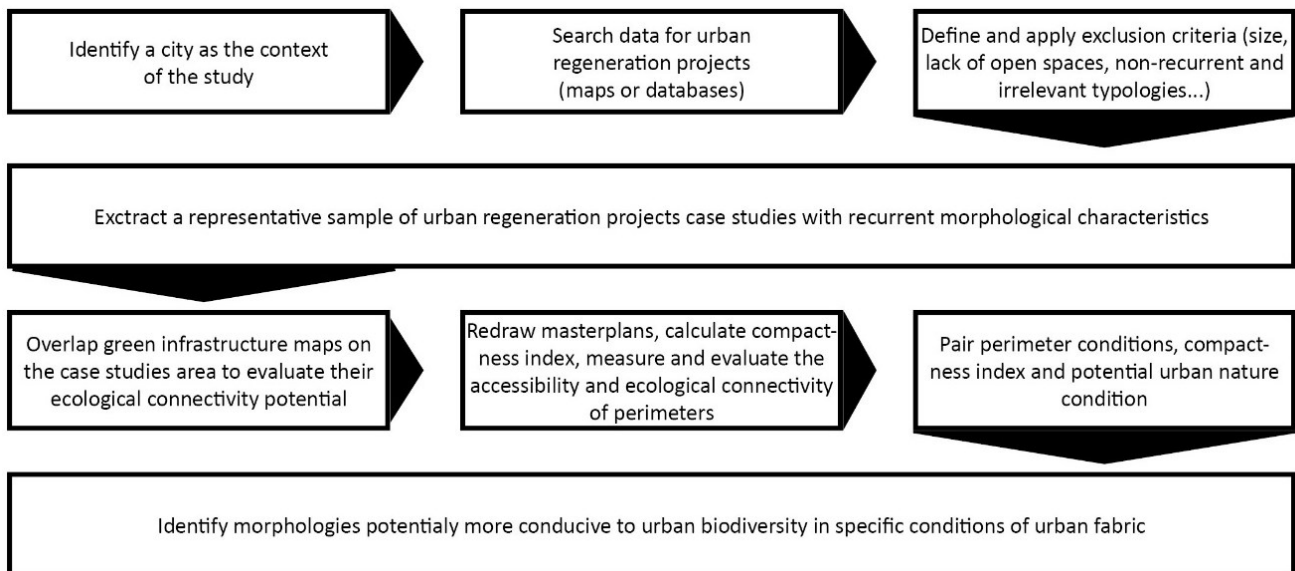


Figure 4. Methodology of the Research.

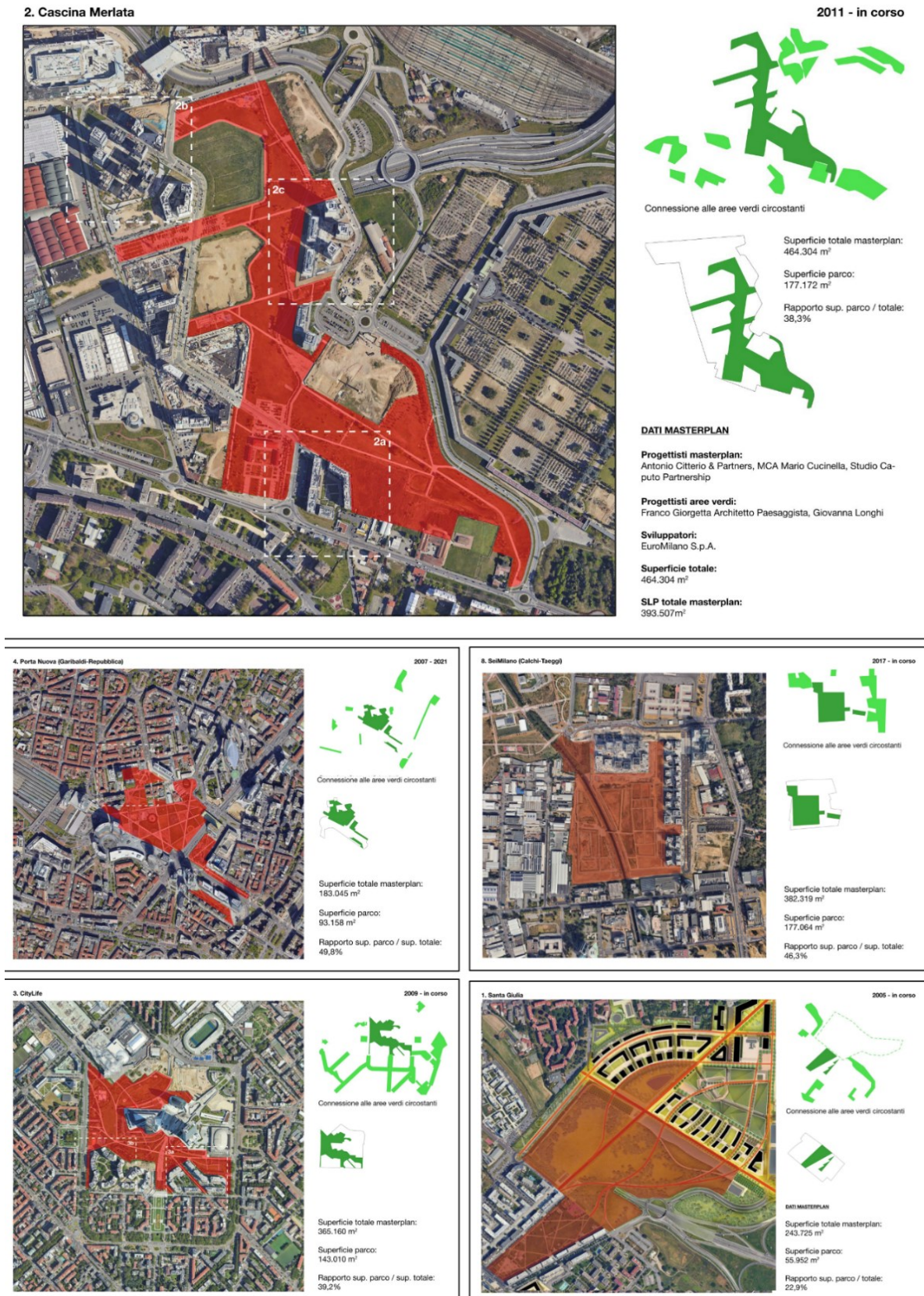


Figure 5. Extract from the analysis files of the five sample projects selected as representative of the most common morphologies. Drawings by the authors with Michele Porcelluzzi. (Map: Comune di Milano. Aerial photographs: Google Earth).

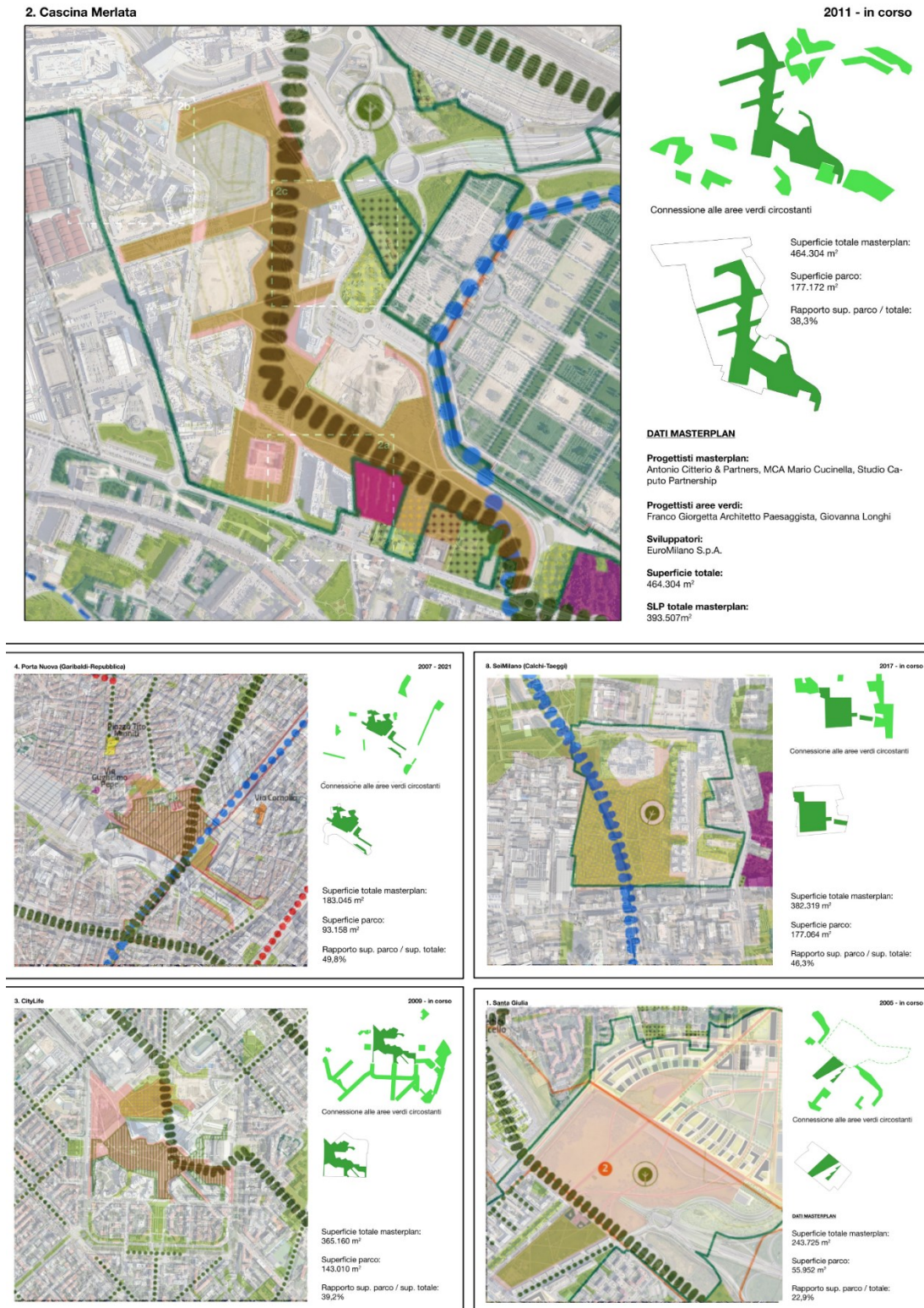


Figure 6. Extract from the analysis files of the five in-depth case studies, superimposed on the map ‘Municipal Ecological Network and Urban Green and Open Space System’ of the Municipality of Milan, to assess consistency with existing or potential green infrastructure. (Aerial photos: Google Earth; map: Comune di Milano; edited by the authors).



4. Results

4.1 Presentation of Key Findings

The results of this investigation allow us to answer the initial research question preliminarily: it is possible to outline some correlations between urban morphology, potential biodiversity, and the level of accessibility and visibility of green spaces. These correlations concern, at the urban scale, some characteristics that may be crucial in defining the biodiverse potential of a given settlement form: (1) the variation in the compactness¹³ of the green surface and/or its articulation, and (2) the continuity conditions that the perimeter edges can establish with the elements of the adjacent urban fabric. During the study, important considerations emerged at the scale of the built plot: (3) the degree of permeability of the building front adjacent to the perimeter and, consequently, the possibility of ecological exchanges to and from the areas pertaining to the plots. The analysis of these characteristics with respect to the cases under study led to the identification of three recurring morphologies, which present different characteristics capable of generating different conditions for the potential development of urban biodiversity in terms of accessibility and visibility: the “Central Park”, the “Fluid Park”, and the “Garden Between Houses”. The study was limited to the Milanese context and a time range identified within the last 30 years.

5. Discussion

5.1 Interpretation of Key Findings

The results obtained from this study have enabled the development of an interpretative framework aimed at substantiating the initial hypothesis, namely the existence of a relationship between urban form and biodiversity. This framework also preliminarily defines an analysis method to evaluate a given settlement's biodiversity potential. The following paragraphs, therefore, present a series of considerations with potential implications for design practice, exploring the geometric reasons that make some settlement forms more predisposed to foster the development of organic components, enhance biodiversity, provide ecosystem services, and define highly accessible and visible urban public spaces. The main distinguishing aspects will be highlighted, initially at the urban scale and subsequently at the scale of each single plot. The analysis method developed has been applied to the urban transformations of the Milanese territory, although it is believed that it can be generalized. This has allowed the identification of some recurring morphological settings that respond to different quantitative and qualitative relationships between green spaces and built parts. The ability to recognize these different geometric settings has enabled us to reflect on the diverse potential that each morphology possesses in favouring (or hindering) the construction of a biodiverse urban environment and equitable access to the latter – inspired by parameters such as the 3-30-300 rule¹⁴ (Konijnendijk, 2021). Considering that this represents the inaugural step in a newly initiated and developing research line, some limitations and directions for future development are outlined.

5.1.1 Compactness / Articulation: Three Morphological Categories

Starting the morphological analysis at the urban scale, the first discriminator that allows categorisation is related to the degree of compactness (or articulation) assumed by the open green areas in relation to the built environment. A compactness index, resulting from the geometric ratio between the perimeter of the green area and the area itself, can give indication of the biodiversity potential of a given urban form, e.g. it quantifies the amount of green front per unit area. The increasing value of this ratio describes the transition from a more compact geometry to a more articulated one, approximating the ability of a given shape to generate areas of exchange with the peripheral built spaces, whether existing or planned. This first phase of the study, limited to the Milanese context and to a specific time period, identified three main categories that, although arising from the specific context of the study, exhibit a certain degree of

¹³ A compactness index can be defined by the ratio of green area perimeter to green area.

¹⁴ Applying the 3-30-300 rule can help improve urban forestation in many cities, promoting health, wellbeing, and resilience. The rule suggests that every citizen should be able to see at least three trees (of a decent size) from their home; that in every neighborhood a minimum percentage of 30% of tree canopy cover can ensure that residents benefit in terms of health and wellbeing; a maximum distance of 300 metres to the nearest green space can encourage the recreational use of green space with positive impacts for both physical and mental health. See Konijnendijk, C. (2021). The 3-30-300 Rule for Urban Forestry and Greener Cities. In *Biophilic Cities Journal*, 4(2).

generalisation: the “Central Park”, the “Fluid Park”, and the “Garden Between Houses”. These three morphological categories present different compactness and connectivity levels to different elements and urban environments, potentially creating the spatial conditions for the development of urban biodiversity.

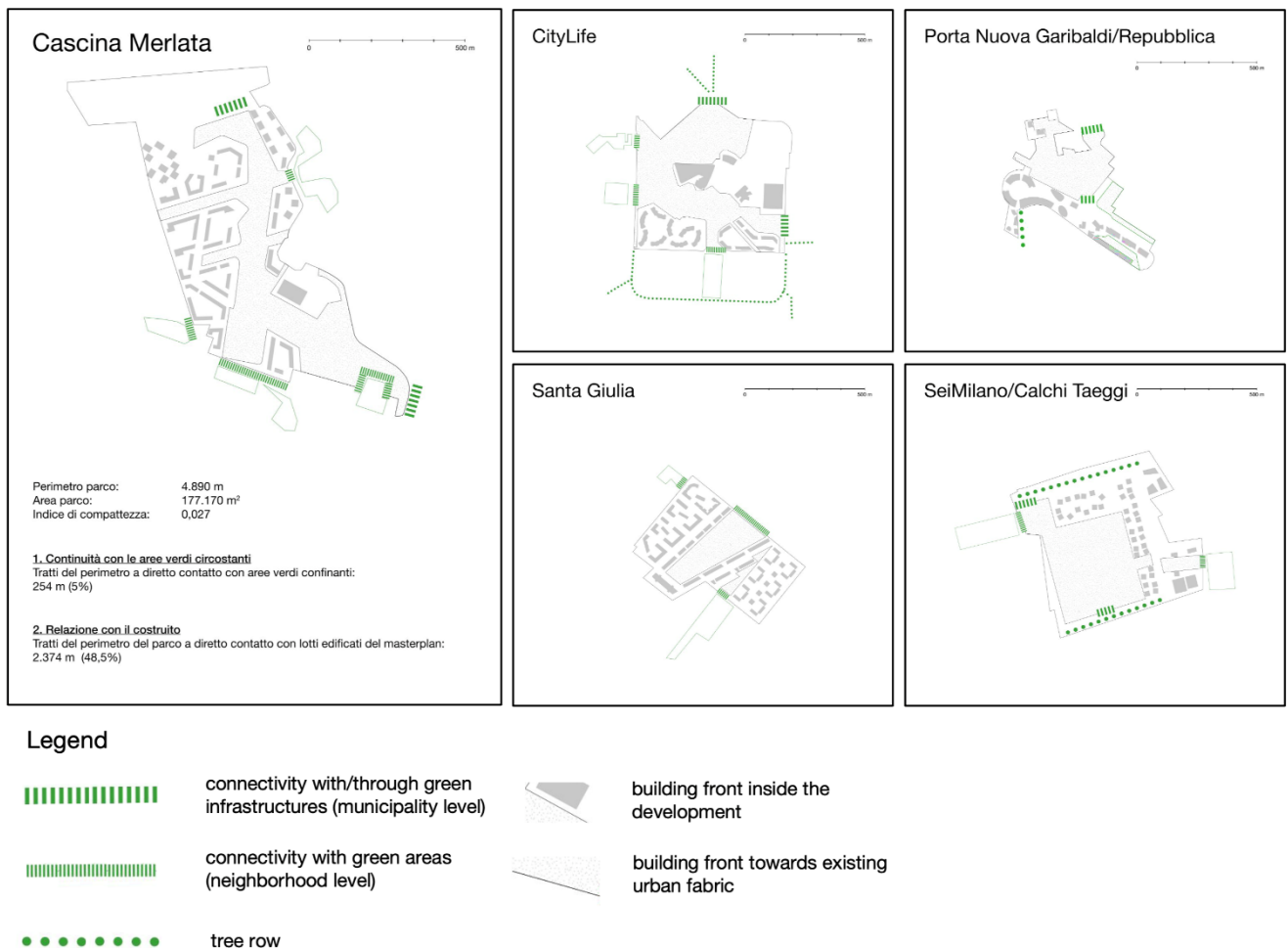


Figure 7. Example of graphical results of the proposed analysis method. The perimeter of the open space is drawn with different graphic symbols to highlight the connectivity with the different elements and the tangency with the different urban environments. (Drawings by the authors with Michele Porcelluzzi).

The “Central Park” features settlement forms that clearly distinguish between the areas allocated to the public park and built lots (mainly residential). In this case, the large green space presents a compact geometry characterized by a low perimeter-to-area ratio. In the most representative cases, the use of a regular form prevails, aspiring to define a recognisable and identity-bearing geometry. Among the characteristics of this settlement form, the reduced perimeter relative to the green surface tends to concentrate and limit contact points with the built environment (newly constructed or belonging to the existing urban fabric) and territorial systems. Additionally, greater geometric compactness correlates with an increased average depth separating from the edge to the park’s centre, creating conditions favourable to biodiversity – for example, reducing light or noise pollution in the park’s core. For this same reason, however, green areas farther from inhabited zones are less frequented at night, which can lead to safety concerns. Examples in this category include the completed interventions of Garibaldi-Repubblica and Calchi Taeggi and the park planned by the Santa Giulia district masterplan, partially realised today.



Like the previous category, the “Fluid Park” refers to settlement forms that define a clear distinction between the areas allocated to the public park and built lots. Unlike the previous case, the “Fluid Park” presents a complex, articulated geometry, resulting in a long perimeter in relation to the enclosed area. In the most representative cases, the perimeter presents a complex and branched geometry that tends to maximize contact points with the surrounding built environment and territorial systems, facilitating the reconnection of natural elements. Compared to the “Central Park” model, this condition can offer more benefits for ecological connectivity at both the neighbourhood and metropolitan scales and greater accessibility and visibility between the park and the built volumes. Examples of this category include the City Life and Cascina Merlata interventions.

A third category emerged from the initial selection of case studies. Even if it was not analysed in detail in the five case studies, it emerged as relevant and will require future investigation. Unlike the previous categories, the “Garden Between Houses” refers to settlement forms that do not clearly distinguish between areas allocated to the park and the built lots. This approach does not introduce a large, autonomous park separate from the built lots, but promotes a more homogeneous and integrated distribution between green spaces and built volumes. In contrast to the previous cases, where there was a concentration of overall volumes in densely built lots with limited spaces for nature, this third category involves a more horizontal distribution of building density and green spaces. With equal overall volumes, the built environment can be developed on a smaller scale, with open spaces more closely resembling a neighbourhood garden: an articulated network of houses and gardens for local use rather than an urban park. This morphological category allows for small-scale green development, which does not necessarily enhance ecological connectivity on a metropolitan scale but can generate local or neighbourhood-scale biodiversity or the possibility to experience biodiversity in domestic outdoor spaces (Uwajeh & Ezennia, 2018), supported by various private frontages (Beumer & Martens, 2015). Integrating green spaces with inhabited areas results in high accessibility, visibility, and safety — both real and perceived — and can benefit from informal surveillance by residents. Examples include the interventions in Figino, Merezzate, and Crescenzago.

5.1.2 Continuity Conditions along the Edge

The proposed analysis method includes a qualitative examination of how the edges along the perimeter of green surfaces are designed. Characterising these edges allows for the description, through quantitative data (percentage of perimeter length) and qualitative planimetric diagrams, of the capacity generated by a given settlement form to interact with (1) primary elements of ecosystem continuity, such as existing ecological corridors and/or green infrastructures at the municipality level, environmental networks, and biodiversity nodes; (2) secondary elements, such as roadside trees or arboreal areas covering parking spaces and green areas at the neighbourhood level; (3) building fronts belonging to the same settlement system or referring to the surrounding urban fabric. The greater a settlement form’s ability to introduce continuity conditions along green surface edges, generate or strengthen ecosystem networks, and interact with the built environment, the greater its biodiversity potential.

5.1.3 Permeability of Built Fronts

A second complementary analysis must be introduced to complete these initial considerations, focusing on the internal morphology of individual built lots. This internal morphology can vary independently of the overall settlement scheme and the geometry assigned to the green surface, impacting ecosystem continuity along the edge. The settlement forms adopted within the lots are clearly influenced by the quality of frontages and the potential relationships the built environment can establish with the surrounding context. Different morphological choices can thus exploit these opportunities to varying degrees, either limiting or multiplying them. The distribution of volumes can propose either closed geometries, defining discontinuous and introverted courtyards, or permeable geometries, where the heart of the lots is in continuity with the surrounding open space system. In these cases, the biodiversity potential



varies depending on a series of interrelated geometric factors impacting the quality of open space between buildings. Designing a permeable building front, for example, involves repositioning volumes to free up the plot's edge. In purely geometric terms, these volumes can find new placement by increasing in height or occupying internal open spaces within the plot. These choices impact aspects such as the presence of trees or shrubs (whether in open ground, planters, or pots) within the lot's depth, as well as the shading and usability conditions of the open spaces themselves. The analysis at this scale was implemented using a taxonomic approach, extracting from the selected urban transformations a number of samples able to represent the most recurring typical conditions.

5.2 Limitations and Implications and Future Directions

As stated, the study does not explicitly consider variables such as management, choice of plant species, or maintenance, nor does it measure biodiversity in any of the cases. The considerations primarily focus on spatial configuration. In this initial study phase, some possible additional morphological categories were excluded, such as modernist open-plan estates. Over the past 30 years, the international trend in Milan, as well as much of the continent, has followed settlement schemes proposing the idea of the *îlot ouvert* (Lucan, 2012), based on a clear identification of buildable lots, generally for private use, interspersed with networks of roadways and public spaces. Open-plan systems, characterised by single buildings distributed over entirely public, often predominantly green, land crossed by pedestrian and vehicular paths, refer to an earlier era of development recurring in Milan within Public Residential Housing contexts. Expanding the initial sample, both geographically and temporally, could, therefore, subsequently reveal additional categories. Future developments of this study, therefore, involve applying to the methodology to other architectural and urban typologies to assess their conduciveness to urban biodiversity.

6. Conclusion

In conclusion, based on the case study analysis and the results that emerged, this research suggests that within the context of large urban transformations involving changes in settlement layouts and new developments adjacent to established urban fabrics, there are no single morphologies definitely more suitable than others for conserving, promoting and implementing urban biodiversity while maintaining accessibility and visibility for citizens. Instead, different morphologies create different conditions that are potentially more favourable to specific objectives. This answers the research question and confirms the initial hypothesis about the possibility of identifying a morphological definition of urban open spaces that can foster the development of organic components, enhance biodiversity, provide ecosystem services, and define highly accessible and visible urban public spaces.

The study unveils how certain morphologies, with specific conditions, can be more suitable for conserving, promoting, and implementing urban biodiversity in specific spatial conditions within the surrounding urban fabric. Although it requires further study, this result is significant on several levels: it provides a possible decision-making tool for architects and urban designers for planning urban spaces to support green infrastructure networks. It also allows the examination of different design options to understand which can increase urban biodiversity, both in support of green infrastructure and as a qualitative factor in building development. This can have implications for quality of life by considering the accessibility and visibility of green spaces in new buildings or in urban and environmental regeneration actions.

Due to the complexity and diversity of variables in the analysed case study, the research scope was limited to analysing open space morphology at the urban scale, deferring an in-depth study at the building plot level to future studies. Another aspect not investigated concerns those factors interacting with morphology in determining the effective conservation, promotion and implementation of urban biodiversity, such as the choice of plant species, the positioning of species, maintenance, and user behaviour in the open spaces, among others. Furthermore, within this study, biodiversity is not measured but rather considered in the spatial characteristics that affect its development.



Another perspective of this research involves identifying issues related to the green transition of urban public spaces from an interdisciplinary perspective. This aims to identify interaction points among different areas of expertise. Future perspectives include transferring and verifying this method to other architectural and urban typologies to assess their conduciveness to urban biodiversity and in contexts other than Milan. This will help examine potential variables related to changes in the scale of the investigation context and/or different planning layouts. It will also verify the method in built environments characterized by settlement schemes from different historical periods, opening up further studies on the possibilities of intervention in the built environment by introducing or intensifying green landscapes. These perspectives contribute to refining and solidifying the methodology, making it not only an analytical tool but also a predictive one.

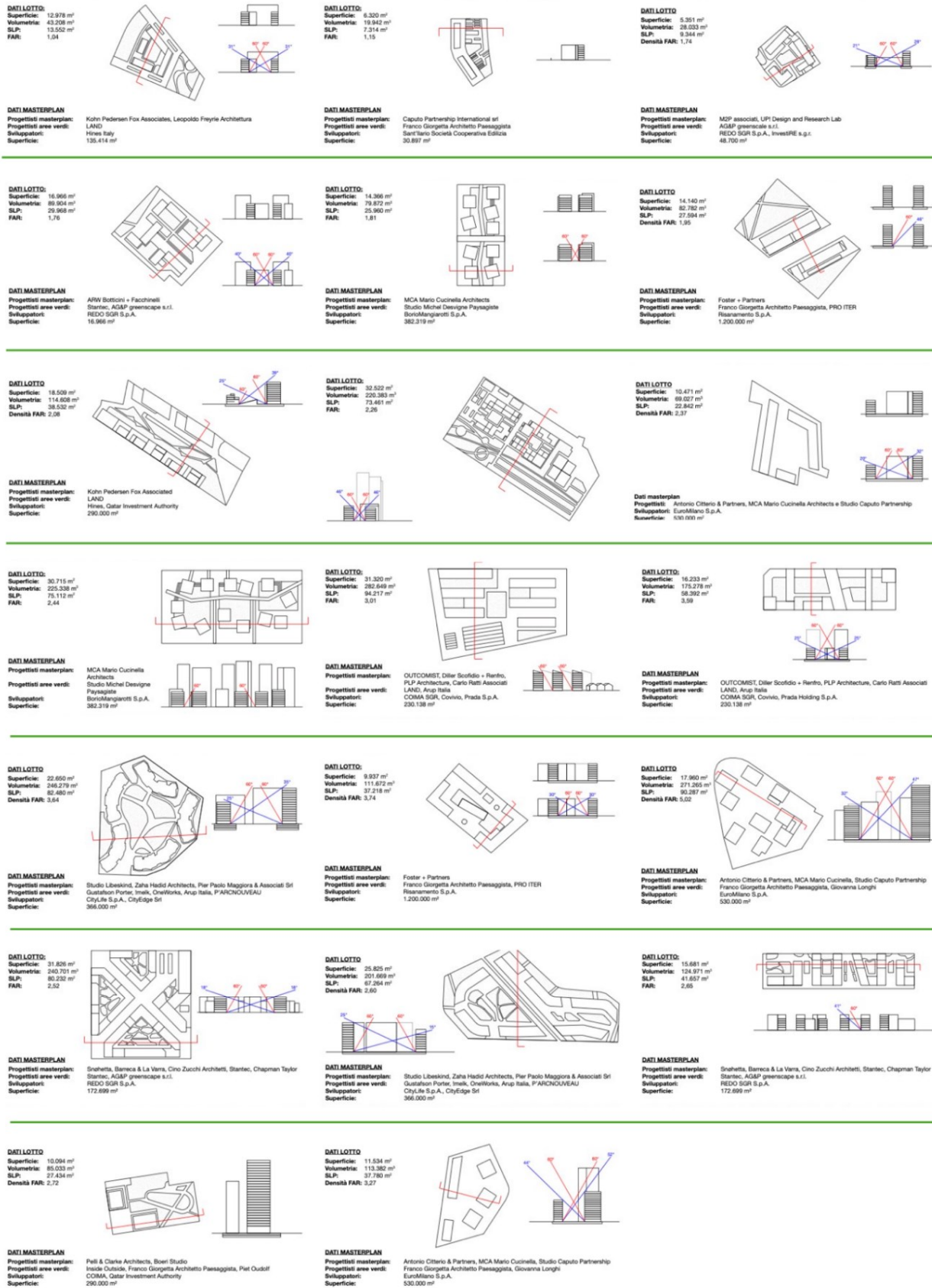


Figure 8. Morphological analyses of a sample of representative built plots extracted from the case studies to interpret the permeability of the built fronts. (Drawings by the authors with Michele Porcelluzzi).



Implications of the Findings

This study and its potential developments highlight the largely unexplored yet crucial role that architectural and urban composition, particularly morphological definition, can play in conserving, promoting, and implementing urban biodiversity while ensuring accessible public spaces. By identifying the correlation between urban morphology and biodiversity potential, this research contributes to the field of architectural and urban design and urban studies by shedding light on the role that architectural composition and urban design – and, therefore, architects and urban designers - can play in the emerging challenge of designing urban spaces aimed at conserving and enhancing urban biodiversity and facilitating ecosystem services provision.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data availability statement

The original contributions presented in the study are included in the article. Further inquiries can be directed to the corresponding author.

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F.L. and F.Z. share first authorship rights; the order is purely alphabetical. Conceptualization and methodology: F.L. and F.Z. Writing: Part 1, 6: F.L. and F.Z. Part 2, 3: F.Z. Part 4, 5: F.L. The figures, unless otherwise indicated, are elaborated by the authors. Both authors have read and agreed to the published version of the manuscript.

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Original scientific paper

Comparing FAHP and FANP Methods in Locating Multi-storey Parking Sites Shiraz's CBD

*1 Alireza Dehghani , 2 Ali Soltani

¹ Department of Urban Planning Faculty of Art & Architecture Shiraz University, Shiraz, Iran

² FHMRI, Flinders University, South Australia, 5042, Australia

¹ E-mail: alireza.dehghani@shirazu.ac.ir , ² E-mail: ali.soltani@flinders.edu.au



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ABSTRACT

The substantial rise in automobile ownership and expansion of metropolitan areas in recent decades, especially in emerging nations, has resulted in a severe shortage of parking spaces. This problem not only causes significant traffic congestion and an increase in accidents but also places a considerable financial burden on individuals and worsens air pollution. Despite extensive research on addressing the parking issue, there is still a notable deficiency in effective approaches for selecting the best locations for multi-story parking structures, particularly in major cities in Iran. Hence, acknowledging the significance of effective parking management in addressing these problems, This study aimed to provide a comprehensive framework for choosing parking locations in Shiraz's business district. This study combined the Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) with a Geographic Information System to make fuzzy multi-criteria decisions. In determining acceptable locations, numerous aspects such as closeness to business hubs, distance from key roads, land prices, population density, and the feasibility of erecting multi-story parking structures were taken into account using these approaches. The findings revealed that districts 13, 14, 15, 16, 17, and 18 in Shiraz's core area had the most potential for the construction of multi-story parking facilities compared to the other 30 central districts. Additionally, the findings showed that accessibility to major roads, population density, and proximity to trip generators were the most relevant factors in deciding where parking facilities should be located in Shiraz. When the results of the two approaches were compared, it was found that while the models' results were basically similar, the AHP model's user-friendliness made it easier for urban managers and planners to understand and apply. Policymakers and urban planners can use the insights provided by the outcomes of these models to make well-informed decisions on parking infrastructure expenditures.

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Highlights:

- Developed a comprehensive decision-making framework using AHP, ANP, and GIS for optimal parking site selection.
- Demonstrated the practical superiority of the AHP model for urban planning due to its user-friendly nature.
- Provided actionable insights for policymakers to enhance strategic investments in Shiraz's parking infrastructure, reducing congestion and pollution.

Contribution to the field statement:

This study introduces a novel decision-making framework integrating AHP and ANP with GIS for optimal parking site selection, specifically targeting Shiraz, Iran. By addressing a critical gap in effective urban parking management, the research provides actionable insights for policymakers and urban planners, thereby enhancing strategic investments in parking infrastructure and contributing significantly to urban transportation planning literature.

*Alireza Dehghani:

Department of Urban Planning, Faculty of Art & Architecture, Shiraz University, Shiraz, Iran

Email address: alireza.dehghani@shirazu.ac.ir

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1. Introduction

Parking problems in Central Business Districts (CBDs) have become a pressing urban challenge, characterized by high demand and limited supply of parking spaces. This imbalance leads to traffic congestion, reduced accessibility, and negative economic impacts on businesses (Agrawaal et al., 2024; Hussein, 2018; Kimpton et al., 2021; Ma & Mészáros, 2024). The issue stems from increasing vehicle ownership, limited space in city centers, and the attractiveness of CBDs for work and leisure activities (Dehghani et al., 2023; Louafi, 2019; Parmar et al., 2020). Resolving these issues is essential to preserving city centers' economic vibrancy and enhancing urban mobility. Cities must strike a balance between meeting immediate parking needs and promoting long-term sustainable urban development, often requiring innovative solutions and integrated urban planning strategies that consider both demand management and supply enhancement.

The supply side of parking solutions, particularly multi-story parking structures, is essential to solving the parking issues that CBDs encounter. (Aljohani et al., 2021; Chen et al., 2023). Multi-story car parks have emerged as an innovative and efficient solution to maximize parking capacity in limited urban spaces (Christiansen et al., 2017; Demir et al., 2021). These structures can accommodate a large number of vehicles vertically, significantly increasing the parking supply without consuming extensive horizontal land area (Kafrawy et al., 2022).

Locating suitable parking infrastructures has been an attractive topic for recent scholars. The growing interest in this topic among scholars and urban planners is driven by the increasing demand for efficient parking solutions in densely populated areas, particularly CBDs (Demir et al., 2021; Fard & Moghaddam, 2019). Multi-Criteria Decision Analysis (MCDA) combined with Geographic Information Systems (GIS) has become one of the most effective techniques for site selection. (Feyzi et al., 2019; Givi, 2015; Jonuzi et al., 2023; Kulinich & Lee, 2016). For instance, Jelokhani-Niaraki and Malczewski (2015) demonstrated the effectiveness of combining GIS with the Ordered Weighted Averaging (OWA) method to analyze multiple factors such as traffic load, land availability, and parking demand. This approach allows for a more nuanced evaluation of potential parking sites by visualizing spatial relationships and considering various weighted criteria simultaneously. Because fuzzy logic models can manage the inherent uncertainties in urban environments, they have become more and more popular in recent years. (Li et al., 2009; Mohammadzadeh et al., 2018; Noor et al., 2017; Wang et al., 2018). This method enhances the accuracy of site selection by accounting for the complex interplay between different urban variables. Optimization algorithms represent another significant strand of research in parking infrastructure location. The work of Choi and Lee (2023) on the Analytical Parking Planning Model (APPM) for Shared Autonomous Vehicles (SAVs) exemplifies this approach. Their model considers various planning scenarios to determine the optimal density and distribution of parking stations, taking into account both macroscopic urban characteristics and inter-zonal passenger trips. Advancements in technology have led to the increased use of predictive and responsive data in parking management. Enríquez et al. (2024) investigated the use of machine learning (ML) and artificial intelligence (AI) in processing real-time data from car sensors to forecast parking availability. This approach not only helps drivers find parking more efficiently but also provides valuable insights for urban planners in optimizing the location and management of parking infrastructures.

Recent urban planning literature has placed a great deal of emphasis on the use of the Fuzzy Analytic Hierarchy Process (FAHP) and Fuzzy Analytic Network Process (FANP) in the selection of parking sites. (Amari et al., 2023; Baseri et al., 2012; Darani et al., 2018; Dehghani & Soltani, 2023; Feyzi et al., 2019; Givi, 2015). These advanced decision-making methods incorporate fuzzy logic to address the inherent uncertainty and complexity in urban environments (Abdi & Soltani, 2022; Soltani & Marandi, 2011). FAHP extends the traditional Analytic Hierarchy Process by using fuzzy set theory to evaluate and prioritize potential parking locations based on multiple criteria, such as proximity to commercial areas, traffic density, and accessibility. It allows for a more nuanced evaluation of alternatives by accounting for the vagueness in expert judgments (Givi, 2015; Ishizaka, 2014; Jonuzi et al., 2023; Kubler et al., 2016). FANP, on the other hand, offers a more sophisticated approach by considering the interdependencies

among decision criteria, capturing the complex relationships between various factors affecting parking location decisions (Mohammadzadeh et al., 2018; Wang et al., 2018). Both methods have been successfully integrated with Geographic Information Systems (GIS) to enhance spatial analysis and visualization of potential sites (Soltani et al., 2019). As urban areas continue to grapple with parking challenges, FAHP and FANP provide robust frameworks for urban planners to make more informed decisions about parking infrastructure placement, contributing to improved urban mobility and reduced traffic congestion.

The CBD of Shiraz in Iran faces significant parking challenges, characterized by high demand and limited supply of parking spaces (Soltani, 2017). This imbalance leads to traffic congestion, reduced accessibility, and negative economic impacts on businesses and residents. Despite the critical nature of this issue, there is a noticeable lack of comprehensive studies focused specifically on Shiraz's CBD parking problems (Dehghani & Soltani, 2023; Panahi et al., 2022; Sodagaran et al., 2016). Addressing these challenges requires a multifaceted approach that incorporates advanced decision-making methodologies, integrates emerging technologies, and considers environmental and economic factors. The lack of comprehensive, localized studies presents a significant research gap that needs to be filled to develop effective and sustainable parking solutions for Shiraz. To rectify this gap, this paper addresses the underutilization of the Spatial Decision Support System (SDSS) method despite the extensive research on parking site selection of Shiraz's CBD.

The objective of this project is to integrate quantitative and geographical approaches for determining ideal parking site placements inside the Shiraz CBD in Iran. Specifically, this will be achieved through the integration of an MCDM approach with the FAHP and Fuzzy Analytic Network Process FANP. The use of trustworthy GIS data in combination with arbitrary expert judgments strengthens the study's robustness. Through the demonstration of a combined method that combines fuzzy MCDM techniques with spatial analytic capabilities, this study makes a substantial contribution to the body of literature by providing decision-makers with extensive information to support effective decision-making procedures.

The research objectives aim to tackle the existing parking demand in Shiraz's CBD by developing a systematic approach to assessing the shortage of public parking spaces and devising an MCDM method to identify the optimal sites for constructing multi-story parking facilities.

The research aims to address multiple important inquiries:

- How can the integration of SDSS with MCDM approaches, specifically FAHP and FANP, improve the identification of optimal parking site locations in Shiraz's CBD?
- Where should multi-storey parking facilities be built in Shiraz's CBD using the proposed MCDM to determine the most suitable locations?
- Finally, how can the findings of this study inform policymaking and regulation to address parking challenges in Shiraz's CBD?

The structure of this document consists of the methodologies employed to compute the parking needs are described in Section 2, along with the strategy for employing fuzzy MCDM and GIS to identify the best places for multi-story parking. The case study area is introduced in Section 3, along with the locations of the parking spaces that are currently allocated within the traffic area zones. In Section 4, The techniques used to calculate the parking balance The methodologies employed to compute the parking balance and the MCDM technique are discussed in detail, and a map showcases the best locations for multi-story parking developments. The findings and their consequences for regulation and policymaking in resolving Shiraz's parking issues are explained in Section 5. In conclusion, Section 6 offers some final thoughts and suggests possible directions for further research.

2. Case Study

One of Iran's largest cities, Shiraz, faces considerable urban issues even though The percentage of automobiles owned in this country is smaller compared to affluent nations. Notably, there are a lot of accidents, Environmental contamination caused by the presence of harmful substances in the air, excessive sound levels, and traffic jams in the city. Shiraz's land size increased from 6,000 to 15,600 hectares and

its population experienced growth from 0.85 million in 1986 to 1.8 million in 2016. The city has experienced significant growth, transitioning from a traditional bazaar-centered development to a contemporary metropolis characterized by extensive road networks (Dehghani & Soltani, 2023). The CBD of Shiraz, an area plagued by various traffic issues, notably exacerbated by on-street parking due to inadequate parking facilities. The CBD of Shiraz spans approximately 800 hectares, with 88 kilometres of roads comprising 5.5% of the total area, and encompasses 30 Traffic Analysis Zones (TAZs) (Damadam et al., 2022; Sodagaran et al., 2016). Nonetheless, the Shiraz CBD faces particular difficulties, such as constrained parking and road areas, stringent vertical zoning laws, and notable non-residential land uses including medical facilities and college campuses. The problem of parking scarcity is exacerbated by the lack of available land parcels, which calls for solutions like multi-story parking structures and enhanced public transportation. Ineffective public transportation systems also play a role in the prevalence of driving, which clogs roads even more as cars look for parking spots. Shiraz's TAZs and public parking locations are shown in Figure 1.

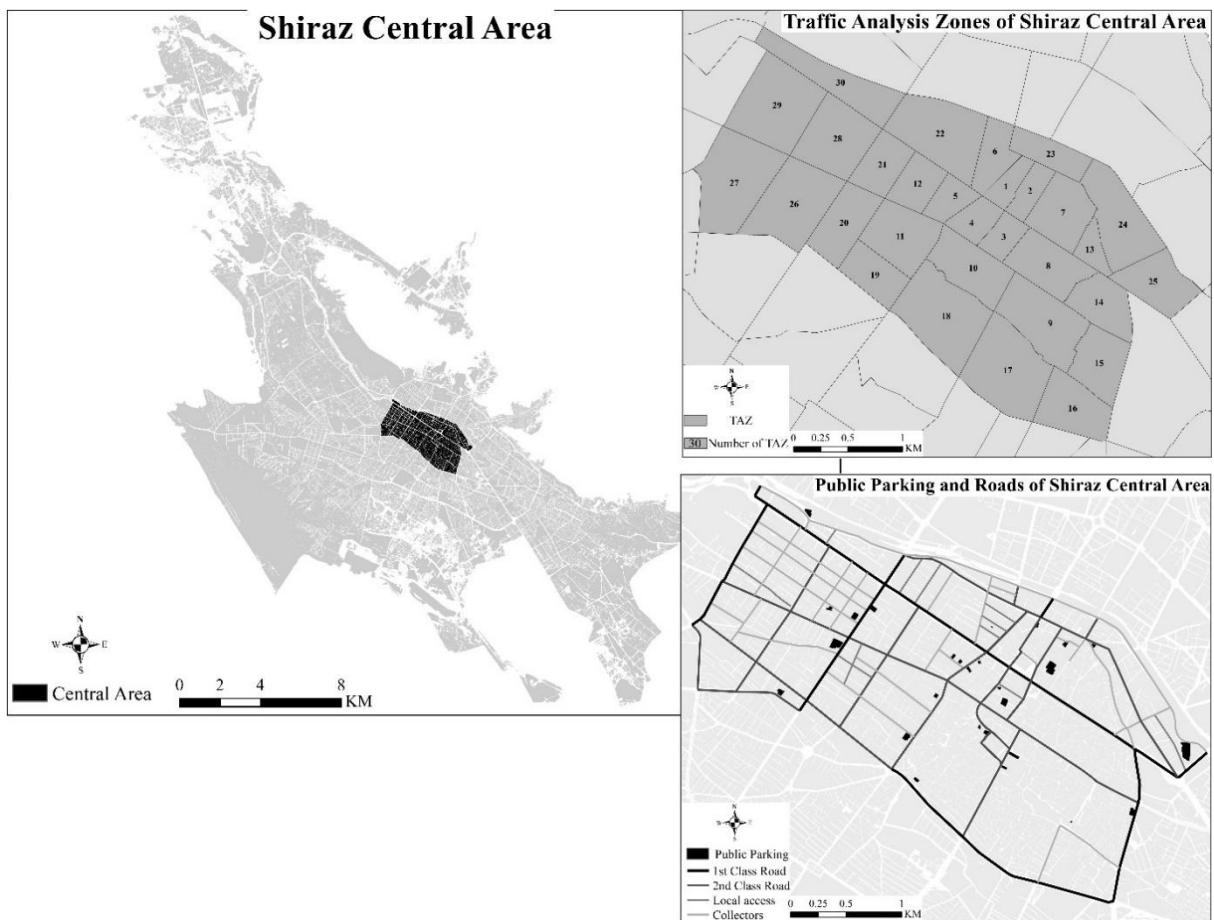


Figure 1. Location of TAZs and public parking in Shiraz central area.

3. Material and Methods

The research process (Figure 2) for finding optimal locations for multi-story parking facilities in Shiraz's CBD can be summarized in four steps:

Data Collection: This stage involves examining the current state of Shiraz's city centre, including traffic patterns, existing parking options (both on and off-street), and road slopes. Data is collected from official sources like the city's comprehensive plan and municipality maps.

Identifying Suitability Factors: Here, experts familiar with Shiraz identify factors that make a location suitable for a new parking facility. This data is likely gathered from sources like the Shiraz's comprehensive plan and municipality.

Weighting Factors using FAHP and FANP: In this stage, experts use two methods, FAHP and FANP, to determine the relative importance of each suitability factor.

Mapping Suitable Locations: Finally, GIS software (ArcMap) is used to combine the data collected in previous stages. This overlay method considers factors like weights and suitability and generates maps showing the most suitable locations for new parking facilities using both FAHP and FANP methods.

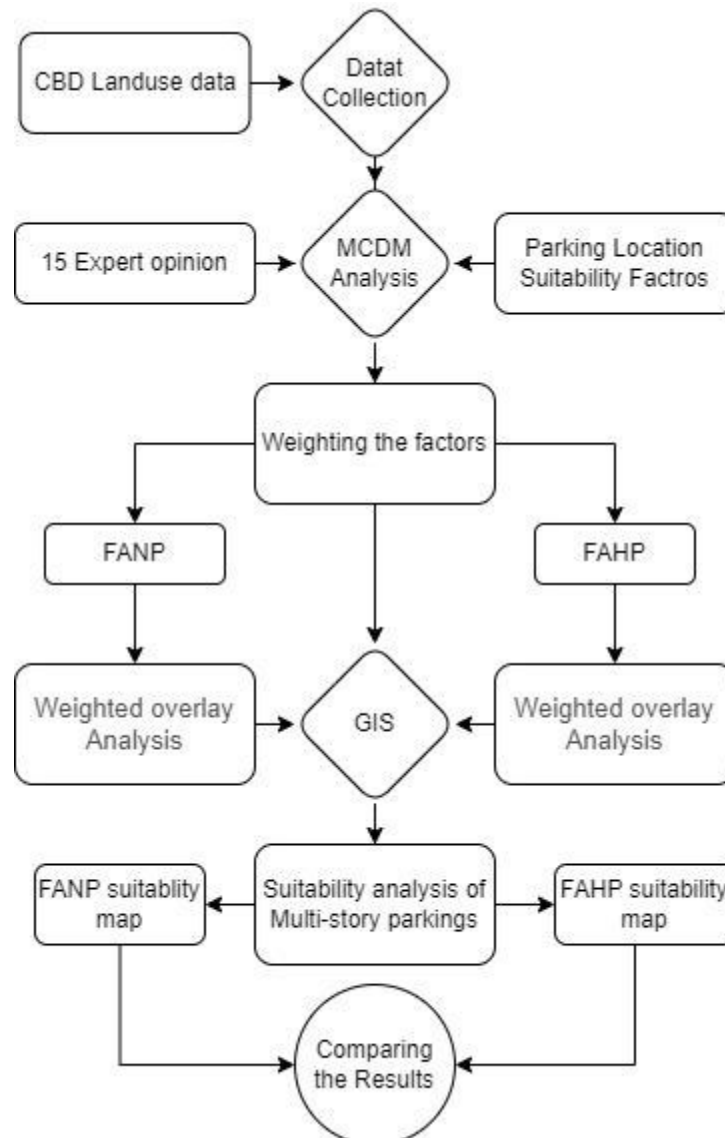


Figure 2. Research steps flowchart.

3.2. Factors affecting site selection of parking

A number of aspects that affect parking facilities' accessibility and efficacy are taken into account throughout the site selection process. Based on previous research and local expertise, five crucial elements were found (Table 1): the distance to roadways, the cost of the property, the population density, and the amount of land that can be used for multi-story parking (Amari et al., 2023; Demir et al., 2021).



Table 1: Influencing factors and data sources.

Factors	Data Sources
Distance to travel attraction centres	Derived from Shiraz municipality land use map
Distance to roads	Derived from Shiraz municipality traffic map
Land price	Derived from Shiraz master plan
Population density	Derived from Shiraz master plan
Available land for multi-storey parking structures	Derived from Shiraz municipality land use map

Distance to travel attraction centers: This component recognizes the value of accessibility to a range of facilities and services, including places of business, government, religion, health care, education, culture, and recreation. Parking facilities must be close to these attractions in order to handle the large number of journeys that are made in these locations (Al Razib & Rahman, 2017; Baseri et al., 2012). An extensive inventory of travel attraction centers, including business, administrative, religious, medical, educational, cultural, and recreational amenities, was carried out in order to construct this layer. After that, point data was created by compiling and digitizing the geographic coordinates of these centers. The Euclidean distance between each grid cell in the research region and the closest attraction center was then determined using a distance analysis. Lower values indicate closer proximity to the nearest travel attraction center, and this is represented by the resulting raster layer. This layer is essential for determining how easily accessible and convenient potential parking facility locations are to different services and facilities, which in turn affects the site's overall acceptability.

Distance to roads: It is imperative to locate parking spaces close to collector and arterial highways in order to promote their use and adherence to parking laws. Increasing the quantity of parking spots close to these routes can reduce traffic jams and discourage vehicles from parked improperly (Bock & Sester, 2016; Christiansen et al., 2017). A distance to the roadways layer was made in order to evaluate this factor. Lower values indicate closer proximity. This layer computes the Euclidean distance between each grid cell and the closest road. It is feasible to discover locations that provide easy access to the road network by including this layer in the weighted overlay analysis, which enhances the parking facility's overall usefulness.

Land price: The selection of sites for multi-story parking lots is heavily influenced by the land's worth. Classifying land prices into low, medium, and high categories based on current market rates (Figure 3) helps determine feasible locations for parking development (Inci, 2015; Wang et al., 2020). This classification provides a qualitative assessment of land cost, enabling a preliminary evaluation of financial feasibility. Areas with lower land prices are generally more attractive for parking facility development due to reduced initial investment. However, it is essential to consider other factors beyond land cost, such as location, accessibility, and demand, when making final decisions.

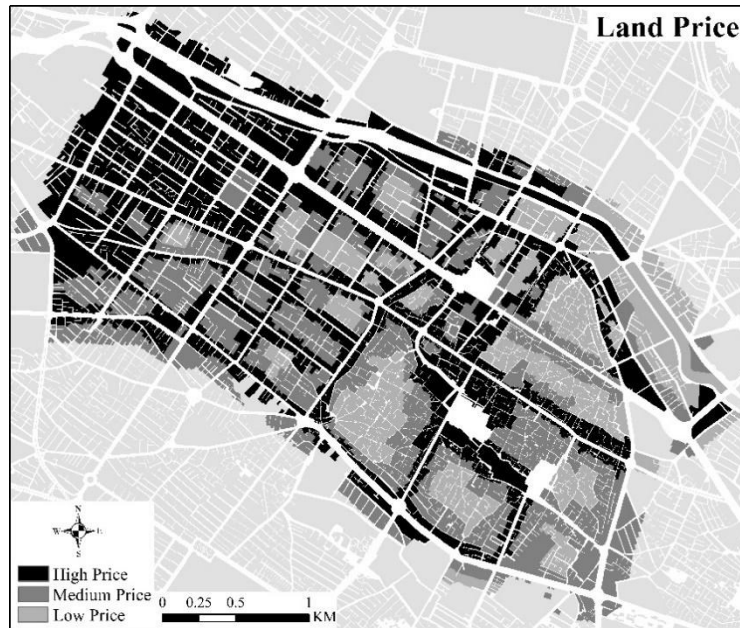


Figure 3. Land price classification map of Shiraz's CBD.

Population density: The main determinant of appropriate locations for multistory parking is population density. By analyzing demographic data and considering areas with varying population densities (Figure 4), planners can prioritize locations where parking demand is high and organize parking infrastructure accordingly (Liu et al., 2017; Scheiner et al., 2020). Initially, population data was sourced from authoritative demographic databases, ensuring data accuracy and reliability. This dataset was meticulously examined for inconsistencies, errors, and missing values, which were rectified to maintain data integrity. Subsequently, the population data was spatially referenced and converted into a raster format to align with the other geographic layers used in the analysis.

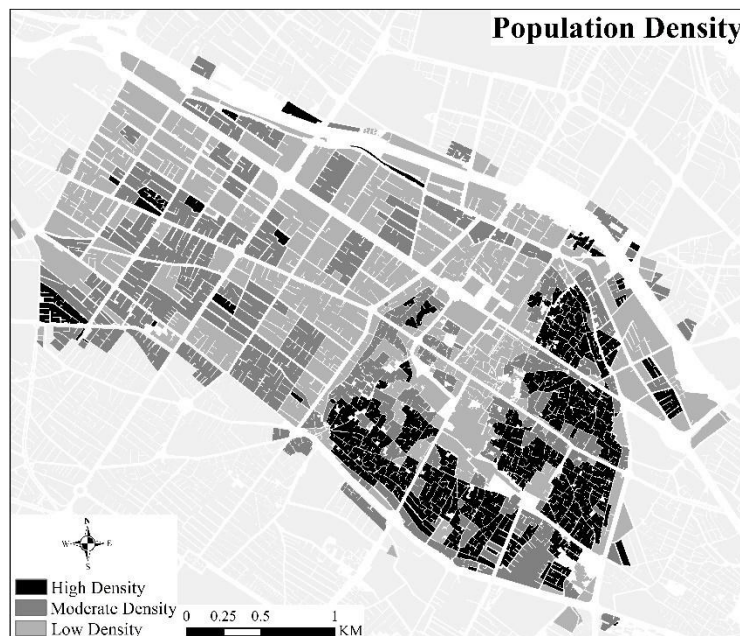


Figure 4. Population density classification map of Shiraz's CBD.

Available land for multi-storey parking structures: Urban growth and traffic management depend heavily on the availability of adequate space for the construction of multistory parking facilities (Figure

5). Analyzing various urban places, including abandoned buildings, garages, and wasteland, can assist find viable parking construction sites without negatively impacting other urban elements.



Figure 5. Available land for multi-storey parking construction in Shiraz's CBD.

3.3. Weighting with MCDM methods

The FAHP and Fuzzy Analytic Network Process (FANP) are sophisticated techniques utilized in multi-criteria decision-making processes, particularly in scenarios characterized by uncertainty and imprecision (Ishizaka, 2014). FAHP extends the traditional AHP by incorporating fuzzy logic to handle vague or ambiguous information, allowing for more nuanced decision-making in complex situations where precise numerical values may be challenging to obtain (Vinogradova-Zinkevič et al., 2021). Similarly, FANP extends ANP by integrating fuzzy logic, enabling the modelling of complex networks of criteria and their interdependencies in a fuzzy environment (Mohammadzadeh et al., 2018; Vinogradova-Zinkevič et al., 2021). These techniques have been widely employed in various studies to address decision-making challenges in metropolitan settings, offering robust methodologies to navigate uncertainties and complexities inherent in urban planning processes.

Fuzzy logic is incorporated into the FAHP, an extension of the AHP, to address ambiguity and uncertainty in the decision-making process. The FAHP uses triangular fuzzy numbers (TFNs) to translate language concepts into mathematical expressions. The steps involved in FAHP can be described mathematically as follows (Kubler et al., 2016; Noor et al., 2017):

1. **Building the Matrix of Fuzzy Comparisons:**

A fuzzy comparison matrix is constructed using TFNs. For example, if we have a TFN represented as (l, m, u) , where l is the lower limit, m is the most likely value, and u is the upper limit, the comparison matrix would consist of these TFNs for each pairwise comparison.

2. **Matrix Consistency Examination:**

As with the crisp AHP approach, the consistency of the fuzzy comparison matrix is analyzed.

3. **Fuzzification and Defuzzification Processes:**

To create a priority vector, the fuzzification procedure entails transforming crisp values into fuzzy numbers, which are then defuzzified back into crisp scores.

4. **Normalization of Weight Vector:**

To ascertain the relative weights of the criteria or alternatives, the weight vector is normalized.

The mathematical expressions for operations on TFNs are as follows:

- **Addition:**
- $(l1,m1,u1)+(l2,m2,u2)=(l1+l2,m1+m2,u1+u2)$
- $(l1,m1,u1)-(l2,m2,u2)=(l1-l2,m1-m2,u1-u2)$
- **Scalar Multiplication:**
- $k \cdot (l,m,u)=(k \cdot l,k \cdot m,k \cdot u)$
- $(l,m,u) \cdot k=(k \cdot l,k \cdot m,k \cdot u)$
- **Multiplication:**
- $(l1,m1,u1) \cdot (l2,m2,u2)=(l1 \cdot l2,m1 \cdot m2,u1 \cdot u2)$
- $(l1,m1,u1) \cdot (l2,m2,u2)=(l1 \cdot l2,m1 \cdot m2,u1 \cdot u2)$
- **Inverse:**
- $(l,m,u)^{-1}=(1/u,1/m,1/l)$
- $(l,m,u)^{-1}=(1/u,1/m,1/l)$

The linguistic statements on the FAHP scale, which translate into matching TFNs for the comparison matrix, are "Equal importance," "Weak importance of one over another," "Essential or strong importance," "Very strong importance," and "Absolute importance." (Li et al., 2009).

A paradigm for making decisions called FANP expands the FAHP to networks in which components may be interdependent (Feyzi et al., 2019; Mohammadzadeh et al., 2018). The FANP involves the following steps:

1. **Building Pairwise Comparison Matrices:** To depict the relative importance of criteria or sub-criteria, fuzzy numbers are used in the construction of pairwise comparison matrices.
2. **Creating the Supermatrix:** Inner dependence matrices are created for each criterion, and a supermatrix is created to illustrate the interdependencies between the criteria.
3. **Computing Global Weights:** The local weights of the subcriteria and the interdependent weights of the associated criteria are multiplied to determine the global weights of the subcriteria.
4. **Fuzzy Inverse Matrix Derivation:** Various techniques, including Basaran's Method, ϵ -Inverse Method, Rohn's Scheme, and Zadeh's Extension Principle, are employed to derive the fuzzy inverse matrix.
5. **Weight Normalization:** To guarantee that the total weight is equal to one, the weights are normalized.

The mathematical formulation for deriving the fuzzy weights in FANP can be represented as follows (Wang et al., 2018):

- **Weight Normalization:** If t and u are any vectors such that $t = u \cdot W$ and W is a weight matrix, then the normalized weight P can be derived based on the equation
- $P = t / \sum t_i$

The steps in FANP can be diagrammatically represented as a flowchart, starting from the construction of pairwise comparison matrices, forming the supermatrix, calculating global weights, deriving the fuzzy inverse matrix, and finally normalizing the weights to obtain the final decision matrix.

The key differences between the FAHP and the FANP lie in their respective application domains and the complexity of decision-making scenarios they address. FAHP is primarily used for hierarchical decision-making structures, where criteria are organized hierarchically with clear top-down relationships. It is effective for evaluating alternatives against multiple criteria with varying levels of importance (Table 2). Conversely, FANP extends beyond hierarchical structures to model decision scenarios with interconnected criteria and feedback loops. It is suited for more complex decision



networks where criteria influence each other directly or indirectly. While FAHP is suitable for simpler structures, FANP is designed to handle higher levels of complexity in decision-making processes.

Table 2: Analysis of triangular fuzzy numbers and subjective expression within five distinct groups:

The quality	triangular fuzzy numbers	Inverse triangular fuzzy numbers
Equivalent	(1, 1, 1)	(1,1,1)
Approximately equivalent	(1, 2, 3)	(1/3, 1/2, 1)
Excellent	(3, 4, 5)	(1/5, 1/4, 1/3)
Extremely superior	(5, 6, 7)	(1/7, 1/6, 1/5)
Supreme	(7, 8, 9)	(1/9, 1/8, 1/7)

Fifteen professionals with backgrounds in civil engineering, traffic engineering, landscape architecture, urban planning, project management, and both the public and private sectors were given a questionnaire designed to gather expert opinions. The weights, FAHP, and FANP were computed with MATLAB. Expert opinions were represented by triangular fuzzy numbers. The weights of the criteria and sub-criteria were then calculated using the arithmetic mean of expert judgments. The center of gravity method was used to normalize and make these fuzzy weights non-fuzzy before they were finally assigned to the GIS layers. We used the FAHP, more especially Buckley's geometric mean technique, to rank and weight each criterion and sub-criteria.

Despite their strengths, FAHP and FANP possess inherent limitations. Both methods rely heavily on expert judgment, which can introduce subjectivity and inconsistency into the decision-making process. Additionally, defining clear and exhaustive criteria can be challenging, as it requires a deep understanding of the problem domain. Furthermore, the computational complexity of FANP, especially for larger-scale problems, can be a significant drawback. Both methods assume a static environment, neglecting potential dynamic changes in the factors influencing the decision.

3.4. Suitability analysis by Weighted overlay analysis (WOA)

Weighted Overlay Analysis (WOA) is a powerful geospatial technique employed to determine the optimal location for a specific purpose by evaluating multiple factors. It involves the integration of various thematic layers into a single output layer representing overall suitability. The core principle of WOA is the assignment of weights to each input layer, reflecting its relative importance in the decision-making process. These weights are numerical values that quantify the influence of each factor on the final suitability assessment. After weights are assigned, each raster layer's cell values are multiplied by the weight that corresponds to it. Subsequently, these weighted values are summed for each location to produce a composite suitability index. The resulting suitability map provides a visual representation of the study area, with higher values indicating locations that more closely align with the desired criteria. This method effectively integrates diverse and often conflicting factors, enabling a comprehensive evaluation of potential sites. WOA is frequently used to determine the best places for infrastructure, conservation areas, or agricultural land, among other things, in a variety of domains, including urban planning, environmental impact assessment, and natural resource management. In this study, we calculated suitability maps using the weights derived from both the FAHP and the FANP in ArcGIS pro-environment. By taking into account the intricate linkages between the evaluation criteria, we hoped to improve the appropriateness assessment's accuracy and reliability by implementing these multi-criteria decision-making procedures.

3.5. Locating possible, effective places with GIS

The criterion weights were linked to the layers using ArcMap, which allowed AHP and GIS to find possibly appropriate parking spots. Using GIS, each criterion was processed to provide maps, weights,

and rating scales based on the FAHP and FANP methodologies. The map of possible parking locations was subjected to an overlay analysis, and weights and rating scales for the sub-criteria were determined using the AHP technique. When assessing possible sites, it is necessary to take into account a few limitations, such as giving priority to lots that score the highest in each zone even if they are not historically or culturally significant and making sure that the geometric dimensions—such as length and breadth—are appropriate and that the total area is at least 1,200 m². The Natural Break method can be used to categorize a continuous weight and score into five groups: not appropriate (less than 0.25), less appropriate (0.25 to 0.35), somewhat appropriate (0.40 to 0.45), highly appropriate (0.45 to 0.50), and the most appropriate (more than 0.5). ArcMap made it easier to overlay criterion layers with varying weights.

4. Results

The results obtained from both the FAHP and the FANP provide valuable insights into the prioritization of criteria for site selection of multi-storey parking facilities (Figure 6).

In both methods, "Distance to travel attraction centers" emerges as the most influential criterion, highlighting the importance of proximity to key destinations such as administrative, commercial, religious, health, educational, cultural, and recreational centers. However, there is a slight variation in the weights assigned by FAHP (0.307) and FANP (0.254), indicating a nuanced difference in their prioritization. Similarly, "Distance to roads" and "Land price" are identified as significant factors in both approaches, albeit with some differences in the weights assigned. FAHP assigns higher importance to "Distance to roads" (0.188) compared to FANP (0.172), whereas FANP assigns higher importance to "Land price" (0.193) compared to FAHP (0.162). These differences may stem from the inherent characteristics of each method and the specificities of the decision-making context.



Figure 6. Weighting results of Factors.

Moreover, "Available land for multi-storey parking" and "Population density" also play crucial roles in both FAHP and FANP, although their relative importance varies slightly between the two methods. FAHP assigns a higher weight to "Available land for multi-storey parking" (0.185) compared to FANP (0.187), while FANP assigns a higher weight to "Population density" (0.203) compared to FAHP (0.155). This suggests that while both criteria are considered essential, their prioritization differs based on the method employed. Overall, the consistency ratios (CR) for FAHP (0.12) and FANP (0.13) indicate a satisfactory level of consistency in the decision-making process for both methods. However, the nuanced differences in the weights assigned to each criterion highlight the importance of considering multiple decision-making techniques and their respective outputs when making complex decisions such as site selection for multi-storey parking facilities.

Figures 7 offer detailed spatial insights into the assessment of prospective sites for parking infrastructure deployment. A comprehensive comparison of the findings derived from these two figures reveals a striking similarity in the outcomes produced by the respective methodologies. This alignment underscores the robustness and reliability of the analytical approaches utilized, affirming the consistency of the results across different evaluation techniques. Notably, Region 13 emerges as a standout candidate for the establishment of new parking facilities in both analyses, underscoring its strategic significance and optimal suitability for such development. Subsequently, regions 14, 18, 17, and 16 emerge as strong contenders for parking construction, demonstrating considerable potential for accommodating additional parking capacity. Moreover, a noteworthy pattern that emerges from the data is the strong inclination towards the southern areas of the research zone regarding their rating and appropriateness for the implementation of parking facilities. This spatial pattern suggests a compelling rationale for prioritizing parking development initiatives in the southern zones, potentially addressing localized parking demands more effectively while optimizing overall urban mobility and accessibility.

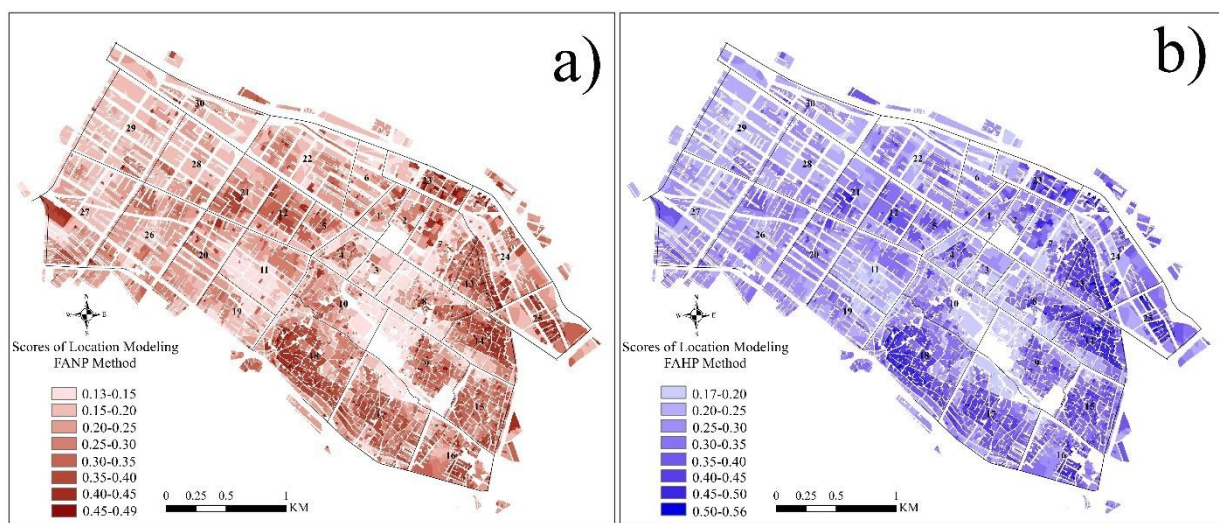


Figure 7. Final Suitability maps for (a) FANP and (b) FAHP results.

5. Discussion

Parking is a difficult and varied issue in highly populated city centers, like Shiraz, Iran's CBD. The results of this study make a substantial contribution to the corpus of knowledge already available on urban parking management and multi-story parking facility site selection. We have offered a thorough analysis of parking demand and supply dynamics in Shiraz's CBD by utilizing a combination of quantitative and geographical models, particularly a GIS-based Fuzzy MCDM framework.

Our results demonstrate that the integration of FAHP and FANP with GIS can lead to more rational, inclusive, and efficient decisions in parking site selection. Interestingly, both FAHP and FANP models yielded similar results in our case study. This finding aligns with the work of Jonuzi et al. (2023) who highlighted the trade-offs between simplicity and complexity in decision-making models. The similarity in results suggests that for this specific case, FAHP's faster processing and simpler structure might have been sufficient. This has important implications for decision-makers, as it indicates that in some cases, a simpler model can provide equally valuable insights with less computational complexity.

However, it is crucial to note that the choice between FAHP and FANP should be context-dependent. While FAHP offers advantages in terms of simplicity and computation speed, FANP remains valuable for more complex situations where interdependencies among criteria are significant. This finding contributes to the ongoing debate in the literature about the most appropriate MCDM methods for urban planning decisions (Jelokhani-Niaraki & Malczewski, 2015). Our study also highlights the potential of multi-storey parking structures as a viable solution to parking scarcity in urban centres. This aligns with the findings of Darvazeh et al. (2018), who emphasized the economic viability of developing parking infrastructure in



congested areas due to economies of scale. However, our research goes further by providing a methodological framework for identifying optimal locations for these structures, considering multiple stakeholders with varying priorities.

The implications of our findings for urban planning and policy are significant. The GIS-based Fuzzy MCDM framework we employed allows for a comprehensive analysis of potential parking facility locations, which can inform more effective urban planning strategies. This approach can help policymakers balance the need for parking spaces with other urban development goals, such as reducing traffic congestion and promoting sustainable transportation options. It's crucial to recognize our study's limitations, though. Only planners and transportation experts participated in the decision-making process, which may have excluded important input from users and customers. This limitation aligns with critiques in the literature about the need for more inclusive decision-making processes in urban planning (Kubler et al., 2016). Additionally, our focus on traditional supply and demand metrics may not fully capture emerging trends in urban mobility and sustainability.

The potential impact of our findings on urban mobility and infrastructure is substantial but requires further exploration. For instance, the strategic placement of park-and-ride (P&R) systems, as suggested by our results, could significantly reduce traffic congestion by encouraging commuters to use public transportation. This aligns with the work of Mei et al. (2020) who emphasized the importance of integrating parking solutions with broader urban mobility strategies. Furthermore, our study opens up several avenues for future research. The incorporation of additional data sources, such as Points of Interest (POI), could provide a more comprehensive understanding of parking utilization patterns. The application of optimization methods could further refine the identification of promising locations for parking facilities. Moreover, future studies should consider emerging concepts like carbon-zero cities, which suggest allocating parking based on vehicle emissions (Abdi & Soltani, 2022; Dehghani & Soltani, 2023).

6. Conclusion

In conclusion, this study makes several significant contributions to the field of urban parking management and site selection for parking facilities. Firstly, we have demonstrated the effectiveness of integrating GIS with Fuzzy MCDM methodologies for parking site selection in dense urban environments. This approach provides a robust, data-driven framework that can support more informed decision-making in urban planning. Secondly, our comparison of FAHP and FANP models provides valuable insights into the trade-offs between simplicity and complexity in decision-making tools. This finding can guide future researchers and practitioners in selecting appropriate methodologies for similar urban planning challenges. Thirdly, our study highlights the potential of multi-storey parking structures as a solution to parking scarcity in urban centres, while also providing a methodological framework for identifying optimal locations for these structures. It's crucial to recognize our study's limitations, though. Our analysis's breadth may have been restricted by the decision-making process's omission of user and customer viewpoints. Additionally, our focus on traditional supply and demand metrics may not fully capture emerging trends in urban mobility and sustainability. For policymakers and urban planners, our study provides several actionable insights:

- The use of GIS-based Fuzzy MCDM frameworks can significantly enhance the decision-making process for parking site selection.
- Multi-storey parking structures, when strategically located, can be an effective solution to parking scarcity in dense urban areas.
- The integration of parking solutions with broader urban mobility strategies, such as park-and-ride systems, can yield significant benefits in terms of traffic congestion reduction.
- A more holistic approach to parking management, incorporating environmental, social, and economic considerations, is crucial for developing sustainable urban mobility solutions.

Future research should build on these findings by:



- Incorporating a broader range of stakeholder perspectives, including consumers and users, in the decision-making process.
- Investigating the application of optimization methods to further refine parking site selection.
- Examining the potential impacts of emerging trends, such as autonomous vehicles and carbon-zero city initiatives, on parking demand and infrastructure requirements.
- Exploring the environmental impacts of parking infrastructure, such as urban heat island effects, and developing strategies to mitigate these impacts.

By addressing these areas, future research can continue to advance our understanding of urban parking challenges and contribute to the development of more efficient, sustainable, and user-friendly urban mobility solutions.

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

Data availability statement

Any additional data related to this study are available from the corresponding author upon reasonable request.

CRedit author statement:

Alireza Dehghani: Conceptualization; Data curation; Formal analysis; Methodology; Software; Visualization; Roles/Writing - original draft. Ali Soltani: Conceptualization; Writing - review & editing; Investigation; Supervision; Validation; Project administration. All authors have reviewed and approved the final version of the manuscript.

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Original scientific paper

Mapping Tomorrow's Cities: GeoAI Strategies for Sustainable Urban Planning and Land Use Optimization

*1 Amina Aidaoui , 2 Dr. Assoule Dechaicha , 3 Prof. Djamel Alkama , 4 Ikram Menai , 5 Dr. Hana Salah Salah

^{1,3,4 & 5}Department of Architecture, Faculty of sciences and technology, University of 08 mai 1945, Guelma, Algeria

² Urban Planning Department, Faculty of management of urban techniques, University of Mouhamed Boudiaf, M'sila, Algeria

¹ E-mail: aidaoui.amina@univ-guelma.dz, ² E-mail: Assoule.dechaicha@univ-msila.dz, ³ E-mail: alkama.djamel@univ-guelma.dz

, ⁴ E-mail: menai.ikram@univ-guelma.dz, ⁴ E-mail: salahsalah.hana@univ-guelma.dz

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ABSTRACT



As urbanization continues to shape the world's landscape, concerns have intensified over environmental degradation and depletion of natural resources. Accordingly, international agendas emphasize managing urban sprawl for inclusive, resilient, and sustainable cities. On this basis, this study consists of exploring the nexus of urbanization and advanced technologies following a methodological approach based on a bibliometric analysis using the Dimensions Database to analyse research related to urban sprawl and LULC Changes from 1994 to the recent years; and a systematic review to synthesize existing literature on different methodologies integrating GeoAI technologies and LULC Analytics in the process of monitoring landscape, which optimizes Urban Planning and empowers predictive modelling to monitor environmental changes, therefore, promoting intelligent decision-making and inclusive growth via enabling the creation of targeted policies that address socio-economic disparities, environmental sustainability and infrastructure enhancement. By improving comprehension of scientific concepts, this article aims to fill the knowledge gap between urban studies and remote sensing using machine learning.

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Highlights:

- Introducing the integration of GeoAI with remote sensing (RS) and geographic information system (GIS) technologies to enhance urban planning and land use optimization.
- Using a unique combination of bibliometric and systematic reviews to synthesize diverse methodologies, bridging urban studies with remote sensing and machine learning.
- Implementing advanced machine learning techniques to improve predictive modelling and forecast urban growth trends more accurately.

Contribution to the field statement:

This paper advances academia by integrating GeoAI with sustainable urban planning, enhancing predictive modelling for environmental monitoring, and informing data-driven policy-making. It bridges urban studies and remote sensing, offering novel applications for optimizing urban growth, and fosters interdisciplinary collaboration through bibliometric and systematic reviews of diverse methodologies.

*Amina Aidaoui:

Department of Architecture, Faculty of sciences and technology, University of 08 mai 1945, Guelma, Algeria

Email address: aidaoui.amina@univ-guelma.dz

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1. Introduction

1.1. Background and Context

By 2030, eighty percent of the world's population is expected to live in cities, surpassing the fifty percent average (Kirati et al., 2023). The population in rural areas is becoming more urbanized, as seen by the rise, which further strains housing and job prospects. Global urbanization is a critical social and economic phenomenon (Dasgupta, 2001) that shows no signs of abating. It is a subject that has generated much discussion over the last 30 years and evolved into a serious policy concern. It is among the most apparent factors that have altered the physical dimensions and patterns of the terrain in cities worldwide (Abebe, 2013). Understanding its dynamics and patterns has proven beneficial for formulating efficient strategies and arriving at better-informed planning decisions (Hembram & Jana, 2022).

The benefits and advancements that accompany urbanization also give rise to several environmental issues and risks, including floods, encroachment into wetlands and agricultural areas, contamination of the environment, population growth, substandard housing, inadequate sanitation and water supply, transportation issues, growing living expenses, and income disparity (Halingali et al., 2012).

Urban expansion is typically described as changes to the physical and functional aspects of the urban environment brought about by social, economic, and political changes (Kivell, 2002). The interactions of many biophysical and socioeconomic factors cause rural landscapes' land use and land covers (LULCs) to change into urban structures (Rahman et al., 2023). While sprawl is a result of emerging nations' faster urbanization (Ghosh, 2019), it poses significant challenges to the delivery of services and quality of life, as well as economic, environmental, cultural, and aesthetic effects on natural resources (Krishnaveni & Anilkumar, 2022). Thus, many urban planning strategies that limited urban sprawl were first supported because accomplishing so would protect the surrounding rural area and the natural environment, providing necessary amenities for city citizens (Beattie & Haarhoff, 2018).

Currently, resource managers and city planners need to understand the dynamics of urban expansion in rapidly evolving cities (Cengiz et al., 2022) and fulfil Sustainable Development Goal (SDG) 11 (Nations, 2018); future-focused urban development and sustainable city planning will depend on how well this urban physical expansion is understood and assessed (Mithun et al., 2022). A comprehensive and well-rounded approach is required to tackle the related issues.

1.2. Problem Statement and Research Gap

Controlling suburban land-use change (LULC) is a significant challenge in emerging nations due to its negative environmental impacts and loss of productive and natural areas. These changes pose an important issue for sustainable development (Degife et al., 2018) and the management of natural resources, and they have been crucial in shaping global environmental settings (Hosseini et al., 2023). According to Hamad et al. (2018), LULC change significantly contributes to environmental deterioration and is mainly caused by human activity. Reducing land-use conflicts and implementing sustainable development techniques (Ruben et al., 2020) depend on land-use planning, which aims to resolve and prevent conflicts by balancing diverse land uses and implementing strategies like urban decentralized growth (Zou et al., 2019). One effective method for examining the geographic pattern of LULC dynamics is to use their models (Motlagh et al., 2020).

Development initiatives highlight the importance of land-use planning, as its neglect causes environmental issues. This decision-making technique allocates land-use types across zones using spatial statistical models and LULC change detection (Xia et al., 2018). Advancements in Geographical Information Systems and remote sensing technologies enable the mapping and monitoring of LULC changes, providing academics with advanced data and spatial analysis (Islam et al., 2018). The key benefit of Geographic Information Systems (GIS) is their modelling capabilities (Murray, 2010) Because they offer a fundamental source of data and strategic land-use planning. Techniques like artificial neural networks, LULC change, and multi-criteria models automate this process, aiding policymakers and legislators (Motlagh et al., 2020). Their most advantageous applications include morphological spatial analysis and land-use appropriateness mapping planning and management (Agboola et al., 2018).



Based on these studies, can GIS and Remote Sensing combined with Artificial Intelligence approaches be as effective in land use management and urban planning to mitigate the predicted effects of urban growth on agriculture and other LULC classes?

1.3. Objectives and Hypotheses

Since urbanization is becoming increasingly prevalent, GIS and remote sensing are essential, not optional. Scientific inquiry indicates that this data precisely maps urban environments, aiding in urban planning and sustainability policies (Hembram & Jana, 2022). Recent advances in deep learning and machine learning, or more broadly, artificial intelligence, have made it possible for a new paradigm of data-driven science to analyse and visualize massive Spatial Big Data, i.e., large volumes, high velocity, and a wide range of geotagged data which is beyond the capabilities of the widely nowadays' used spatial computing platforms (P. Liu & Biljecki, 2022). Furthermore, the synergy between AI and GIS allows for more accurate predictions and comprehensive insights into urban dynamics (Alastal & Shaqfa, 2022), aiding in proactive planning and mitigation strategies. By also combining geographical data with socioeconomic data, initiatives that encourage equity in development and eliminate gaps may be promoted by analysing the link between urbanization and employment, income distribution, and service accessibility.

1.4. Significance and Structure of the Paper

This study conducts a systematic literature review and bibliometric analysis of three decades of research on urban growth dynamics. It integrates management systems, remote sensing, GIS, and artificial intelligence to enhance landscape analysis, resource management, infrastructure access, and management strategies, demonstrating AI's effectiveness in these areas.

Introduction

Research fomulation

- Addressing Rapid Urbanization implications.
- Urban Growth, Urban Sprawl and Land Use Land Cover Concepts.
- the Use of GeoAI Strategies and LULC Alanytics.

Research

Methodology

- Leading countries in Urban Sprawl studies and LULC changes: Bibliometric Analysis.
- a Key-word based search of recent articles on LULC Changes and Urban Sprawl Modeling in prestigious scientific Journals.

Results

- GeoAI: an in depth exploration
- The Key role of GIS and RS in monitoring Urban Expansion

Discussion

- Highlighting different techniques, methods and approaches for tracking, monitoring and modeling Expansions.
- Exploring the impact of the findings on Urban Sustainability for researchers and policy makers.

Conclusion

- GIS, RS and GeoAI support for sustainable urban planning: Meeting the cities' needs through an effective urban monitoring and Prediction.

Figure 1. Structure of the Study (Developed by the Authors).



2. Materials and Methods

The review concentrates on the application of GeoAI models in urban socio-geographical research. It delves into utilizing these advanced models for detecting and predicting changes in land use and land cover (LULC); illustrating the potential of these models to provide insights into urban dynamics, including urbanization patterns, environmental impacts, and the socioeconomic variables influencing land-use alterations, by analysing how traditional and new spatial mapping techniques can analyse spatial data. The focus is on how GeoAI can enhance the understanding and management of urban growth and transformation. It is divided into two sections:

2.1. Bibliometric Analysis of Urban Sprawl Modelling and LULC Changes using DIMENSIONS Database:

The study extensively used the Dimensions database, a widely recognized academic data source, to evaluate information. The VOSviewer software was employed to create a bibliometric map, a tool known for its ability to visualize and analyse bibliometric data. We conducted data mining on March 11, 2024, focusing on 'Urban Sprawl Modelling' and 'LULC Changes' in titles, abstracts, and keywords. We primarily sourced academic papers due to the database's widespread use in the scientific community. Our data collection process was thorough and meticulous, ensuring the validity and reliability of our findings.

The outcome of the initial search, which used the search string query TITLE-ABS-KEY (urban AND sprawl AND modelling), yielded old to recent year articles from 1994 to 2024. The previous search string query generated 81759 documents in the search results, adding the option to limit the number of articles obtained to 39180 documents. TITLE-ABS-KEY (urban AND sprawl AND modelling) AND (LIMIT-TO (OA, "all")) was the second search string query that produced 19300 items. The main focus of this study will be the distribution of the top 30 papers, chosen based on publication quality, among various nations between 1994 and 2024. In addition, it will examine the bibliometric map of co-authorship, the year-by-year published papers since 1994, and the co-authorship nations about the core topic of "urban sprawl modelling".

Applying the same proceeds to the second search revealed 25737 items following the choice to limit to Article. The string query used for this search was TITLE-ABS-KEY (LULC AND Changes). The second search string query produced 14972 items: TITLE-ABS-KEY (LULC AND Changes) AND (LIMIT-TO 5OA, "all").

2.2. Systematic Review

For this review, we followed the field's commonly used systematic review process to select relevant publications. We began by creating a set of relevant keywords (Urban Planning, GeoAI, LULC Changes, GIS, Remote Sensing, Change Detection, Landscape Metrics, Shannon's Entropy) to use in our search. These keywords were chosen because they are commonly used in GeoAI and urban socio-geographical research, and they represent key concepts and methods in the study of urban dynamics and land-use alterations. We then used the ELSEVIER and DIMENSIONS databases to identify the first set of prestigious articles from which we pulled data. Given the relatively new nature of GeoAI and LULC Changes, we ensured our review was sufficiently diverse. To gather state-of-the-art, we divided the review into two workflows: one focused on papers based on technological models developed or used with vector data (i.e., points, polylines, polygons, graphs, or networks) that are spatially organized in more irregular formats, and another focused on papers published in the last four years (2021, 2022, 2023, and 2024), where we encountered no limitations due to the abundance of papers on the topic, tackling up-to-date ones that use new methods and GeoAI techniques, to see how these methods may be used to create practical tools for tracking land changes throughout time.

3. Results

3.1 Results of the Bibliometric Analysis

The comprehensive set of published publications for the search term “urban sprawl modelling” from 1994 to March 11, 2024, is graphically depicted in Figure 2. This data, which we have observed to follow a unique trend, provides valuable insights into the evolution of urban sprawl modelling over the years. The peak in 2022, with 2741 published papers, and the subsequent drop in 2023 to 2551, are particularly noteworthy.

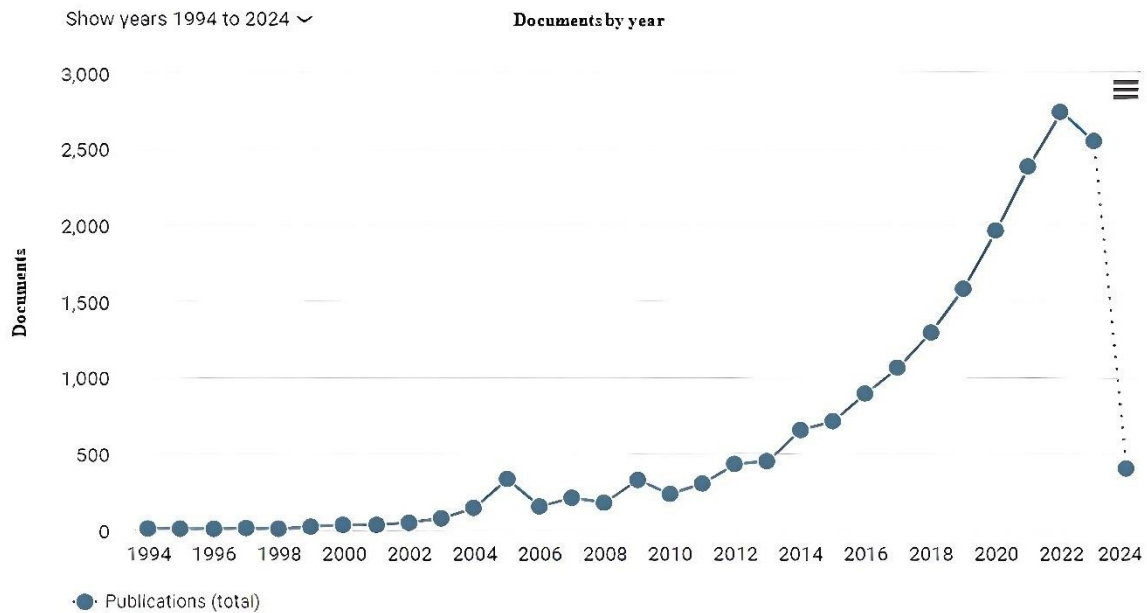


Figure 2. Urban sprawl modelling documents covering the years 1994 through March 11, 2024. Source Dimensions Database: (<https://www.dimensions.ai>).

Using a network diagram, the map (Figure 3) displayed co-authorship. In total, there were 9672 co-authors, of whom 190 met the criteria. The software played a crucial role in determining the final author selection number, 50, after applying all the filters. Notably, Chen, Y., published the most papers of any author, with 13 and 572 citations and total strength links, respectively.

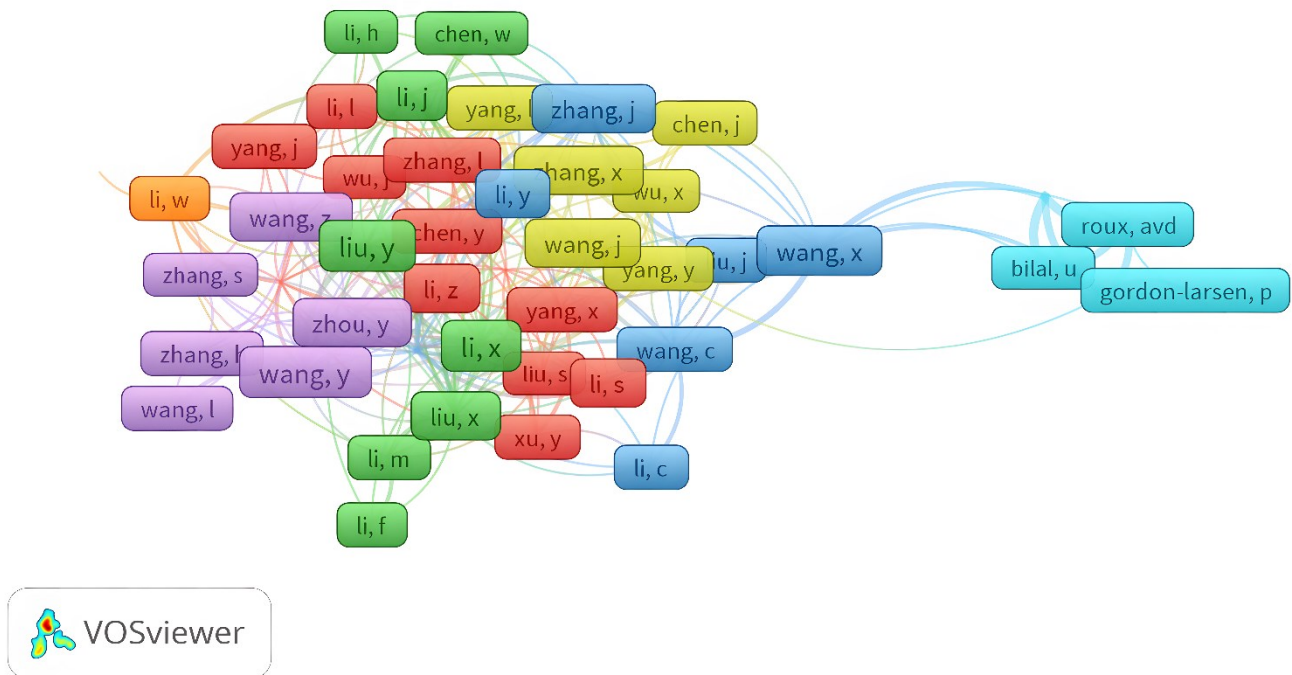


Figure 3. Network visualization mode and co-authorship-based bibliometric map.

The distribution of previous authors' published works throughout various nations from 1994 to March 11, 2024, is shown in the map (Figure 4) below. A total of 19300 published articles have the United States of America contributing 899 articles, with the United Kingdom (288), Australia (178), Canada (157), Germany (124), Spain (115), Italy (112), France (105), India (80), Netherlands (77), Switzerland (63), Brazil (61), Sweden (56), Japan (52), Portugal, South Africa (42), Belgium (39), Austria (33), Iran (33), Mexico (31), Norway (29), South Korea (28), and so forth. Other nations include Ghana, Uganda, and Lithuania. A few articles were published by countries such as Hungary, Estonia, Ecuador, etc. The availability of papers served as the basis for generating the bibliometric map. Apart from a country's minimal quantity of documents, 110 nations satisfied the 62 thresholds. After all the limitations had been applied, 50 nations were chosen. The program determined which 50 countries had the highest overall strength links among the 2711 co-authorship relationships with other nations.

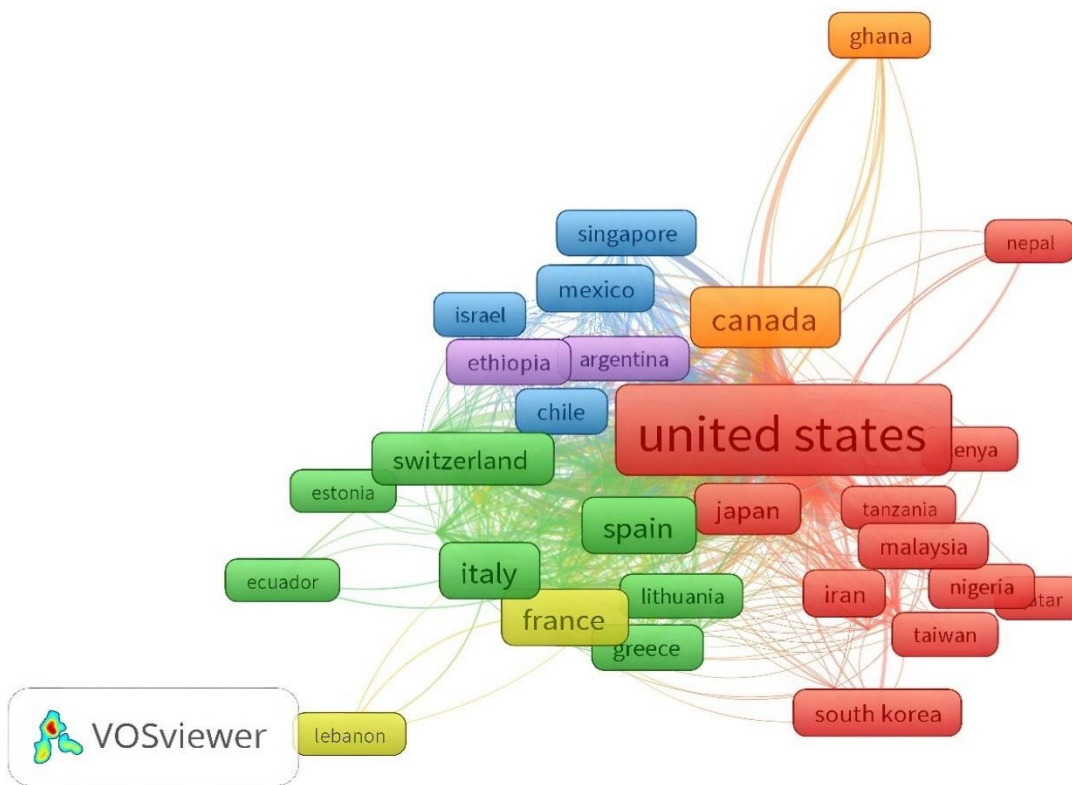


Figure 4. A network visualization mode bibliometric map based on co-authorship nations.

The total number of published papers from the "LULC Changes" search from 1994 to April 2024 is illustrated in the graph (Figure 5) presented downward. It has been seen that there have been notably fewer published documents since the first few years. However, this trend altered in an increasing and decreasing way after 2006. Out of 14972 papers, the maximum number published in 2022 was 3134.

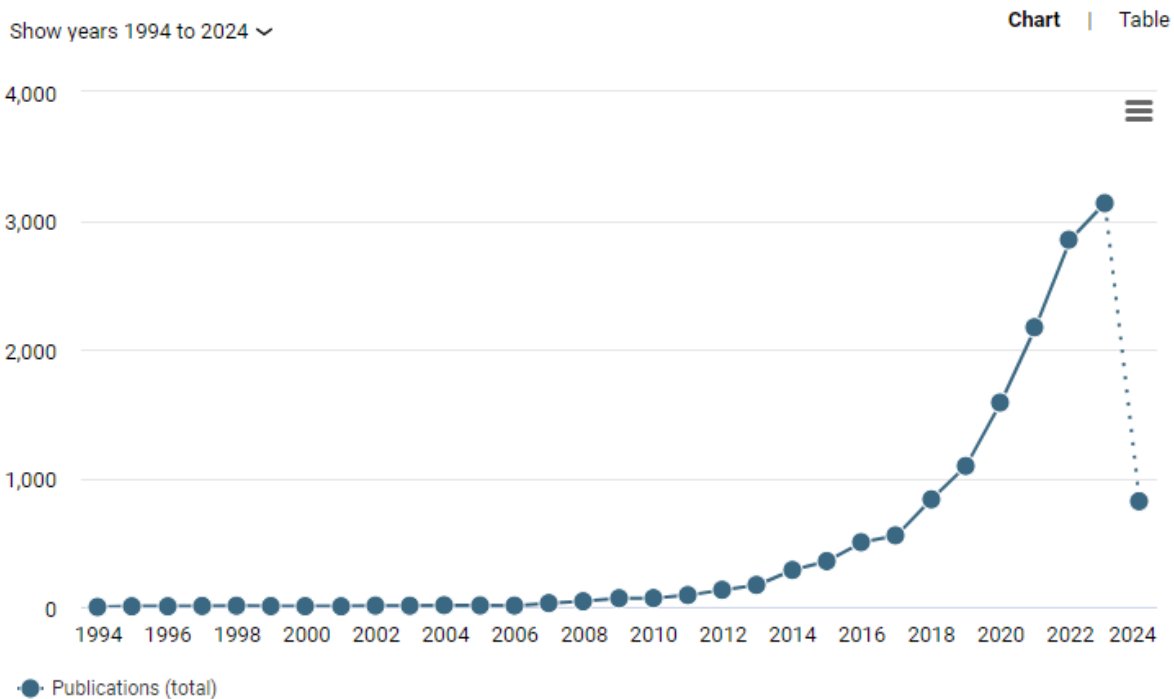


Figure 5. LULC Changes graph from 1994 to 2024. Source Dimensions Database: (<https://www.dimensions.ai>).

Using a network layout, the map (Figure 6) demonstrated co-authorship. In total, there were 11382 co-authors, of whom 67 met the criteria. The software played a crucial role in determining the ultimate author selection number, 67, after applying all the filters. Notably, Pradhan Biswajeet published the most documents of all the writers, with a total of 13 and 1 strong link. Another author, Kumar Pankaj, has eight total strength connections despite only ten published papers.

Other recognizable authors were Xiao X., Li Xia, Li Li, Furst Christine, Tariq Aqil, and Almirew T. Distinct colors, varying line thicknesses, and proximity indicate several clusters and authors with shared interests.

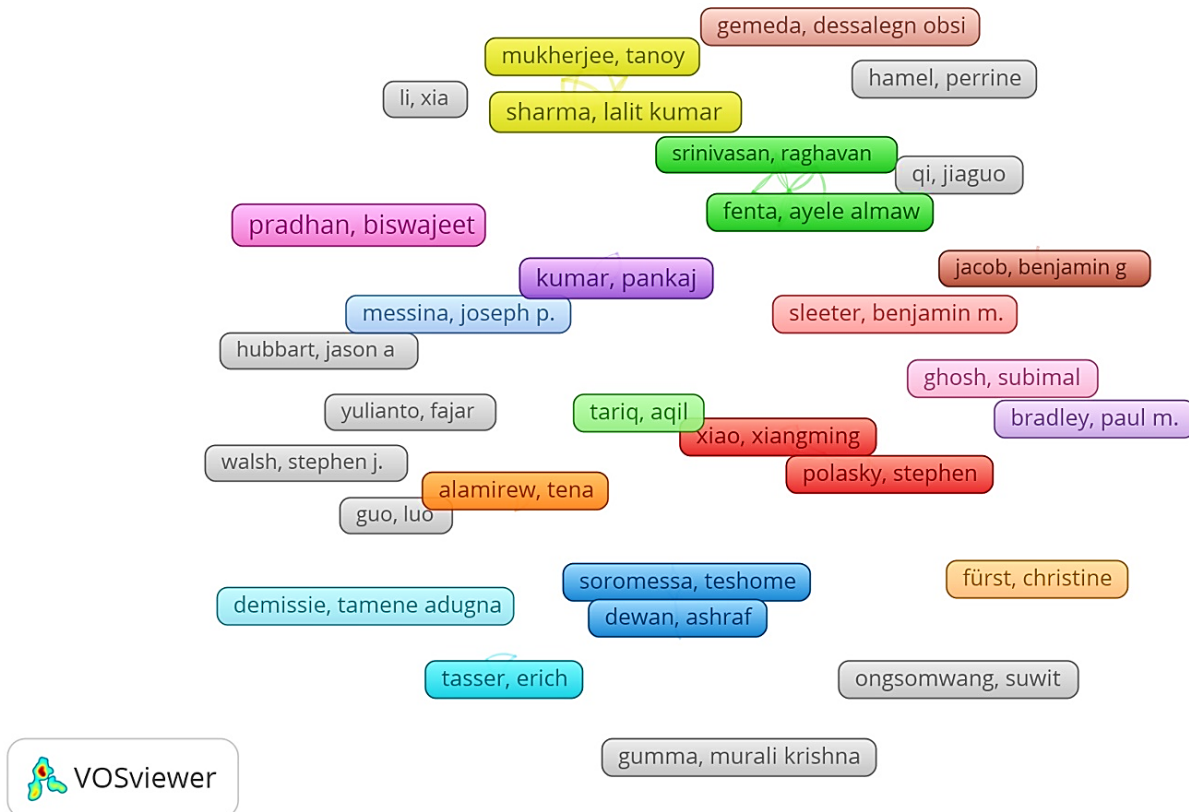


Figure 6. Network visualization mode and co-authorship-based bibliometric map.

The distribution of previous authors' published works throughout various nations from 1994 to 2024 is shown in the map (Fig. 7) below. China contributed by 599 articles out of the total 14972 published articles, with the United States (581), India (314), Ethiopia (201), the United Kingdom (161), Germany (155), Australia (90), Japan (85), Spain (81), Netherlands (79), Canada (66), Brazil (66), Italy (65), South Africa (60), Bangladesh (60), France (55), Pakistan (52), Indonesia (49), Ghana (48), Iran (47), Switzerland (46), South Korea (42), Austria (41), Nigeria (40), and so on. Other nations, including Cameroon and the United Arab Emirates, published a minimum number of articles. The availability of papers served as the basis for creating the bibliometric map. One hundred nineteen nations satisfied 69 threshold levels in addition to the minimum number of a country's documents. Sixty-nine nations were ultimately chosen after all constraints were applied. These nations determined which co-authorship ties with other nations had the most substantial total link strength out of 2484, and all of the above choices were made using the software.



Figure 7. A network visualization mode bibliometric map based on co-authorship nations.

3.2 Results of the Systematic Review

3.2.1. Studies in Urban Growth and Urban Sprawl

In contemporary urban research, assessing urban expansion and growth alongside their temporal dynamics is a critical focus (Schneider, 2012). It is a standard practice to identify and measure patterns and manifestations of urban physical growth (Tv et al., 2012). Dechaicha et al. (2021) emphasized the use of remote sensing satellite images in monitoring and understanding the uncontrolled and fast-growing expansion of urban and peri-urban regions and evaluating the effects this has on nearby ecosystems. Wilson and Chakraborty (2013) highlight that urban sprawl is characterized by examining physical growth patterns. Urban built-up areas effectively measure this growth. Traditional surveying is costly and time-consuming, leading to integrating statistical methods with GIS and remote sensing in studies of expanding cities (Punia & Singh, 2011).

In recent years, remote sensing has emerged as a practical, and widely used method for analysing urban expansion (Yeh & Li, 2001). As a result, the use of remote sensing and GIS techniques for mapping and monitoring urban sprawl has increasingly attracted the attention of researchers (Epsteln et al., 2002), Implementing a specific process (fig. 8) that shares some steps but differs in its approaches.

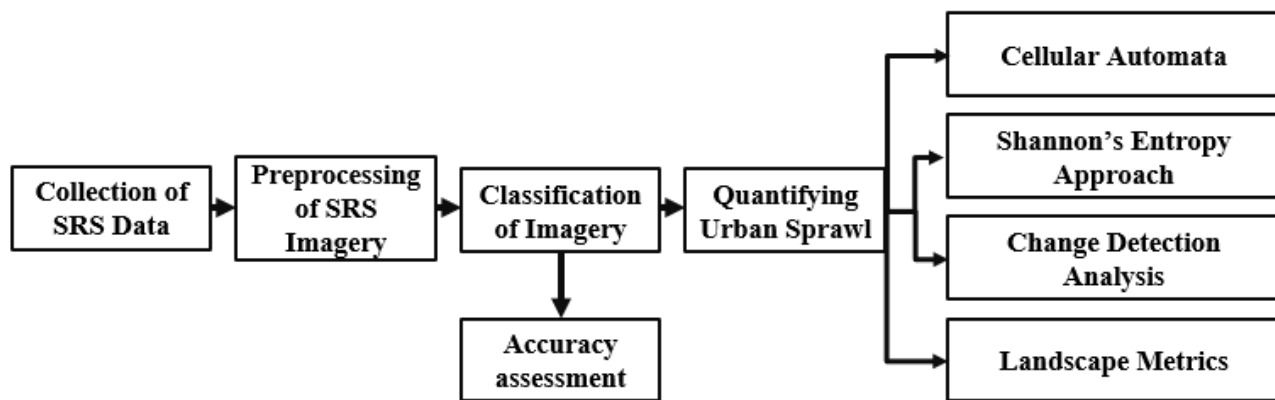


Figure 8. Framework for integrating GIS, Remote Sensing and AI in Urban Studies (Developed by the authors).

3.2.1.1. Collection and Pre-processing of Satellite Remote Sensing Data:

Analysing satellite data allows easy identification of temporal and geographical changes in the urban landscape. The collected remote sensing data preprocessing entails topography correction, geometric rectification or picture registration, radiometric calibration, atmospheric correction, and poor line restoration (Lillesand *et al.*, 2015). Image preprocessing, extensively covered in textbooks and papers, requires precise geometric rectification and atmospheric calibration, especially when combining multi-temporal or multi-sensor data for classification. Several techniques are developed for atmospheric normalization, correction, and radiometric calibration, including relative calibration, dark object removal, and other complex calibration methods (Lu & Weng, 2007). According to Nazeer *et al.* (2014), some of the advanced techniques that are often used include quick atmospheric correction (QUAC), fast line-of-sight atmospheric analysis of hypercubes (FLAASH), second simulation of the satellite signal in the solar spectrum (6S), and atmospheric correction (ATCOR). One of the most advanced and widely used atmospheric correction programs, FLAASH, is implemented by many researchers to calibrate multi- and hyper-spectral images, such as those from Landsat (Wang *et al.*, 2019), Hyperion (Perkins *et al.*, 2005), AVIRIS (Perkins, 2012). Several studies find that, in terms of consistency, the FLAASH radiometric calibration performs better than many other techniques (Jinguo Yuan & Zheng Niu, 2008). Furthermore, ENVI is an established software for FLAASH correction (Rahman *et al.*, 2023).

3.2.1.2. Classification of imagery and accuracy assessment

Preprocessing of RS data should ideally be followed by picture classification, which examines image pixels using various guidelines and methods (Lillesand *et al.*, 2015) that generate the predetermined land cover classes (Araya & Cabral, 2010).

Image Classification is a main focus. The information that may be extracted from satellite imagery through the thereby produced LULC maps depends on how well the categorization is done. Many variables affect the accuracy of this classification, including (a) the type of image to be used, including its sensor, resolution, and quality (e.g., haze, clouds, and shadows); (b) the area coverage and type of landscape being examined (e.g., local, regional, or global; homogeneous or heterogeneous); (c) the number of classes to be extracted; (d) the individual's own local or expert knowledge of the area of interest, as well as the availability of relevant ground truth information; and (e) the classification technique to be used (Estoque *et al.*, 2015). Although many effective remote sensing applications, such as LULC mapping, still rely on pixel-based image processing, this method has limitations regarding context, relative size, and smooth or fuzzy transitions (Blaschke *et al.*, 2000). The advent of high-resolution satellite sensors has spurred the development of GEOBIA methods (Blaschke *et al.*, 2014), replacing old pixel-based techniques. Object-based approaches offer advantages like incorporating expert knowledge and optimizing feature space



during classification (Platt & Rapoza, 2008). Also, object-based techniques are known for their advantage in reducing the 'salt-and-pepper effect' (Blaschke et al., 2000). It has been noted that GEOBIA has gained more incredible notoriety than conventional pixel-based analysis (Estoque et al., 2015).

Researchers have used various methods to categorize satellite images (Lu & Weng, 2007). The per-pixel supervised classification based on the parametric maximum likelihood classifier (MLC) is one of the most used techniques (Aburas et al., 2017). Additionally, nonparametric classifiers—such as neural networks, decision trees, and knowledge-based classifiers—are being utilized increasingly in categorizing images (Rahman et al., 2023). However, because mixed pixels are often included in this sort of data, per-pixel LULC classification may not be helpful for moderate-resolution satellite imagery, such as that collected by the Landsat thematic mapper (TM) and Landsat operational land imager (OLI) (30 m) (Lu & Weng, 2006). Machine learning techniques have advanced so that medium-resolution satellite images, such as Landsat TM and OLI, can be identified more precisely at the per-pixel, sub-pixel, and object basis (Estoque et al., 2015). The support vector machine (SVM), an AI classifier, is an effective non-linear, non-parametric, supervised classification technique with good classification accuracy (Rimal et al., 2018). When Schneider (2012) used Landsat data to analyse LULC change over urban and peri-urban regions, the results showed that SVM and decision tree (DT) were better classifiers than MLC. SVM is superior because it is less sensitive to noise, correlated bands, and an uneven distribution of training sites within each class (ESRI, 2018).

An evaluation of their accuracy follows the procedure of classifying images. "Accuracy assessment" refers to conveying the degree of "correctness" in picture categorization. According to Congalton (2001) and Congalton and Green (1993), accuracy assessment research can be divided into four main stages. The fourth type uses ground truth verification to evaluate how well-classified images match real-world observations, using a confusion matrix to show class allocation patterns compared to reference data. This era is characterized by error matrices, which may also be used to calculate the producer's accuracy (PA), user's accuracy (UA), and overall accuracy (OA). The most often reported accuracy assessment method is the measure of OA; however, individual class accuracies are represented by PA and UA (Yang et al., 2017). Another crucial factor in determining the accuracy of categorized photos is sample size. Researchers Congalton & Kass Green (1993) advise obtaining at least fifty samples of each classified image for images smaller than one million acres and include less than twelve groups or categories. For multi-spectral and temporal Landsat imagery, studies (e.g., Belal & Moghanm, 2011; Zaki et al., 2011) have attained accuracy levels of 3-7 land-cover classes ranging between 85 and 95%. The sampling technique chosen for site selection is essential to assessing accuracy. The Kappa discrete multivariate approach is utilized in accuracy evaluation to statistically determine whether there is a significant difference between two error matrices (Congalton, 1991).

3.2.1.3. *Quantifying Urban Sprawl*

Researchers have developed numerous indices and models linked with RS-GIS to evaluate urban growth patterns. These include the relative entropy index, sprawl dimensions, landscape metrics, and Shannon's. These metrics can be absolute or relative, allowing us to distinguish between sprawling and non-sprawled cities (Rahman et al., 2023). So many approaches have been developed, mentioning:

a. **Change Detection Analysis**, pertains to using co-registered multi-temporal Satellite Remote Sensing data to determine an aerial change in land coverings. Various perspectives led to a summary and categorization of change detection methodologies. In general, there are two kinds of approaches for detecting changes in land cover: (1) utilizing different image-enhancing techniques to identify the change and (2) extracting specific categories of land cover change by employing classification algorithms (Jensen & Im, 2007). Various studies employ distinct methods for detecting changes, including principal component analysis (PCA), differences in vegetation index, image rationing, post-classification comparison (PCC), and image differencing. The PCC is arguably the most extensive and well-liked change detection method (Abd El-Kawy et al., 2011). In post-classification comparison, each corrected imagery date is independently classified and aligned with a shared land type schema, then categorized and



contrasted pixel-by-pixel (Punia & Singh, 2011). With remote sensing and GIS, statistical methods are used to quantify, estimate, map, and monitor urban expansion (Jat et al., 2008).

b. **Shannon's Entropy Approach** is the haphazardly occurring mathematical calculation of urban expansion. Entropy may also be used to assess how scattered or compact a city's land development is, which might reveal information about the extent of urban expansion or sprawl (Lata et al., 2001). According to Bhatta (2010), this metric is robust because it can categorize sprawl in black and white.

c. **The Cellular Automata model** has also been applied to research on urban expansion. CAs are described as elementary dynamic spatial systems in which each array cell's state is determined by its neighbours' past states and a collection of transition principles (White et al., 1999).

d. **Landscape Metrics** are a frequently applied method in landscape ecology (H. Liu & Weng, 2013). They are widely used in studies on landscape variability over time (Mcalpine & Eyre, 2002) and have been defined as quantifiable biotic or abiotic environmental characteristics that allow for the collection of quantitative information on ecological resources and the functioning of the landscape. The metrics are applied to evaluate the functioning, status, and features of the spatial structure of different types of landscapes, such as degraded, urban, rural, and forest landscapes (Barwicka & Milecka, 2021). According to Herold et al. (2005), landscape metrics may quantify spatial variability at patch, class, and landscape metrics at three levels. As per McGarrigal and Marks (1995), A class is an assembly of all the patches in a specific category, a landscape is the collection of all the patches in all patches within a landscape, and a patch is a homogenous unit of a class or category being investigated. Measurements capture spatial properties even in the absence of spatial explicitness. On the other hand, pixel- or patch-based indices might represent spatially explicit measurements (Herold et al., 2005). Similarly, Dechaicha et al. (2021) claim that measures based on remote sensing and landscape metrics are essential to controlling the unbridled urbanization occurring in oasis cities and lessening its adverse consequences on palm groves. Herold (2005) also advocated connecting RS and geographical metrics to give more comprehensive and consistent data on urban structure, analysis, and dynamics. To demonstrate the importance of the metrics and argue for further research into urban analysis, some specific metrics have been used and proposed by the RS-GIS integrated studies that deal with the application of spatial metrics, including James, 2012, H. Liu & Weng, 2013, Motlagh et al., 2020. Nevertheless, there is not a set of metrics universally applicable to urban studies, and because the significance of metrics varies depending on the research goal, selecting independent measures for a given study has proven to be challenging for researchers (Parker et al., 2001). Because of this, it is critical to evaluate and examine metrics' ability to gather pertinent data while using them (Mithun et al., 2023). These metrics might include, for example, point density, edge density, the edge effect, most extensive point index, and landscape index (Elmi et al., 2022).

The methods mentioned happen to take place thanks to different software such as FRAGSTATS, ArcGIS, QGIS, ERDAS IMAGINE, and Google Earth Engine.

3.2.2. Artificial Intelligence in Urban Sprawl Prediction and Modelling

Resource managers and city planners should be aware of the dynamics of urban expansion (Herold et al., 2005). particularly in rapidly changing cities. Urban expansion has been modelled using various analytical and static techniques since the 1950s. These methods were based on assumptions about social dynamics, economic activity, and urban geometry (Berling-Wolff & Wu, 2004). Hybrid models, such as neural network CA (Yeh & Li, 2001), fuzzy-CA (Y. Liu, 2012), logistic-CA, and CA-Markov (Mithun et al., 2022), have been used to improve performance. Other sophisticated models, such as artificial neural network (ANN) (Shafizadeh-Moghadam et al., 2021), agent-based model (Jokar Arsanjani et al., 2013), genetic algorithm (Tang et al., 2007), geographically weighted regression (Mondal et al., 2015), bivariate or step-wise multiple regression (Al-sharif & Pradhan, 2013), SLEUTH model (Serasinghe Pathirana et al., 2018), analytic hierarchy process (Devendran & Lakshmanan, 2019), logistic regression, Markov chain (Jokar Arsanjani et al., 2013), and fuzzy logic (Y. Liu, 2012), have also been created to forecast LULCs in metropolitan areas in the future (Rahman et al., 2023).



One popular Artificial Neural Network (ANN) for modelling and predicting urban expansion is the multi-layer perceptron (MLP) (Sahana et al., 2018). In comparison to other methods, its transition potential is the best. MC is helpful for simulating changes in LULC in intricate regions. When paired with MC, ANN modelling may accurately represent urban dynamics by fitting intricate non-linear relationships between urban land use dynamics and the forces propelling population expansion. This method works exceptionally well for intricate changes in land cover (Eastman et al., 2005).

Urban growth may be effectively detected, mapped, monitored, and analysed using satellite images and GIS technologies. Satellite imaging may obtain a synoptic picture of a landscape, revealing trends in land cover and usage. RS-GIS technology is robust and affordable and simulates and tracks urban sprawl dynamics. Since 1972, Landsat data has identified spatiotemporal urban expansion, with advanced models integrated into RS-GIS for trend assessment and simulation (Mithun et al., 2023).

4. Discussion

The perception of urban expansion as a looming threat to sustainable development underscores the necessity for infrastructure projects, effective resource allocation, and urban planning. The bibliometric study, a crucial tool in this field, has revealed that China leads research on LULC change, while the USA is at the forefront of urban sprawl research. This study, which selected papers aimed at providing a clearer overview, guides future research and underscores the importance of understanding the leaders in this field, thereby keeping the audience informed and knowledgeable. Researchers have concluded that remote sensing and geographic information system tools are optimal for mapping, measuring, evaluating, and modelling the spatiotemporal dynamics of urban expansion, as they have been employed in most studies on urban sprawl over the past few decades. One common, easy-to-use criterion for evaluating urban expansion and sprawl is the urban built-up cover, and the primary way that urban sprawl is researched is as an urban expansion pattern and process about the cause and effect of that indicator.

Urban sprawl studies extensively use open-source satellite remote sensing data from IRS LISS III, TM, ETM+, and Landsat 5-7-8, and they also preprocess that data, which is very important.

Moreover, FLAASH atmospheric correction is a widely used method for radiometric calibration and atmospheric correction of satellite images. This is followed by a classification of the data, and the MLC approach is the most commonly used classifier for identifying the different types of land cover using RS data. However, there has been a significant rise in the use of some machine learning methods, including SVM, decision trees, and random forest classifiers. Urban sprawl and expansion may be measured using various metrics and indices. Nevertheless, Shannon's entropy approach and landscape metrics are now widely used to quantify urban sprawl and are very efficient and reliable approaches; they can be used to evaluate and improve city management decisions. These tools provide the chance to formalize the most appropriate choices and solutions that fulfil the requirements for promoting and protecting ecosystems.

MC, CA, SLEUTH, and LR are the most common modelling approaches used with RS-GIS. Moreover, specific machine learning methods (such as MLP) have been utilized for this purpose very recently. However, parameterization and model calibration remain important and challenging processes.

The study on GeoAI strategies and LULC analytics reveals significant patterns in urban development, underscoring their role in sustainable urban planning and policymaking. By leveraging advanced GeoAI techniques, the research provides insights into LULC changes and can be vital in helping decision-makers make informed choices. Yet, more research should focus on the inclusion of real-time data, improving prediction models, and taking socioeconomic consequences into account to further improve urban planning methods and guarantee thorough policy formulation for sustainable cities.

5. Conclusion

Urban expansion is perceived as a significant threat to sustainable development, necessitating robust infrastructure projects, effective resource allocation, and comprehensive urban planning. Remote Sensing (RS) and Geographic Information System (GIS) tools are optimal for mapping, measuring, and modelling the spatio-temporal dynamics of urban expansion due to their use over the past decades. Studies heavily



employ open-source Satellite Remote Sensing data, with preprocessing and FLAASH atmospheric correction being crucial steps. Preprocessing is usually followed by the classification of the collected and assessed data, and the Maximum Likelihood Classifier (MLC) is the most commonly used. However, there has been a notable rise in the use of machine learning methods like support vector machines (SVM), decision trees, and random forest classifiers. This shift towards machine learning methods is significant, as it not only enhances the accuracy and efficiency of urban expansion studies but also opens up new avenues for future research and development in this field. As for the quantification of sprawl, several measures are employed; Shannon's entropy and landscape measures are frequently used. While machine learning techniques like multi-layer perceptron MLP have recently gained popularity, RS-GIS modelling approaches like Markov Chain, Cellular Automata, and SLEUTH remain popular despite difficulties with parameterization and model calibration.

GeoAI strategies and LULC analytics reveal essential patterns in urban development, underscoring their role in sustainable planning for providing insights into urban space (infrastructure maintenance needs, reducing costs...), such as population density, traffic flow, and environmental impact, supporting evidence-based decision-making. When AI is integrated into RS-GIS technology, it becomes more effective in predicting future evolutions, foreseeing problems, and making implicit decisions that lead to successful land planning and more sustainable, resilient, and liveable cities. These technologies have proven reliable, affordable, and technically sound, allowing the simulation and tracking of urban expansion dynamics. To further improve urban planning and policy development, future research should concentrate on integrating real-time data for more timely and accurate analysis; improving predictive models to better anticipate urban growth patterns; investigating sophisticated machine learning techniques for data classification and modelling; and carrying out socio-economic impact assessments.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data availability statement

All data generated during this study are included in this published article and its supplementary information files.

CRedit author statement

-Dr. Assoule Dechaicha performed Supervision.

-Pr. Djamel Alkama performed Conceptualization; Methodology; Supervision.

-Ph.D Candidate Ikram Menai helped with Writing – Original Draft.

-Dr. Hana Salah Salah also performed supervision. All authors have reviewed and approved the final version of the manuscript.

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Original scientific paper

Innovative Design Synthesis: AI-Driven Solutions for Sustainable Urban Planning: Development, Evaluation, and Insights

*¹ Dr. Koudoua Ferhati , ² Ahmed M. Elgohary , ³ Ahmed N. Elghar , ⁴ Ahmad S. Abdelaal , ⁵ Ahmed M. Kamel , ⁶ Mohamed A. Elsayed , ⁷ Ahmed E. Sheimy , ⁸ Mena E. Habib

¹ Department of Project management, Faculty of Architecture and Urbanism, Constantine 3 University, Algeria

²⁻⁸ Department of Research and Development, MIRANDO Solutions, Egypt

¹ E-mail: koudoua.ferhati@univ-constantine3.dz, ² E-mail: Elgohary@mirandosolutions.com, ³ E-mail: Anader370@gmail.com,

⁴ E-mail: Ahmadsameh010@gmail.com, ⁵ E-mail: Amostafaarslan@gmail.com, ⁶ E-mail: Elsayadmohamed396@gmail.com,

⁷ E-mail: Ahmedamad456478@gmail.com, ⁸ E-mail: Menaesam76@gmail.com

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ABSTRACT



This research aims to explore the capabilities of Artificial Intelligence model applications in sustainable urban planning design, aiming to create an AI-powered model that detects urban sprawl, urban decay, infrastructure deficiencies, and environmental degradation, and generates sustainable solutions. The methodology includes model development, data preprocessing, architecture design, training, and comprehensive questionnaire design and statistical analysis. Insights into the model's performance and perception were gathered from 200 participants, including researchers, developers, architects, and urbanists. Results reveal significant variations in perceived model performance across demographic groups. Statistical tests and correlations study showed that participants from urban areas rated the model's effectiveness in detecting urban sprawl significantly higher than those from rural areas, and urban planners found the model's infrastructure deficiency detection less accurate compared to architects. These findings provide valuable guidance for enhancing urban planning strategies and underscore AI's potential in transforming urban planning with more effective and inclusive solutions.

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Highlights:

- Developed an AI-driven model that integrates real-time data and multimodal analysis for urban problem detection.
- Demonstrated superior performance compared to traditional GIS-based approaches and recent machine learning models.
- Addressed key urban issues such as urban sprawl, decay, infrastructure deficiencies, and environmental degradation.
- Contributed a novel methodological framework combining supervised and self-supervised learning for urban analysis.

Contribution to the field statement:

This study advances urban planning literature by integrating AI-driven methodologies with traditional urban analysis. Our novel model combines real-time data integration with multimodal analysis, offering dynamic, data-driven insights that surpass the capabilities of traditional GIS and recent machine learning models. This research contributes unique methodological advancements and practical applications, enhancing urban problem detection and decision-making processes.

*Samruddhi Purohit:

Department of Architecture, MKSSS' Dr. Bhanuben Nanavati College of Architecture for Women, India

Email address: a19104.samruddhip@bnca.ac.in

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1. Introduction

1.1 Background and Context

The accelerating pace of urbanization and the escalating threats of climate change and resource depletion underscore the urgent need for sustainable urban development (Li et al., 2022). Cities, as major contributors to environmental degradation, require strategies for creating sustainable, resilient, and livable urban environments (Bibri et al., 2024; Paris et al., 2023). Traditional urban planning and architectural design often struggle to balance built form, environmental impact, and human well-being (Fallmann & Emeis, 2020; Ferramosca & Terracciano, 2023).

1.2 Previous AI Applications in Urban Planning

Previous attempts to integrate AI in urban planning have shown promise but also highlighted limitations. AI has emerged as a transformative force within architecture and urban planning, revolutionizing design, planning, and sustainability (Regona et al., 2024). The early adoption of AI in these fields dates back to the 1960s with computer-aided design (CAD) and automated drafting, evolving to include generative design and optimization (Zhang et al., 2023). Notable examples include the Metropol Parasol in Seville, Spain, and the Masdar City project in the UAE, which utilized AI for design and sustainability (Ersen et al., 2022; Auwalu & Bello, 2023). In urban design, AI has been applied to traffic management and public transportation optimization, with smart city initiatives like Singapore leveraging AI for infrastructure and service optimization (Herath & Mittal, 2022; Sons et al., 2023). AI tools have enabled architects and urban planners to enhance building efficiency, reduce energy usage, and minimize environmental impact (Almaz et al., 2024). The creation of digital twins allows for real-time monitoring and simulation, ensuring designs meet sustainability goals (Omran et al., 2023). However, despite these advancements, there are discrepancies between perceived benefits and actual adoption rates, and some scepticism remains among practitioners (Dwivedi, Kshetri, et al., 2023). Milestones include the development of a reinforcement learning model for urban planning by Tsinghua University (Peng et al., 2023) and advancements in automated design optimization (Rafsanjani & Nabizadeh, 2023). Case studies like The Edge in Amsterdam and Sidewalk Labs in Toronto exemplify successful AI-driven sustainable design, while best practices include generative design and biophilic design integration (Edge, n.d.; Goodman & Powles, 2019; Smorzhnikov & Ignatova, 2021; Ramm et al., 2024). These examples underscore AI's potential to drive sustainable design solutions in architecture and urban planning (Bibri, Huang, & Krogstie, 2024; Berčić et al., 2024).

1.3 Gap identification

While traditional methods face limitations, integrating cutting-edge AI methods into urban design processes offers a promising solution. Existing AI applications in urban planning, such as traffic optimization and land-use analysis, often lack the comprehensive capability to address broader sustainability concerns (Bibri, Huang, et al., 2024). This study aims to investigate the transformative potential of AI-driven models in the design and inhabitation of built environments, addressing gaps in current methodologies.

1.4 Research objectives

The primary objective of this research is to conceptualize and develop an AI-driven model that detects urban problems like urban sprawl, urban decay, infrastructure deficiencies, and environmental degradation, and suggests innovative, sustainable solutions. Specifically, the study will:

1. Harness the generative capabilities of GANs and the semantic understanding of language models to create a novel AI-driven model.
2. Assess the model's performance through a questionnaire-based evaluation process with experts in urban planning and development.

3. Evaluate the model's effectiveness in addressing urban challenges and its potential to revolutionize design practices.

1.5 Significance of the study

This study examines the convergence of AI and urban planning to catalyze a paradigm shift in urban development (John-Nsa et al., 2023b). Beyond technical innovation, the research emphasizes the importance of human-centred design in shaping our built environment. The outcomes of this research are expected to extend beyond academia, inspiring a new generation of urban planners and policymakers to create sustainable, equitable, and resilient cities (Kanyepe, 2023).

By adopting an interdisciplinary approach that integrates urban expertise with AI-driven computational design methodologies, this research contributes significantly to academia by advancing the discourse on sustainable urban development. It charts a course toward a future where sustainability, innovation, and social responsibility converge, fostering the development of urban environments that are not only more intelligent but also more sustainable, inclusive, and conducive to quality living. This research not only enhances the theoretical framework surrounding urban studies but also provides empirical insights that can inform future academic inquiry and policy-making in the field of urban planning and design.

2. Materials and Methods

This study is grounded in two key theories: Urban Systems Theory and Multimodal Learning Theory. Urban Systems Theory allows for a nuanced understanding of the complexities inherent in urban environments (Batty, 2013; Jiang, 2017), while Multimodal Learning Theory enhances the model's capacity to analyze diverse data sources effectively (Kress, 2010; Alper et al., 2020). The methodological processes outlined in the chart (Figure 1) include data collection, preprocessing, model architecture, training procedures, and evaluation metrics, which collectively contribute to the robustness and efficacy of the urban problem detection model. This comprehensive framework supports the overarching goal of developing an innovative and responsive solution to urban challenges, ensuring that both theoretical and practical considerations are addressed throughout the research process.

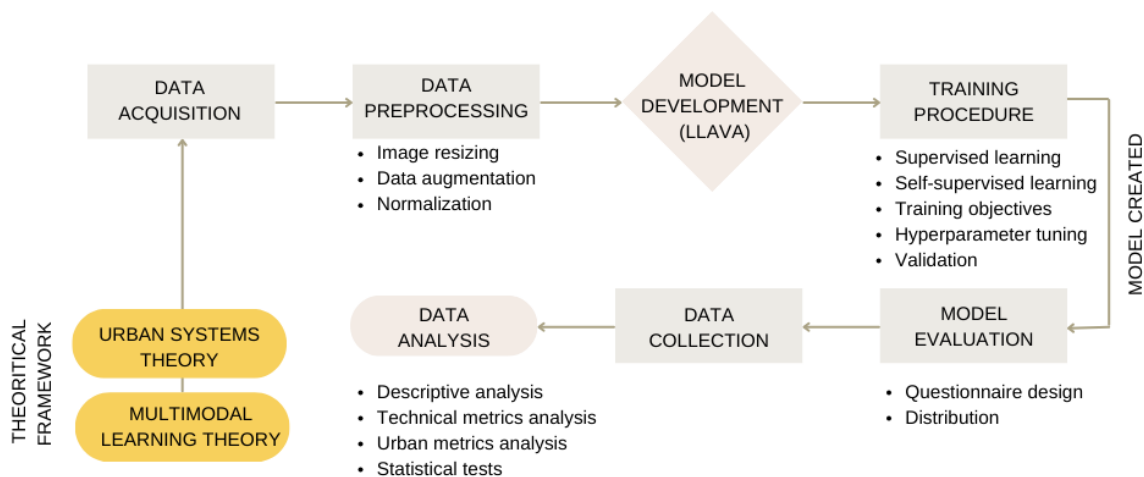


Figure 1. Theoretical and Methodological Framework.



2.1 Model development

2.1.1 Data Collection

The dataset employed for model testing is the UC Merced Land Use Dataset, which features 21 land use categories. It includes 100 images per category, each with dimensions of 256x256 pixels. These images were manually selected from larger images in the USGS National Map Urban Area Imagery collection, covering various urban regions across the country. This dataset was chosen due to its comprehensive representation of land use types relevant to urban planning, making it an ideal benchmark for detecting urban issues globally.

2.1.2 Preprocessing

The preprocessing steps for the dataset include:

- **Image resizing:** The images were adjusted to a consistent size of 256x256 pixels, ensuring uniformity across the dataset and facilitating more efficient model training.
- **Data augmentation:** The dataset was augmented by applying random transformations such as rotation, flipping, and colour jittering to the images, which enhances the model's robustness by providing a wider variety of training samples and helping to prevent overfitting.
- **Normalization:** The pixel values of the images were scaled to a standard range, specifically between **0 and 1**. This step is crucial as it ensures that the model converges faster during training and improves the overall performance by reducing the risk of numerical instability.

2.1.3 Model Architecture

The model used for this task is the LLaVA (Large Language Model for Visual Analysis) model, which is a multimodal transformer-based model that combines the capabilities of a large language model with those of a computer vision model. The architecture consists of an **encoder** and a **decoder**, where the encoder is responsible for processing the input image and the decoder generates the corresponding output text. The model utilizes attention mechanisms to focus on specific parts of the input image and associated text, allowing for more accurate associations between visual elements and textual descriptions. The training employs **transfer learning** strategies, leveraging pre-trained weights from existing models to enhance the learning process.

2.1.4 Training Procedure

The model was trained using a blend of supervised and self-supervised learning methods. The supervised learning aspect includes training the model on an extensive dataset of labeled images paired with corresponding text descriptions (Zhao et al., 2024). The self-supervised learning component entails training the model on a large dataset of unlabeled images, with the model's predictions serving as labels. The training objectives included:

- a- Masked language modelling:** The model was trained to forecast the missing words in sentences enhancing its understanding of language context.
- b- Image-text matching:** The model was trained to match the input image with the corresponding text description.
- c- Visual reasoning:** The model was trained to analyze the input image and generate a text description that explains the observed elements in the image, aiding in the identification of urban issues...

The model was utilizing a batch size of 32 and a learning rate of 1e-5. The training process was conducted for 10 epochs, with the model being evaluated on a validation set after every epoch to monitor performance and prevent overfitting.

d- Zero-Shot Prompting:

The model was used for zero-shot prompting, where the model received a prompt and was required to produce a response without any additional training data. The prompt used for this task was:

"Analyze the image and indicate whether each of the following urban problems is present, providing reasoning based on the visual cues observed. Respond with 'Yes' or 'No' for each problem and explain your reasoning."

The model was able to generate responses for each of the urban problems, providing reasoning based on the visual cues observed in the image.

2.2 Model Evaluation

The evaluation framework for the generated designs is made using a questionnaire that includes both technical and urban metrics to assess their performance.

2.2.1 Questionnaire design

A structured questionnaire is developed to collect data on demographic information, technical metrics feedback, and urban metrics feedback. To extract quantitative results from the study, we designed it using the following metrics alongside the demographic information like age, gender, education and country:

- **Accuracy:** Measure the model's overall correctness in identifying urban problems correctly (Chaudhuri & Clarke, 2013).
- **Precision:** Evaluate the ability to identify urban problems without false positives (Safabakhshpachehkenari & Tonooka, 2023).
- **Recall:** Assess the capability of identifying the instances of urban problems present in the images (Safabakhshpachehkenari & Tonooka, 2023).
- **F1 Score:** Combine precision and recall to provide a balanced evaluation of the model's performance (Chaudhuri & Clarke, 2013).
- **Confusion Matrix:** Offer insights into the model's performance by showing true positives, true negatives, false positives, and false negatives (Chaudhuri & Clarke, 2013).
- **Feature Importance:** Analyze the importance of visual cues/features in detecting urban problems to understand which cues contribute most significantly to the model's decisions (Chaudhuri & Clarke, 2013).

In addition to the technical metrics, we added to the evaluation questionnaire urban metrics that can quantify the urban problems detection of the model per image:

- **Urban Sprawl Detection Rate (USR):** Calculate the percentage of images correctly identified as exhibiting urban sprawl out of the total images labelled as having urban sprawl (Sonde et al., 2020).

$$USR = \frac{TP_{sprawl}}{TP_{sprawl} + FN_{sprawl}}$$

where TP_{sprawl} is the number of true positives for urban sprawl, and FN_{sprawl} is the number of false negatives for urban sprawl.

- **Urban Decay Detection Rate (UDR):** Measure the proportion of images correctly identified as displaying urban decay out of the total images labelled as having urban decay (Vallebuena & Lee, 2023).

$$UDR = \frac{TP_{decay}}{TP_{decay} + FN_{decay}}$$

where TP_{decay} is the number of true positives for urban decay, and FN_{decay} is the number of false negatives for urban decay.

- **Infrastructure Deficiencies Detection Rate (IDR):** Determine the percentage of images correctly identified as indicating infrastructure deficiencies out of the total images labelled as having infrastructure deficiencies (Kanyepe, 2023)

$$IDR = \frac{TP_{infra}}{TP_{infra} + FN_{infra}}$$

Where TP_{infra} is the number of true positives for infrastructure deficiencies, and FN_{infra} is the number of false negatives for infrastructure deficiencies.

- **Environmental Degradation Detection Rate (EDR):** Compute the proportion of images correctly identified as showing environmental degradation out of the total images labelled as having environmental degradation (Khatun, 2017).

$$EDR = \frac{TP_{env}}{TP_{env} + FN_{env}}$$

Where TP_{env} is the number of true positives for environmental degradation, and FN_{env} is the number of false negatives for environmental degradation.

2.2.2 Population Selection

The study targets a diverse population comprising 200 individuals, including researchers, developers, architects, and urbanists. This sample size was determined based on statistical power analysis, indicating that a minimum of 200 responses would provide sufficient power to detect significant differences in urban metrics across various demographic groups, ensuring the results are representative of the broader population in urban planning contexts.

2.2.3 Questionnaire Distribution and Data Collection

- **Distribution:** The questionnaire is distributed electronically via email or online survey platforms to the identified population. Participants are invited to complete the questionnaire voluntarily.
- **Data Collection:** Responses from participants are collected over a specified time period, ensuring adequate representation from each demographic category.

2.2.4 Data Preparation

- **Cleaning:** The collected data is cleaned to address any inconsistencies or missing values.
- **Coding:** Likert scale responses for technical and urban metrics are coded numerically for analysis purposes.

2.2.5 Data Analysis

- **Descriptive Analysis:** Analyzed descriptively to characterize the study population.
- **Technical Metrics Analysis:** To comprehend the central tendencies and variability of each technical metric, we calculate fundamental descriptive statistics. This analysis enables a clear understanding of the distribution and characteristics of these metrics.
- **Urban Metrics Analysis:** Mean scores for urban metrics feedback (urban sprawl detection rate, urban decay detection rate, infrastructure deficiencies detection rate, environmental degradation detection rate) are computed and compared across degrees of consent.

2.2.6 Statistical Tests

- **Correlation Analysis:** To explore relationships between demographic variables and Likert scale responses for technical and urban metrics.

3. Results

3.1 Model Performance

To present the model's outcome results we start with the main used prompt:

USER: <image>\n

Analyze the image and indicate whether each of the following urban problems is present, providing reasoning based on the visual cues observed. Respond with 'Yes' or 'No' for each problem and explain your reasoning.

Urban Problems:

Urban Sprawl: (Yes/No) Reasoning:

Urban Decay: (Yes/No) Reasoning:

Infrastructure Deficiencies: (Yes/No) Reasoning:

Environmental Degradation: (Yes/No) Reasoning: """"

For this prompt, we present the following examples (01, 02 and 03):



Figure 2. Example 01, 02 and 03.

Model response for example 01:

- ✓ Urban Sprawl: Yes. Reasoning: The image shows a large number of cars parked on the street, which indicates that the area is densely populated. This suggests that the urban area is experiencing urban sprawl, where the city expands outward, leading to increased population density and limited space for infrastructure development.
- ✓ Urban Decay: No. Reasoning: The image shows a well-maintained street with cars parked neatly, indicating that the area is well-cared for and not experiencing any signs of urban decay.
- ✓ Infrastructure Deficiencies: No. Reasoning: The image shows a well-maintained street with cars parked neatly, indicating that the infrastructure in the area is well-developed and not experiencing any deficiencies.
- ✓ Environmental Degradation: No. Reasoning: The image shows a well-maintained street with cars parked neatly, indicating that the area is not experiencing any signs of environmental degradation.

Model response for example 02:

- ✓ Urban Sprawl: Yes. Reasoning: The presence of multiple cars parked in the parking lot indicates that the building is a commercial or office building, which is a common characteristic of urban sprawl.
- ✓ Urban Decay: No. Reasoning: The building appears to be well-maintained and in good condition, which suggests that it is not experiencing urban decay.
- ✓ Infrastructure Deficiencies: No. Reasoning: The parking lot is well-maintained, and there are no visible signs of neglect or deterioration, which indicates that the infrastructure is not deficient.
- ✓ Environmental Degradation: No. Reasoning: The building is surrounded by trees, which suggests that the area is not experiencing significant environmental degradation.

Model response for example 03:

- ✓ Urban Sprawl: Yes. The image shows a street with many houses and cars, indicating that the area is densely populated and has likely expanded beyond its original boundaries.
- ✓ Urban Decay: Yes. The image shows a street with many houses and cars, indicating that the area is densely populated and has likely expanded beyond its original boundaries.
- ✓ Infrastructure Deficiencies: Yes. The image shows a street with many houses and cars, indicating that the area is densely populated and has likely expanded beyond its original boundaries.
- ✓ Environmental Degradation: No. The image shows a street with many houses and cars, indicating that the area is densely populated and has likely expanded beyond its original boundaries. However, there is no clear indication of environmental degradation in the image.

3.2 Model evaluation

This section presents the results of the model evaluation questionnaire, which was distributed to assess the performance of the urban problems detection model. Out of 200 questionnaires sent, 132 were completed and returned, resulting in a response rate of 66%. The analysis is divided into three main parts: demographic characteristics, technical metrics, and urban metrics.

3.2.1 Descriptive Analysis

The following section presents descriptive statistics summarizing the demographic characteristics of the participants involved in the evaluation of the urban problems detection model.

a- Age: Figure 3 displays the age distribution frequencies of participants in the study, categorized into three age ranges: 18-24, 25-44, and 45-64. It shows the frequency and percentage of participants in each age group, along with valid and cumulative percentages. The majority of participants (37.1%) fall within the 25-44 age range, followed by those aged 18-24 (34.1%) and 45-64 (28.8%).

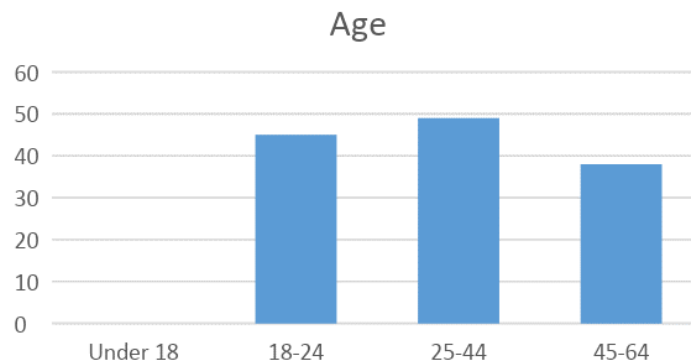


Figure 3. Age distribution.

b- Gender: Figure 4 shows the gender distribution of participants, divided into Male and Female categories. It indicates that 56.8% of participants are Male, while 43.2% are Female.

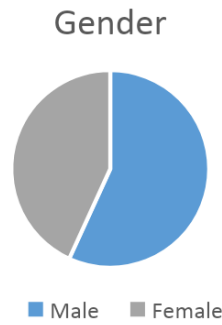


Figure 4. Gender distribution.

c-Education: Figure 5 displays the education level frequency distribution of participants, categorized into four groups. It shows the percentage of participants in each category, with the highest proportion having a Bachelor's degree (28.8%), followed by a Doctorate (23.5%), High school (28.0%), and Master's degree (19.7%).

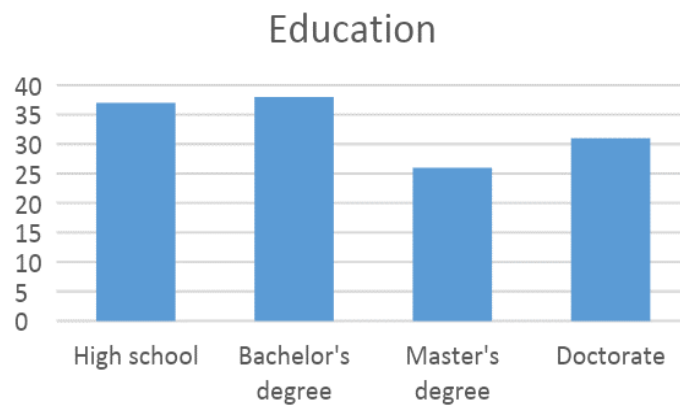


Figure 5. Education level.

d-Country : Figure 6 shows the distributions by country. It indicates the percentages from each country, with Algeria (14.4%), Egypt (12.1%), and Romania (15.9%) being the most represented.

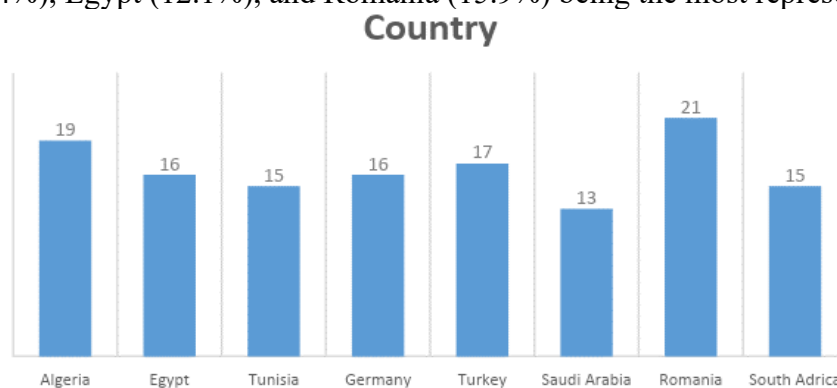


Figure 6. Countries distribution.

3.2.2 Technical Metrics Analysis

The evaluation results reveal varying perceptions among participants regarding the technical metrics of the model. In terms of accuracy, a notable portion (27.3%) strongly agree with the model's accuracy, while 18.9% express disagreement as mentioned in Figure 7. Similarly, for precision, opinions are split, with 13.6% strongly disagreeing and 22.7% strongly agreeing (Figure 8).

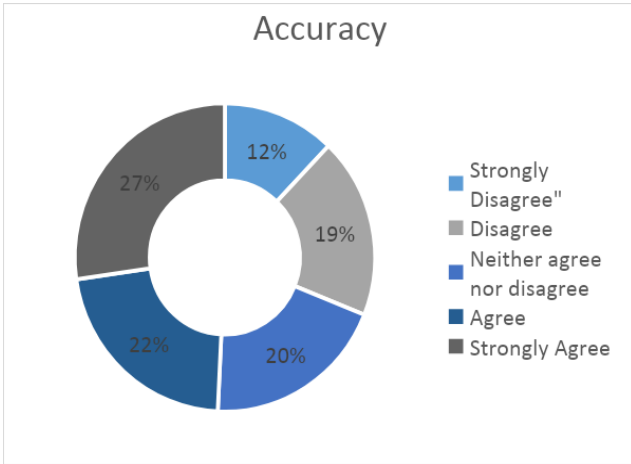


Figure 7. Precision results mean.

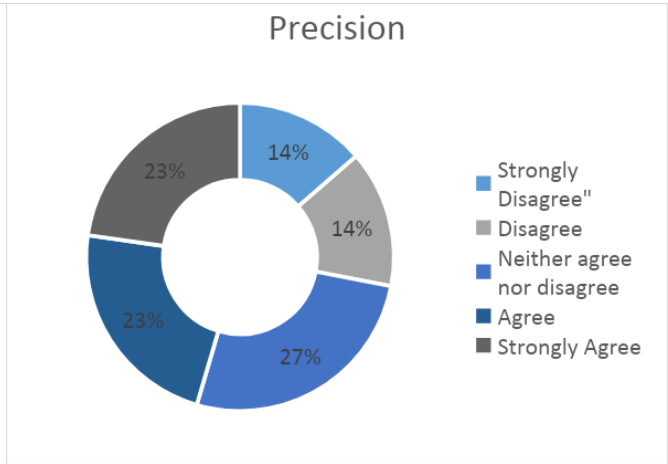


Figure 8. Accuracy results mean.

Regarding recall, there is a divergence of opinions, with 17.4% strongly disagreeing and 17.4% strongly agreeing with the model's recall (Figure 9). Participants also display varied sentiments towards the F1 score, with 20.5% strongly disagreeing and 19.7% strongly agreeing as in Figure 10.

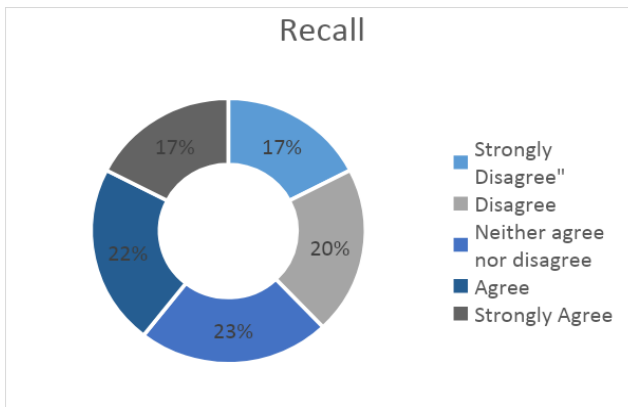


Figure 9. Recall results mean.

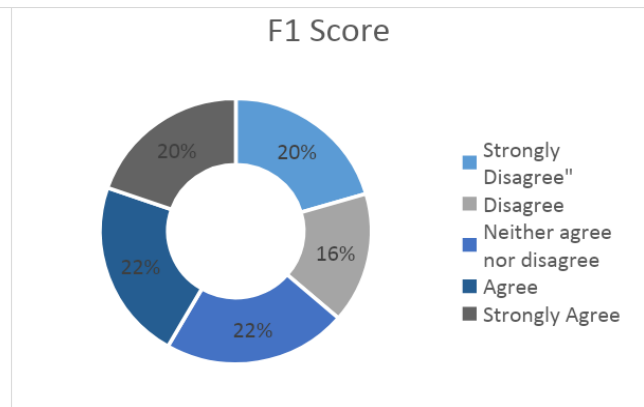


Figure 10. F1 Score results mean.

Regarding the understanding of the confusion matrix, Figure 11 shows that 20.5% strongly disagree, and 22.0% strongly agree. Interpretation of feature importance generates mixed responses, with 19.7% strongly disagreeing and 26.5% strongly agreeing (Figure 12).

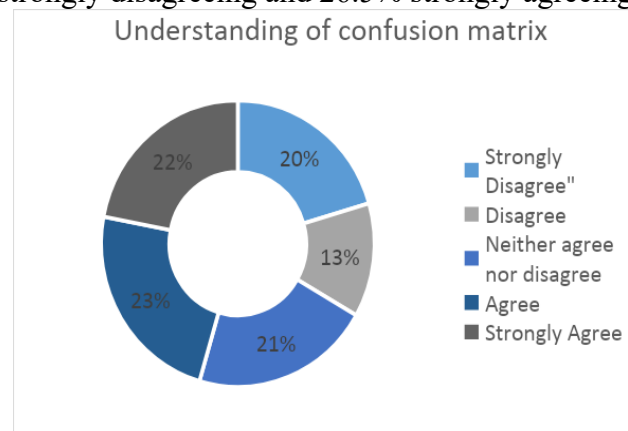


Figure 11. IFI results mean.

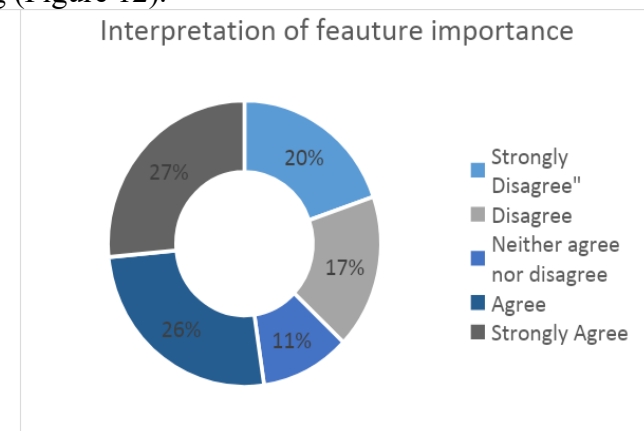


Figure 12. UCM results mean.

These results underscore the nuanced perceptions of participants regarding the model's technical performance, highlighting areas of consensus and divergence.

3.2.3 Urban Metrics Analysis

The assessment of urban metrics unveils a spectrum of perspectives among participants regarding the model's efficacy in identifying specific urban issues. Regarding the detection rate of urban sprawl, Figure 13 shows some opinions diverge, with 25.8% of participants strongly agreeing with the model's capability, while 16.7% strongly disagree (Figure 14).

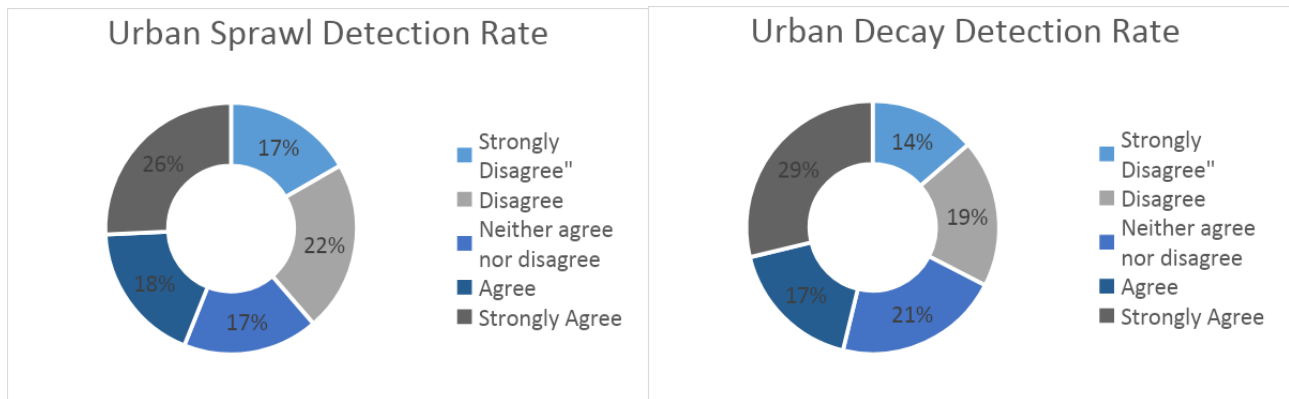


Figure 13. UDDR results mean. **Figure 14.** USDR results mean.

Similarly, for urban decay detection, Figure 15 shows that 28.8% strongly agree, contrasting with 13.6% who strongly disagree. Infrastructure deficiency detection prompts varied responses, with 23.5% disagreeing and 17.4% strongly agreeing. Figure 16 shows the Environmental degradation detection's results which elicits mixed sentiments, as 28.0% disagree and 22.0% strongly agree.

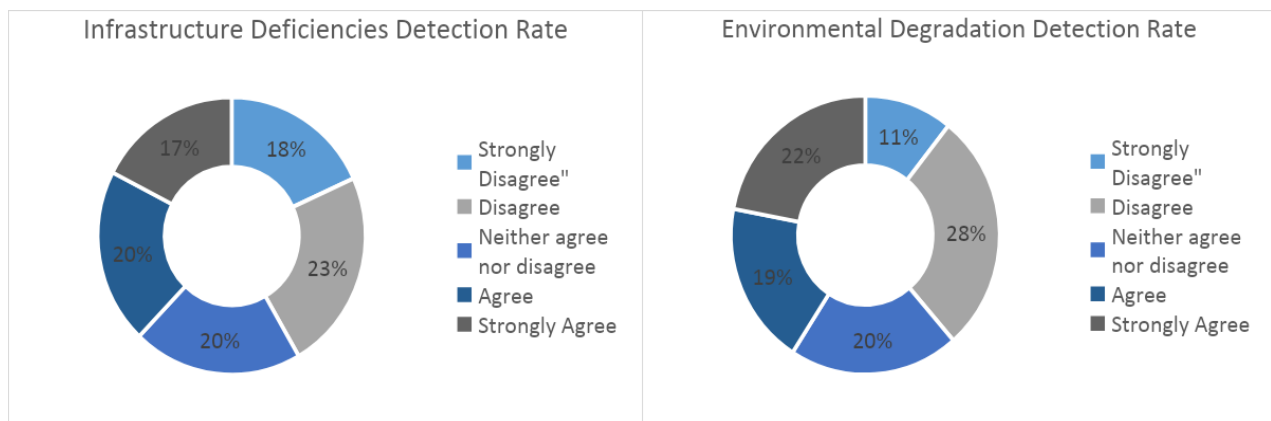


Figure 15. EDDR results mean. **Figure 16.** IDDR results mean.

These results underscore the nuanced perceptions among participants regarding the model's effectiveness in identifying distinct urban challenges.

3.2.4 Statistical Tests

a- Correlations:

Accuracy and F1 Score: There is a significant positive correlation between accuracy and F1 score ($r = 0.216, p < 0.05$), indicating that as accuracy increases, the F1 score tends to increase as well.



Precision and Infrastructure Deficiencies Detection Rate: There is a significant negative correlation between precision and infrastructure deficiencies detection rate ($r = -0.174$, $p < 0.05$), suggesting that higher precision is associated with lower rates of detecting infrastructure deficiencies.

Recall and F1 Score: Recall and F1 score ($r = 0.123$, $p < 0.05$), indicating that higher recall tends to be associated with higher F1 scores.

Understanding of Confusion Matrix and Urban Sprawl Detection Rate: There is a significant negative correlation between understanding of the confusion matrix and urban sprawl detection rate ($r = -0.113$, $p < 0.05$), suggesting that better understanding of the confusion matrix is associated with lower rates of urban sprawl detection.

Interpretation of Feature Importance and Environmental Degradation Detection Rate: There is a significant negative correlation between interpretation of feature importance and environmental degradation detection rate ($r = -0.051$, $p < 0.05$), indicating that better interpretation of feature importance is associated with lower rates of environmental degradation detection.

4. Discussion

4.1 Interpretation of the Model Performance Findings

The model's performance in detecting urban problems, as assessed through the presented prompt and examples, reveals both strengths and areas for improvement.

In Example 01, the model correctly identifies urban sprawl by reasoning about the density of cars parked on the street, indicative of increased population density and limited space for infrastructure development. However, it erroneously identifies the absence of urban decay, infrastructure deficiencies, and environmental degradation based solely on the appearance of a well-maintained street. This suggests that while the model effectively recognizes certain visual cues associated with urban sprawl, it may lack the contextual understanding required to accurately assess other urban problems.

Example 02 demonstrates a similar pattern, with the model correctly identifying urban sprawl based on the presence of cars parked in a commercial or office building's parking lot. However, its assessment of urban decay, infrastructure deficiencies, and environmental degradation appears oversimplified, relying solely on visual cues such as the building's condition and surrounding trees. This highlights the model's tendency to overlook nuanced indicators of urban problems beyond surface-level observations.

In Example 03, the model correctly identifies urban sprawl based on the presence of houses and cars indicating dense population and expansion beyond original boundaries. However, it incorrectly identifies urban decay and infrastructure deficiencies, presuming them based on the density of houses and cars without considering other contextual factors. Nonetheless, the model correctly refrains from identifying environmental degradation due to the absence of clear visual cues in the image.

Overall, while the model demonstrates proficiency in identifying certain urban problems such as urban sprawl, its performance is limited by its reliance on visual cues and its inability to contextualize these cues effectively. To enhance the model's accuracy and effectiveness, future iterations may benefit from incorporating contextual information, semantic understanding, and real-time data integration to provide more nuanced assessments of urban environments.

4.2 Model evaluation

4.2.1 Demographic analysis

The demographic analysis of the model evaluation questionnaire reveals insights into participant characteristics. With a response rate of 66%, the study shows diverse representation across age groups, genders, education levels, and countries of residence. Most participants are aged 25-44, with a relatively balanced gender distribution. The majority hold Bachelor's degrees, and respondents come



from various countries, indicating a broad geographic scope and a diverse pool of perspectives in assessing the urban problems detection model.

4.2.2 Technical Metrics Analysis

The technical metrics analysis showcases diverse perspectives among participants regarding the model's performance. While a significant portion strongly agrees with its accuracy (27.3%) and precision (22.7%), there are notable percentages expressing disagreement. Similarly, opinions on recall and F1 score vary, with some strongly disagreeing (17.4% for each) and others strongly agreeing (also 17.4% for each). Understanding the confusion matrix and interpreting feature importance elicits mixed responses, indicating varying levels of understanding and interpretation among participants. These findings highlight the complexity of evaluating technical metrics and the importance of considering diverse viewpoints in assessing model performance.

4.2.3 Urban Metrics Analysis

The analysis of urban metrics reveals a diverse range of viewpoints among participants regarding the model's ability to identify specific urban issues. While a significant portion strongly agrees with the model's efficacy in detecting urban sprawl (25.8%) and urban decay (28.8%), there are also notable percentages expressing disagreement. Similarly, opinions on infrastructure deficiencies detection and environmental degradation detection are varied, with some disagreeing (23.5% and 28.0%, respectively) and others strongly agreeing (17.4% and 22.0%, respectively).

4.2.4 Correlation interpretation

The correlation analysis (Appendix 01) reveals several significant relationships between different variables:

- Accuracy and F1 Score: There is a positive correlation, suggesting that as accuracy increases, the F1 score tends to increase as well.
- Precision and Infrastructure Deficiencies Detection Rate: A negative correlation indicates that higher precision is associated with lower rates of detecting infrastructure deficiencies.
- Recall and F1 Score: A positive correlation indicates that higher recall tends to be associated with higher F1 scores.
- Understanding of Confusion Matrix and Urban Sprawl Detection Rate: A negative correlation suggests that a better understanding of the confusion matrix is associated with lower rates of urban sprawl detection.
- Interpretation of Feature Importance and Environmental Degradation Detection Rate: Another negative correlation indicates that better interpretation of feature importance is associated with lower rates of environmental degradation detection.

4.2.5 Comparison with previous studies

Our findings were contextualized by discussing the model's performance in relation to existing urban analysis methodologies, such as traditional GIS-based approaches and recent machine learning models. Traditional GIS-based approaches, while providing comprehensive spatial analyses, often lack real-time capabilities and struggle to integrate diverse data types effectively (Yu and Fang, 2023). Recent machine learning models offer advanced pattern recognition and predictive capabilities but are limited by their dependence on large, labelled datasets and susceptibility to biases (Mumuni and Mumuni, 2024; Lepakshi, 2022). In contrast, our model combines real-time data integration and multimodal analysis, offering a more nuanced and dynamic understanding of urban problems. This discussion highlights the added value of our proposed model in providing real-time, data-driven insights for urban planners, effectively addressing the limitations found in both traditional and recent (Šoštarić et al, 2021).

4.2.6 Implications of Enhancing Model Robustness in Urban Planning

The model's reliance on visual cues can be mitigated by incorporating multimodal data sources, such as socio-economic indicators, historical data, and environmental metrics, to provide a more comprehensive analysis of urban problems. Integrating Geographic Information System (GIS) data, real-time sensor data, and textual data from urban reports and social media can enhance contextual understanding and improve the model's accuracy. To address contextual misinterpretations, the AI model could benefit from advanced techniques such as transfer learning and domain adaptation. These approaches would allow the model to leverage pre-trained networks on large datasets and fine-tune them for specific urban contexts. Additionally, incorporating human-in-the-loop feedback mechanisms can help refine the model's predictions by allowing urban planners to provide corrective input and context-specific insights. Biases and fairness issues were addressed by implementing rigorous data preprocessing steps, such as balancing the dataset to represent diverse urban environments and demographic groups. The model's fairness was further evaluated by conducting subgroup analyses to ensure equitable performance across different regions and population segments. Ethical considerations were embedded in the design process to promote transparency, accountability, and inclusivity in urban planning.

Based on the study's findings, several actionable recommendations are proposed for urban planners to enhance their decision-making processes. Firstly, integrating the AI model with existing urban planning tools can significantly improve data-driven decision-making. Utilizing the model's insights allows planners to identify priority areas for infrastructure development and environmental conservation more effectively. Engaging with local communities to validate the model's predictions and gather contextual information is crucial for ensuring the relevance and accuracy of the assessments. Continuously updating the model with new data and feedback will further improve its performance over time. Finally, promoting interdisciplinary collaboration between urban planners, data scientists, and policymakers can leverage the full potential of AI in urban development, ensuring a more comprehensive and informed approach to addressing urban challenges.

5. Conclusion

This study provides a comprehensive synthesis of the performance and perceptions of an urban problems detection model, revealing significant correlations. Notably, there is a positive relationship between accuracy and F1 score ($r = 0.216$, $p < 0.05$) and a negative correlation between precision and infrastructure deficiencies detection rate ($r = -0.174$, $p < 0.05$). These findings highlight areas for improvement in the model's accuracy and precision, offering valuable insights for both academic research and practical applications.

The implications of this research extend to the field of urban planning, where AI-driven decision-making processes can benefit from more accurate and reliable detection models. Practical applications for urban planners include the potential for more informed decision-making processes, leading to better infrastructure development and environmental conservation efforts. Ethical considerations were a core component of this research, with rigorous data preprocessing steps implemented to mitigate biases and ensure fairness. Transparency and accountability were prioritized throughout the design process to promote equitable outcomes in urban planning. Additionally, the findings are generalizable to different urban contexts, provided that the model is adapted to account for local variations and specificities. Future research should explore new areas such as the integration of multimodal data and advanced machine learning techniques to further enhance the model's performance.

Methodological limitations inherent in the research methodology or model architecture may include constraints related to data availability, model complexity, or computational resources, potentially



affecting accuracy and reliability as reported in the study of Aldoseri et al. (2024). The generalizability of findings may be limited by biases or assumptions in the research approach, necessitating careful consideration when interpreting results. Future directions could involve refining the generative model by optimizing hyperparameters or expanding the dataset to encompass a wider range of architectural styles and environmental conditions. Addressing these limitations in future studies is crucial for achieving more effective and equitable urban problem detection.

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The authors declare no conflicts of interest.

Data availability statement

Additional data related to this study can be obtained from the corresponding author upon request.

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Not applicable.

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Appendices

Appendix 1: Correlation table.



Correlations

	Accuracy	Precision	Recall	F1 Score	Understanding of Confusion Matrix	Interpretation of Feature Importance	Urban Sprawl Detection Rate	Urban Decay Detection Rate	Infrastructure Deficiencies Detection Rate	Environmental Degradation Detection Rate
Accuracy	1									
Corrélation de Pearson		-.040	.014	.216	.139	-.147	.060	.056	-.012	-.013
Sig. (bilatérale)		.646	.876	.013	.111	.093	.493	.521	.890	.887
N	132	132	132	132	132	132	132	132	132	132
Precision		1								
Corrélation de Pearson	-.040		-.053	.018	-.007	-.045	-.056	.081	-.174	-.047
Sig. (bilatérale)	.646		.545	.839	.936	.610	.526	.356	.047	.596
N	132	132	132	132	132	132	132	132	132	132
Recall			1							
Corrélation de Pearson	.014	-.053		.123	-.001	.047	.003	.026	-.049	-.120
Sig. (bilatérale)	.876	.545		.159	.990	.591	.975	.770	.577	.171
N	132	132	132	132	132	132	132	132	132	132
F1 Score				1						
Corrélation de Pearson	.216	.018	.123		.035	.118	.101	-.045	-.054	.045
Sig. (bilatérale)	.013	.839	.159		.694	.179	.248	.609	.538	.605
N	132	132	132	132	132	132	132	132	132	132
Understanding of Confusion Matrix					1					
Corrélation de Pearson	.139	-.007	-.001	.035		-.003	-.113	-.023	.128	.062
Sig. (bilatérale)	.111	.936	.990	.694		.969	.199	.791	.145	.478
N	132	132	132	132	132	132	132	132	132	132
Interpretation of Feature Importance						1				
Corrélation de Pearson	-.147	-.045	.047	.118	-.003		.031	-.034	-.056	.027
Sig. (bilatérale)	.093	.610	.591	.179	.969		.724	.701	.454	.759
N	132	132	132	132	132	132	132	132	132	132
Urban Sprawl Detection Rate							1			
Corrélation de Pearson	.060	-.056	.003	.101	-.113	.031		.006	.088	.081
Sig. (bilatérale)	.493	.526	.975	.248	.199	.724		.948	.315	.356
N	132	132	132	132	132	132	132	132	132	132
Urban Decay Detection Rate								1		
Corrélation de Pearson	.056	.081	.026	-.045	-.023	-.034	.006		-.029	-.029
Sig. (bilatérale)	.521	.356	.770	.609	.791	.701	.948		.744	.740
N	132	132	132	132	132	132	132	132	132	132
Infrastructure Deficiencies Detection Rate									1	
Corrélation de Pearson	-.012	-.174	-.049	-.054	.128	-.056	.088	-.029		-.051
Sig. (bilatérale)	.890	.047	.577	.538	.145	.454	.315	.744		.561
N	132	132	132	132	132	132	132	132	132	132
Environmental Degradation Detection Rate										1
Corrélation de Pearson	-.013	-.047	-.120	.045	.062	.027	.081	-.029	-.051	
Sig. (bilatérale)	.887	.596	.171	.605	.478	.759	.356	.740	.561	
N	132	132	132	132	132	132	132	132	132	132

*. La corrélation est significative au niveau 0.05 (bilatérale).



Original scientific paper

Assessing Urban Green Space Accessibility for Sustainable Development in Mostaganem, Algeria: A Space Syntax Approach

*1 Dr. Okba Benameur , 2 Fouad Leghrib , 3 Abdelbasset Laroui

¹ Department of Architecture, Faculty Of Sciences and Technology, University of Mostaganem, Algeria

² Architecture Urban Design and Environment Laboratory (LaCoMoFA), University of Biskra, Algeria

³ Department of hydraulics and civil engineering, Faculty Of Sciences and Technology, University of Ghardaia, Algeria

¹ E-mail: okba.benameur@univ-mosta.dz, ² E-mail: fouad.leghrib@univ-mosta.dz, ³ E-mail: laroui.abdelbasset@univ-ghardaia.dz

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 Geographic Information Systems (GIS).

ABSTRACT



The rapid urbanization of Mostaganem, Algeria, has led to significant challenges in the accessibility of urban green spaces (UGS), crucial for promoting environmental sustainability and public health. This study uses a space syntax approach, specifically angular segment analysis (ASA), to assess UGS accessibility at city-wide and local scales. By integrating quantitative measures like "Choice" and "Integration" with Geographic Information Systems (GIS), the research identifies spatial disparities in green space distribution and accessibility, with global integration values ranging from 0.469 to 0.801. Results reveal unequal distribution, infrastructure inadequacies, and safety issues affecting accessibility. The study highlights areas like Boudjemaa and Emir Abd El Kader, which offer high connectivity, while others like Jannat El Aarif suffer from limited accessibility. Recommendations include enhancing transportation infrastructure, prioritizing green spaces in urban planning, and diversifying facilities to improve accessibility and promote social inclusion. This research provides a comprehensive framework for policymakers and urban planners, aiming to optimize urban green space accessibility and contribute to sustainable urban development in Mostaganem, aligning with global efforts towards equitable urban environments.

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Highlights:

- Urban green spaces in Mostaganem, Algeria, face significant accessibility challenges due to rapid urbanization.
- The integration of Angular Segment Analysis (ASA) with Geographic Information System (GIS) methodologies reveals spatial disparities in green space distribution.
- Inequitable distribution of green spaces negatively impacts accessibility and urban quality of life.

Contribution to the field statement:

This study advances urban planning methodologies by integrating Angular Segment Analysis (ASA) with Geographic Information System (GIS) to assess urban green space accessibility in Mostaganem, Algeria. By identifying spatial disparities and proposing targeted improvements, it provides actionable insights for policymakers and urban planners, enhancing urban development strategies and contributing to equitable and sustainable urban environments.

* Okba Benameur:

Department of Architecture, Faculty Of Sciences and Technology, University of Mostaganem, Algeria

Email address: okba.benameur@univ-mosta.dz

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1. Introduction

Since 2008, there has been a notable transition towards urbanization globally, marked by the urban population exceeding the rural population for the first time in the annals of humanity (United Nations, 2022). This shift underscored the consistent pattern of urbanization, especially in regions with lower levels of development, where Asia and Africa emerge as the primary focal points (van Maarseveen et al., 2018).

Algeria, the largest African country, has encountered a significant challenge of rapid population growth following the attainment of independence in 1962. This urban population rate has witnessed a notable increase from 33.2% in 1962 to 73.7% in 2020, with projections indicating a further rise to 85% by the year 2050, as reported by the United Nations in 2018 (United Nations, 2019). Throughout the past three decades, the predominant approach to urban planning has involved a simultaneous expansion of urban areas, and increased land consumption (Leghrib et al., 2021). This particular strategy has discernible implications for the availability and accessibility of public parks and other green spaces within the Algerian context.

The process of rapid urbanization has been accompanied by a multitude of challenges, encompassing environmental concerns, health hazards, and social inequalities (Anwar et al., 2023), thus underscoring the need for a concentrated effort toward sustainable urban development. The dearth of green spaces within urban areas stands out as a prominent ramification of swift urbanization witnessed in numerous global cities (Li et al., 2022). Algerian authorities, through urban and territorial planning documents such as SNAT 2025 and SNAT 2030, are promoting sustainable development by providing long-term guidelines and perspectives. This policy has notably enhanced various aspects of urban quality of life, including public transportation, public spaces, and urban green spaces. For example, the implementation of Law No. 07-06 of May 13th, 2007, outlines specifications for the management, protection, and development of green spaces, resulting in significant improvements. According to the Ministry of Environment (2021), the area of urban green spaces increased from 80 million square metres in 2014, with a ratio of 2.06 m² per capita, to 174 million square metres, or a ratio of 4.01 m² per person, in 2021. However, this ratio still falls short of the World Health Organization's international minimum standard of 9 m² per person.

Despite these advancements, the policy lacks detailed specifications regarding the distribution of urban green spaces within urban areas and their usability. This includes aspects such as adaptability for different uses and groups of users, as well as their accessibility. This gap hinders the full realization of the potential benefits of urban green spaces, limiting their contribution to enhancing the quality of urban life and sustainable development. Much like other regions, Mostaganem in Algeria is grappling with the repercussions of accelerated urban growth, particularly in terms of the quality and quantity of available green areas. Algeria ranks 4th in the Arab region with a Sustainable Development Goals (SDGs) index score of 67 out of 100. However, it faces significant challenges related to target 11.7, which focuses on urban green and public spaces as part of sustainable cities and communities' goals, as highlighted by the recent Arab Region SDG Index and Dashboard Report (Bayoumi et al., 2022).

UGS play a crucial role in offering a diverse array of advantages, which span across various dimensions. These advantages encompass environmental benefits such as the enhancement of air quality (Lee et al., 2015), the mitigation of water pollution, protection against soil erosion, and the improvement of the aesthetic appeal of urban areas. Moreover, UGS contribute to social benefits by enhancing the overall well-being and health of residents (Addas, 2023; Festa et al., 2022; Vilcins et al., 2022), generating employment opportunities, boosting tourism, and addressing issues related to climate change adaptation and biodiversity preservation. Consequently, it is imperative to ensure the appropriate design of green spaces to materialize these benefits effectively, along with implementing accessibility measures in alignment with the idea that green spaces play a role in fostering positive outcomes.



The issue of providing equal access to green areas in urban settings persists, especially in rapidly expanding metropolitan regions such as Mostaganem, Algeria. Consequently, the quantification and comprehension of the availability of UGS using the configurational metrics of Space Syntax theory could positively impact the physical and social performance of UGS within a city.

Given the challenges posed by rapid urbanization, the lack of prioritization for green spaces, and the absence of comprehensive studies within the Algerian context, this research aims to investigate the intersection of accessibility and sustainability of urban green spaces (UGS) in Mostaganem. By reviewing the current availability of green spaces and analysing the characteristics of 12 existing green spaces within the urban spatial network, the study focuses on the role of space syntax angular segment analysis in assessing spatial configuration and accessibility. This research aims to provide a novel understanding of the role and importance of green spaces within the urban planning framework of Mostaganem, thereby contributing to the broader discourse on sustainable urban development in Algeria.

1.1 Urban Green Spaces Accessibility Assessment

Beyond the space syntax community, several studies have investigated urban green spaces (UGS) from diverse perspectives using different methods. In particular, remote sensing (RS) and geographic information systems (GIS) have been utilized to analyze and quantify the spatiotemporal dynamics and changes of UGS (Chen et al., 2017; Wang et al., 2018) and evaluate their characteristics, such as abundance, spatial distribution, and species composition (Shahtahmassebi et al., 2021). Furthermore, RS and GIS-based suitability analyses are used to strategically identify suitable locations for UGS development (Moisa et al., 2023). Further research has focused on other localized concerns, such as the concept of human thermal comfort (Ahmadi Venhari et al., 2019), as well as strategies to mitigate urban heat island (UHI) effects and land surface temperature (LST) (Du et al., 2017; Gherraz et al., 2020; Yu et al., 2018).

By definition, accessibility refers to the convenience of accessing numerous destinations from various origins within the urban network across different spatial scales. It holds significant importance in determining the placement of public amenities to enhance usability for a broad population or restrict usage to a smaller community (Huang et al., 2023).

The unequal distribution of urban green spaces within cities poses significant challenges, in front of them those related to "Accessibility", necessitating thorough spatial assessments to guarantee social and environmental equity for the urban residents. Choosing unsuitable locations for UGS can result in reduced accessibility for the intended populations they are meant to serve, potentially leading to inefficiently utilized or neglected spaces, and, at the extreme, misused spaces that could be exploited for illegal and criminal activities (Hillier, 2007).

Diverse methods are used to quantify and understand the accessibility of UGS, such as GIS-based network analysis (Buckland & Pojani, 2023), and location-based methods that consider the traditional definition of accessibility in terms of the ease of reaching different land uses through available modes of transportation (Morales et al., 2019).

On the other hand, Space Syntax offers quantitative assessments of different levels of accessibility within the urban spatial network since it examines accessibility through network centrality, focusing solely on the topological and geometric characteristics of urban layouts.

Studies highlight the significance of spatial syntax methods in assessing the accessibility of UGS to enhance their physical and social functionality within a city (Long et al., 2023; Tannous et al., 2021).

The advantage of space syntax lies in its ability to describe how the overall spatial structure or morphology influences the accessibility of UGS from a spatial relations perspective.

1.2 Urban Green Spaces as a Key to Sustainable Cities

UGS are increasingly acknowledged as key elements of sustainable urban development, contributing to environmental quality, social well-being, and economic prosperity. They play a pivotal role in fulfilling various United Nations Sustainable Development Goals (SDGs), specifically, they contribute to the achievement of the eleventh goal concerning sustainable cities and communities, and its seventh target that emphasizes "ensuring universal access to safe, inclusive, and accessible green and public spaces, particularly for women, children, older individuals, and those with disabilities" (Bayoumi et al., 2022).



Figure 1. The interconnectivity between SDG 11 targets and the other SDGs and their respective targets (Source: Orsetti et al., 2022).

In this context, UGS serve a purpose beyond mere ornamentation, constituting a crucial component of an ecosystem that fulfils a diverse array of physical and social roles and functions (Tannous et al., 2021). The significance of UGS to the urban environment can be seen through many lenses. These spaces offer a wide spectrum of advantages, encompassing various aspects, ranging from environmental to social and economic dimensions (Belmeziti et al., 2018; Dipeolu et al., 2020; Lee et al., 2015).

The importance of UGS lies in the environmental advantages it offers, such as mitigating the urban heat island (UHI) effect and decreasing the energy expenses associated with cooling structures. The presence of green areas in urban settings helps in reducing air, water, and noise pollution, while also potentially compensating for greenhouse gas emissions by absorbing CO₂ (Haq, 2011; Strohbach et al., 2012). Additionally, urban greenery contributes to stormwater attenuation by serving as a flood mitigation strategy (Pataki et al., 2011). Other ecological benefits encompass the conservation of biodiversity and natural habitats (Roy et al., 2012).

From a health perspective, UGS permit health-promoting activities, such as encouraging physical exercise, enhancing overall public health, and improving the psychological well-being of urban residents (Tok et al., 2020). Another significant aspect of UGS lies in its social advantages. Research indicates that incorporating UGS can lead to a decrease in crime rates and vandalism, a reduction in

stress levels, and an encouragement of physical activity through the creation of a greener and safer environment (Branas et al., 2011). Furthermore, UGS offer opportunities for social engagements to take place, potentially aiding in the mitigation of social isolation (Haq, 2011), fostering the development of social capital, promoting social unity, and reinforcing connections within communities (Mears & Brindley, 2019; Wolch et al., 2014).

2. Case Study Presentation

Mostaganem is a coastal city in the northwest of Algeria, located approximately 350km away from the capital Algiers (Figure 2). The littoral and touristic municipality of Mostaganem covers an area of 50km square and offers a rich canvas for studying the spatial dynamics of urban green spaces. It provides an array of urban green space amenities, including lively parks, gardens, and open public spaces.

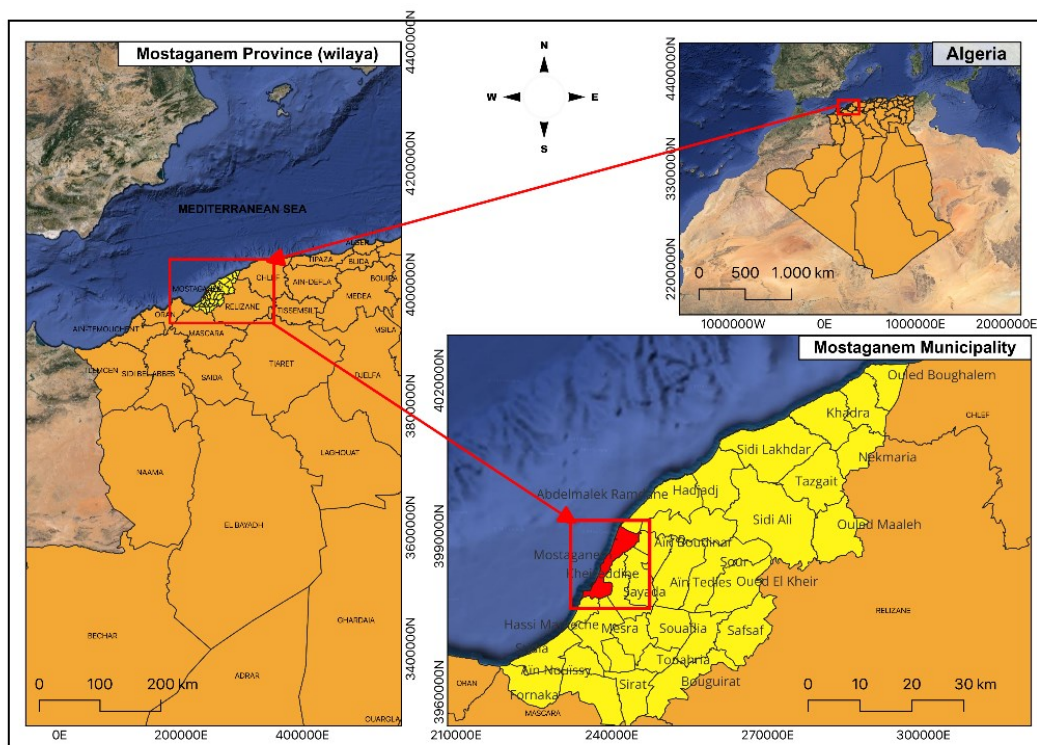


Figure 2. Location map.

Table 1: Urban Green Spaces physical features.

ID	UGS name	Type	Area (ha)	Scale	Location
1	Mostaland	Park	43.497	National	North-east
2	Emir Abd El Kader	Garden	2.352	Community	Downtown
3	Jannat El-Aarif	Garden	2.015		South
4	Houria	Park	1.887		East
5	Foussha	Garden	1.446		South-west
6	Matrba	Plaza	1.220		North-east
7	El Arsa	Park	1.170		East
8	Es-salam	Garden	0.342	Neighborhood	South
9	1 st November	Plaza	0.272		Downtown
10	Salamandre	Plaza	0.213		South-west
11	Boudjemaa	Garden	0.132		Downtown
12	Barail	Square	0.107		Downtown

Therefore, our case study comprises twelve UGS and recreational parks of various sizes operating at multiple scales—national, community, and neighbourhood levels (Table 1). The spatial arrangement of the examined UGS is illustrated in Figure 3.



Figure 3. Urban green spaces geographical distribution.

3. Material and Methods

The assessment of the accessibility and connectivity of UGS is conducted through two key phases: data collection and data analysis (Figure 4). For the initial phase, OpenStreetMap (OSM) provides basic data on the road centrelines network, while UGS are digitized using GIS tools in addition to high-resolution images captured for detailed examination.

Thereafter, the analysis phase comprises a multidimensional approach implemented via two datasets, physical properties and syntactic measures. The first dataset includes physical characteristics such as size, operating scale, and spatial distributions. Thus, the second dataset encompasses the syntactic measures of the Angular Segment Analysis of Space Syntax theory.

Space Syntax theory provides a framework for exploring spatial patterns within a particular environment and their impact on social behaviour, human movement and urban accessibility. Originally developed in the 1970s by “Bill Hillier” and “Julienne Hanson” at University College London, the theory investigates how the layout and connectivity of spaces in a built environment influence human activities and relationships (Hillier & Hanson, 1984). Examining the spatial interactions between different areas, the theory sheds light on how people navigate and use environments, thus providing an understanding of how spatial design can affect movement patterns and the quality of social interactions within a community (Hillier, 2007). Angular segment analysis provides a more precise understanding of spatial relationships and connectivity within urban environments, it refines integration analysis by incorporating angular weights into street segment connections. Unlike Axial analysis, ASA models curved streets using multiple street segments that connect at their ends. These segments are then processed and analysed as a single spatial entity. In addition, ASA has opened up new perspectives for further research into urban planning, architecture and transportation, and is helping to design more efficient, inclusive and sustainable environments (Turner, 2007; van Nes & Yamu, 2021).

The ASA employs integration and choice to measure accessibility and compare the configurational properties of the urban fabric under scrutiny (Turner, 2007, 2009). Moreover, the normalization of these measures remains useful in investigating the inner structure of an urban fabric since it incorporates angular, topological, and metric distances (Hillier et al., 2012; Serra & Hillier, 2019). Accordingly, the syntactic outcomes of the road network of Mostaganem municipality are extracted from “DepthmapX” software and then exported to “QGIS”.

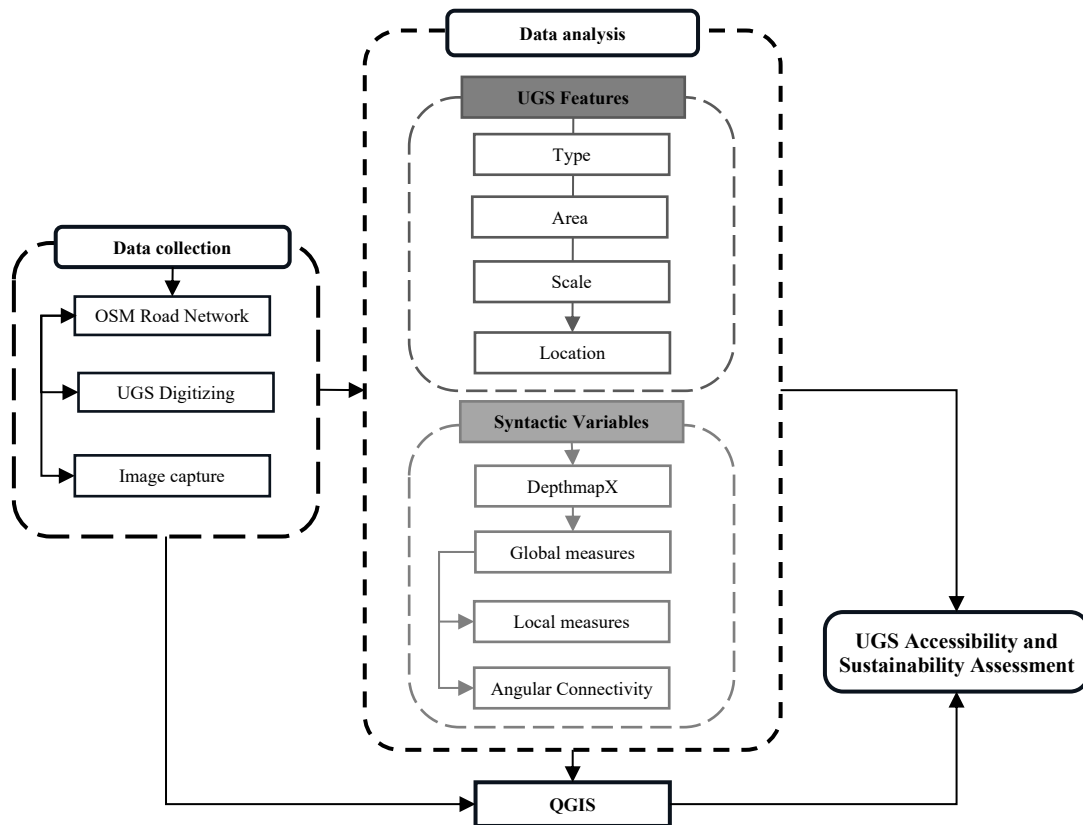


Figure 4. Flowchart of the methodological approach.

Therefore, the accessibility assessment involves several measures such as angular connectivity, normalized angular choice (NACH), and normalized angular integration (NAIN) on a global scale (R_n), and local metric scale within various radii comprising R200, R400, and R800 meters.

Angular Connectivity characterizes the structure of the local urban network by representing it as a graph composed of nodes and edges. This metric effectively captures the extent to which different parts of the urban network are interconnected. Analysing the nodes and edges, provides a comprehensive view of how well-integrated the various segments of the urban landscape are, revealing critical insights into the network's overall connectivity and coherence.

Normalized Angular Integration (NAIN) highlights the relative accessibility or movement potential of a road element within the network, indicating the topological closeness of a road element to all other elements. At specific metric radii, NAIN reveals spatial hierarchies for local sub-centres by assessing movement potentials and relative accessibility. This enhanced understanding of NAIN illuminates the density of road elements and the distribution of sub-centres within a region. By emphasizing their location and connectivity, NAIN provides valuable insights into the overall spatial structure and dynamics of the urban network.

Furthermore, employing GIS enhances the thorough assessment of accessibility and enables accurate digitization and analysis of the extracted syntactic measures, thereby improving visualization and guiding strategic decisions in urban planning.

4. Results and Discussions

The angular segment analysis provides a refined insight into urban spatial patterns of Mostaganem city, through the prism of Space Syntax theory, specifically via the two key measures of normalized angular choice and normalized angular integration (Hillier et al., 2012). The highest values appearing on the global NACH metrics reveal the major urban arteries within the urban layout, highlighting highways such as RN 90, RN 11 and the main thoroughfares, namely avenues Benyahia Belkacem, Ould Aissa Belkacem, Khattab Abdelkader, Mohamed Khemisti, and boulevards Benkara Mostafa and Dahra, being the main arteries of movement, distinguished by high NACH values around 1.487 (Figure 5. A). They constitute the backbone of urban connectivity, guiding the flow of people and resources. Besides, the NAIN map reveals a no-edge effect, where segregated urban structures appear on the periphery and the most integrated layouts are clustered around the city centre core. This concentration signifies the centrality and urban vitality of downtown areas (Figure 5.B). The juxtaposition of high NACH and NAIN values on main roads and in downtown highlights the interaction between vehicular traffic efficiency and urban centrality. The values of NACH and NAIN also enable us to distinguish the disparities in use and accessibility among these urban spaces according to their locations.



Figure 5. Visual representation of the global measures of NACH Rn and NAIN Rn.

The subsequent table presents the derived findings of the syntactic measures of the Angular Segment Analysis, providing insights into Angular connectivity, global and local normalized angular Choice and Integration (Table 2).

Table 2: Syntactic measures of the Angular Segment Analysis:

ID	UGS name	Angular connectivity	NACH R	NAIN R200	NAIN R400	NAIN R800	NACH R	NACH R200	NACH R400	NACH R800
1	Mostaland	1.815	0.524	1.399	1.674	2.116	1.013	1.605	2.472	3.404
2	Emir Abd El Kader	2.445	0.781	2.003	2.361	2.690	1.255	3.143	4.190	4.940
3	Jannat El-Aarif	1.567	0.518	1.228	1.388	1.784	0.793	1.240	1.959	2.842
4	Houria	1.738	0.731	1.604	1.942	2.298	1.295	1.987	2.999	4.163
5	Foussha	1.885	0.551	1.275	1.736	2.203	0.571	1.479	2.037	2.422
6	Matrba	1.820	0.552	1.386	1.670	2.130	1.155	2.039	2.806	3.743
7	El Arsa	1.247	0.606	1.309	1.670	2.249	1.078	2.080	3.121	4.256
8	Es-salam	1.549	0.621	1.242	1.823	2.335	0.974	1.913	3.149	4.456
9	1 st November	2.626	0.736	1.903	2.220	2.560	0.873	2.729	3.289	3.791
10	Salamandre	3.482	0.469	1.781	2.021	2.150	0.810	2.746	3.261	3.332
11	Boudjemaa	4.008	0.801	2.101	2.365	2.698	1.157	3.015	3.764	4.410
12	Barail	3.425	0.720	1.982	2.270	2.593	0.742	2.556	2.892	3.200

On the global scale, Boudjemaa, Emir Abd El Kader, 1st November, and Barail exhibit high connectivity and accessibility within their immediate environment (Figure 6). Located in the city center core areas and surrounded by economic and social functions, these spaces serve as central hubs for social interactions, recreational activities, and cultural events. Boudjemaa and Barail, situated in a bustling commercial district, attract numerous visitors seeking recreational opportunities within the historical urban fabric. The second city's largest park "Emir Abd El Kader" serves as a verdant oasis amidst the urban setting, offering playgrounds and relaxation amenities.

Despite having relatively lower NACH values compared to others, the 1st November Plaza in front of the Badr Mosque exhibits high NAIN values, indicating an optimal ease of access. This accessibility enhances its role as a central urban place with cultural and symbolic significance, fostering community cohesion and spiritual contemplation. These high integration and accessibility metrics extend to the local scale of the various radii (Figure 7), indicating that their location and proximity have a direct impact on accessibility despite the differences in terms of size and functions.

Likewise, Houria Park displays notable accessibility metrics on a city-wide scale, owing to its proximity to the national road 90 (Figure 6). However, varying centrality levels appear within local radii of 200m and 400m, scoring 1.608 and 1.942 respectively. The extensive green spaces of Houria Park blend smoothly with the neighbouring urban forest, creating an outstanding recreational destination for downtime. Nevertheless, there is restricted access to the park from adjacent residential areas, alongside a potential concern for vehicular air and noise pollution (Benameur et al., 2021).

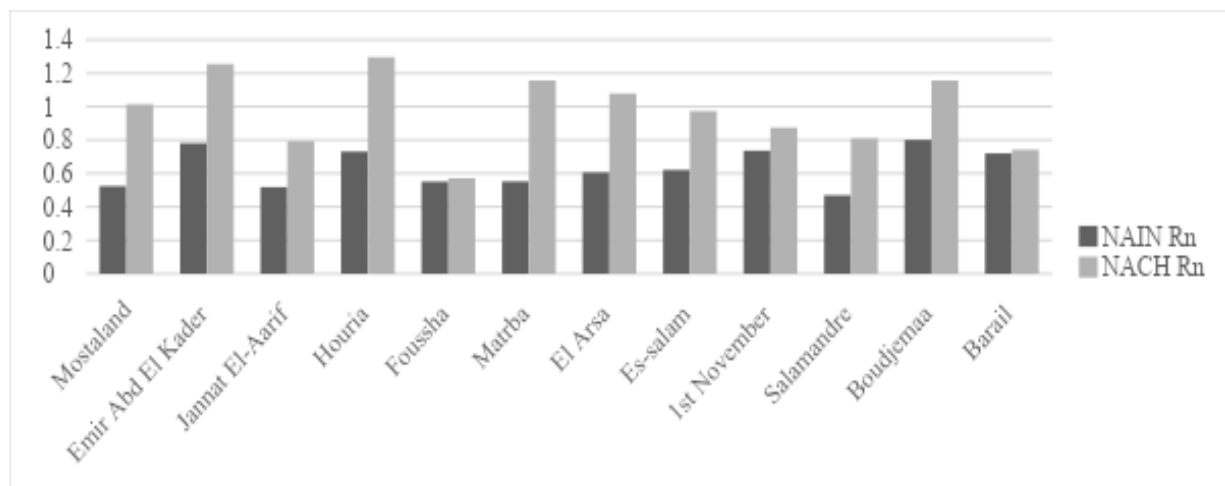


Figure 6. Global syntactic measures NAIN Rn, and NACH Rn attributed for the scrutinized UGSs.

The findings further demonstrate moderate integration and accessibility for Es-salam, El Arsa, Matrba, and Mostaland, on both global and local scales. The remoteness of Es-salam Square and El Arsa Park from residential areas may limit their accessibility at both global and local scales. Yet ongoing attempts to address safety issues may improve their usage as neighbourhood green spaces. Within the last two years, these spaces have benefited markedly from their proximity to the Khemisti and El Arsa tramway stations, respectively. Such alternatives potentially address crime and vandalism issues (Ogletree et al., 2022) and enable community revitalization and engagement opportunities.

Similarly, despite the segregation of the northern urban network, Matrba Plaza strikes a balance between global and local priorities, emphasizing moderate accessibility on both scales. Conveniently situated alongside the road leading to the swimming beaches, it offers numerous entertaining opportunities for families and their children. In addition, the promenade and playground areas enhance its appeal as a verdant and scenic place offering panoramic views of the Mediterranean, attracting residents and visitors alike.

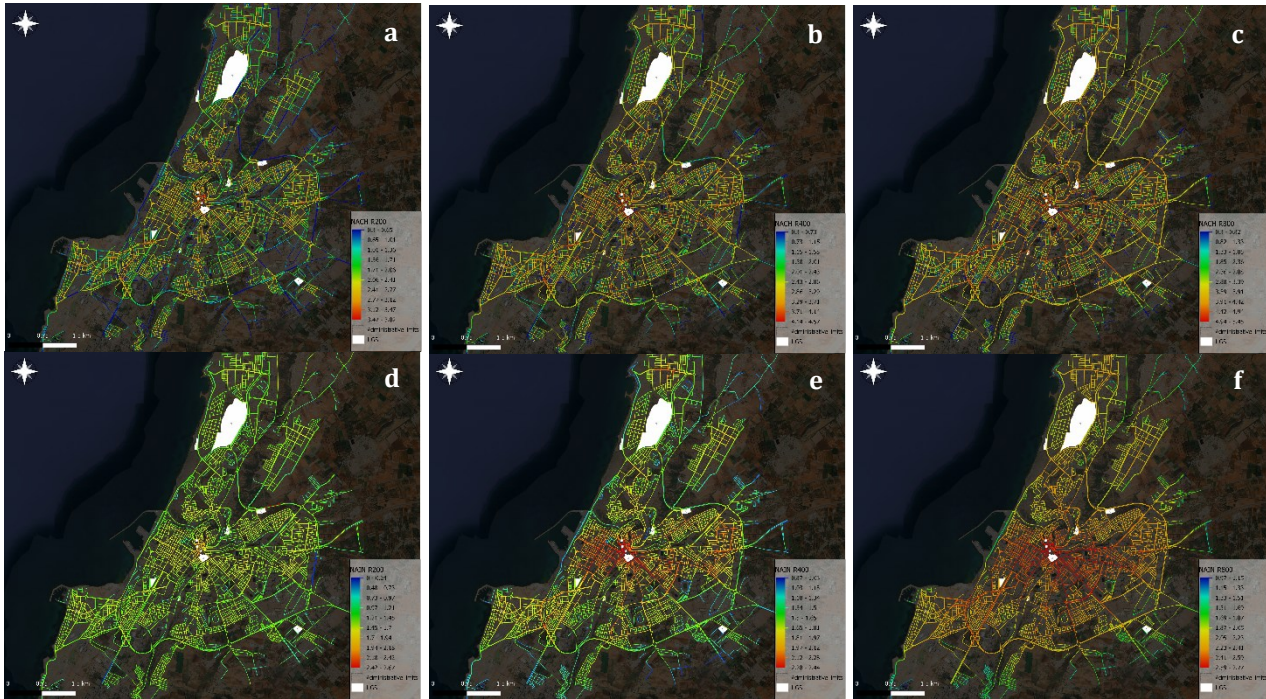


Figure 7. Visual representation of the local measures of NACH Rn and NAIN Rn (a: NACH R200, b: NACH R400, c: NACH R800, d: NAIN R200, e: NAIN R400, f: NAIN R800).

Located in the north-east of Mostaganem city, Mostaland Park is a comprehensive entertainment venue suitable for visitors and tourists of all ages. It features a variety of high-quality recreational and attraction facilities, including a zoo, indoor and outdoor play structures, a swimming pool, a go-kart track, quad biking trails, a central esplanade with a musical fountain, an artificial lake, picnic areas, a luxury hotel complex, retail outlets and a wide range of catering options. However, the configurational analysis shows a moderate global integration of 0.524, notwithstanding its extensive size and outstanding infrastructure. This highlights several accessibility issues brought on by the location of this national park, which limit its attractiveness and usage.

In addition, the Foussha garden displays a severe concern about accessibility, explained by the moderate integration Rn of 0.551, and the low measures of 1.479, 2.037, and 2.422 for the respective hierarchical radii, despite its ideal location within a residential area of 400 dwellings and its proximity to the main facilities, including the old central station. Consequently, recent redevelopment strategies have been implemented to improve the quality of the garden's interior spaces. Such endeavours sought to provide alternatives to address the current accessibility issue.

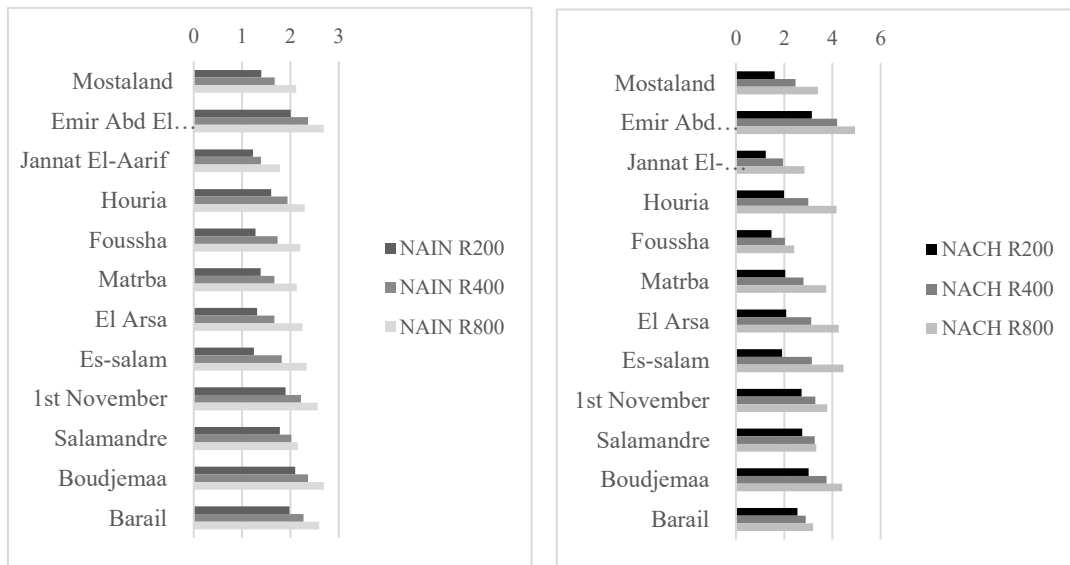


Figure 8. Local Normalized Angular Integration and Choice.

Moreover, the location of Salamandre Square on the western outskirts of the municipality illustrates desegregation and difficulty in achieving strong connectivity within the urban fabric. Despite these limitations, this UGS plays a vital local role, illustrated by its ranking in the Pareto diagram, which shows a high degree of integration on different radii, specifically for the 400m radius which corresponds to 5 minutes-walk where the NAIN values reach 2.021 (Figure 9). Salamandre Plaza, also known as Palestine Square, represents a key element of the attractive continuity of the Salamandre Corniche, contributing to the district's appeal as a recreational asset and capturing visitors keen for a convivial family gathering space. Conversely, “Jannat El Aarif” or the connoisseur's paradise, as translated into Arabic, ranked last among the UGS analysed (Figure 9), scoring the least syntactic metrics such as angular connectivity, integration and choice at all levels. This signifies an alarming accessibility problem that requires immediate consideration and improvement to reinforce its socio-cultural functions.

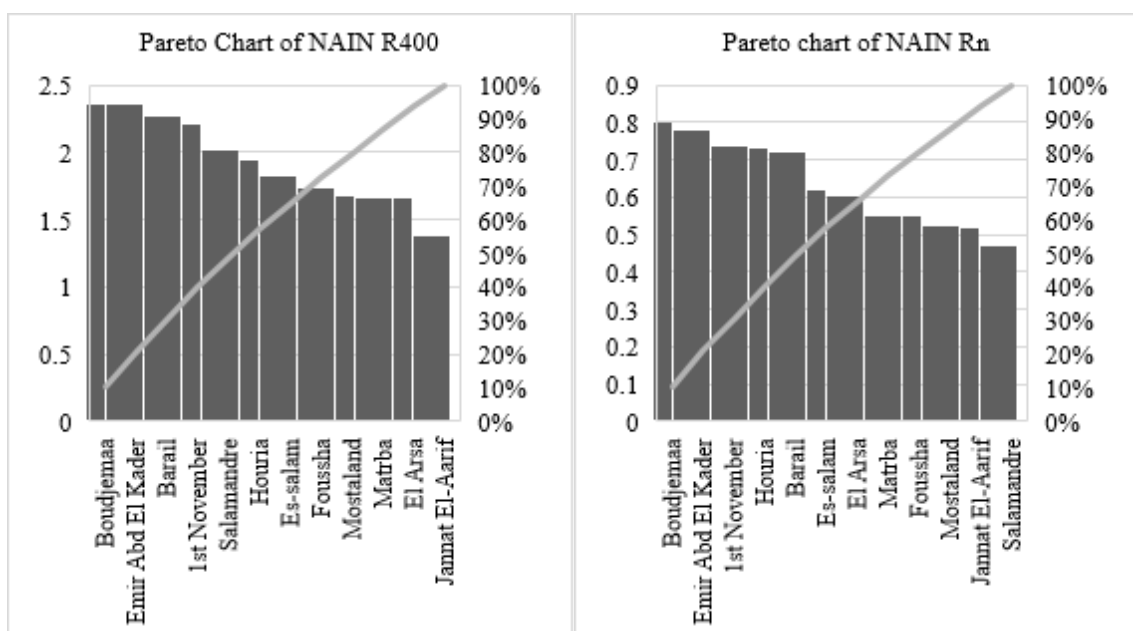


Figure 9. Pareto charts of NAIN Rn and NAIN R400.



5. Conclusion

This research provides a framework that bridges the relationship between accessibility and sustainability of urban green spaces. The angular segment Analysis enables the assessment of this factor on a global and local scale and provides an insightful comprehension of users' priorities and how these spaces operate and function across various scales. It further highlights the pivotal role of accessibility as a key factor in shaping urban development strategies in Mostaganem City. The analysis of exemplary urban green spaces demonstrates significant disparities in accessibility, highlighting three interrelated challenges:

1. Unequal Distribution of Green Spaces: The limited availability of land results in spatial inequality. Urban green spaces in downtown Mostaganem, characterized by high connectivity and accessibility, serve as key hubs for social interaction, recreation, and cultural activities. In contrast, spaces on the city's outskirts, such as Jannat El Aarif, face significant accessibility challenges at both global and local levels. The large size and diverse amenities of Mostaland help mitigate some accessibility issues despite its segregated network, emphasizing the impact of physical attributes like size, location, and spatial quality on user experience and community engagement. While distribution, dimensions, and quality enhance user satisfaction, ease of access ultimately dictates usage.

2. Lack of Priority in Urban Planning: Green spaces often receive inadequate development and maintenance due to their low priority in urban planning. This deficiency impacts accessibility for nearby residents and may lead to security and vandalism concerns, as observed in El Arsa and Es-Salam parks.

3. Insufficient Variety of Facilities: Many green spaces suffer from a lack of diverse facilities and amenities, negatively affecting their overall quality and functionality. However, recent strategies by authorities to revitalize and restructure these spaces, including Foussha Garden, show promise. To address these challenges effectively, enhancing infrastructure and transportation networks in peripheral and segregated areas can improve accessibility, promoting sustainable urban mobility. Prioritizing the development and maintenance of green spaces, especially those with high connectivity, can enhance the quality of life and contribute to environmental sustainability. Efforts to improve accessibility to parks and public spaces in peripheral areas can boost community well-being and promote social cohesion. Implementing strategies to improve safety and engage communities can maximize the potential of these spaces, enhancing their sustainability and usability. Moreover, designing urban spaces with mixed land uses and interconnected networks can reduce reliance on private vehicles, promote active transportation, and support a more sustainable urban lifestyle.

This research acknowledges several limitations. There are literature gaps related to the topic within the Algerian context, particularly concerning the application of regulations and laws, which is where the novelty of our research lies. These gaps highlight the need for further detailed studies specific to Algeria's unique urban landscape. Future research should aim to combine the methods used and the findings with surveys and subjective assessments to better understand accessibility and sustainability. Additionally, generalizing the applicability of this approach to other Algerian cities, which share similar issues regarding urban green spaces' accessibility, can provide broader insights and solutions. By implementing these recommendations and addressing the identified limitations, Mostaganem can overcome current obstacles and ensure equitable access to high-quality urban green spaces for all residents. This research not only contributes to the academic understanding of urban green spaces but also offers practical strategies for urban planners and policymakers in Algeria.



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Conflict of Interests

The authors declare no conflict of interest.

Data availability statement

The data that support the findings of this study are available from the corresponding author, [Dr. Okba Benameur], upon reasonable request.

CRedit author statement:

Conceptualization: O.B., F.L. Data curation: O.B. Formal analysis: F.L., A.L. Investigation: O.B., F.L., A.L. Methodology: O.B., F.L. Project administration: O.B. Writing—original draft: O.B., F.L., A.L. Writing—review and editing: O.B., F.L., A.L. All authors have read and agreed to the published version of the manuscript.

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Original scientific paper

Integrating Dynamic Culture and Participatory Design in Urban Spaces for Sustainable Futures

*¹ Assoc. Prof. Dr. **Ines Sahtout Gaha** , ² Prof. Dr. **Imen Ben Youssef Zorgati** , ³ Prof. **Zoubeir Lafhaj**

¹ Department of Design, Higher Institute of Fine Arts, University of Tunis, Tunisia
² School of Design, Faculty of Planning, University of Montreal, Montreal, Canada
² Department of Science and Technologies, Lille University, France

¹ E-mail: ines.sahtout@isbat.u-tunis.tn, ² E-mail: imen.ben.youssef.zorgati@umontreal.ca, ³ E-mail: zoubeir.lafhaj@gmail.com

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ABSTRACT

This study explores the intersection of dynamic culture and participatory design in urban spaces, emphasizing the role of user experiences in shaping urban environments. By integrating residents' input in the design and planning processes, this research aims to foster sustainable, viable urban futures that reflect local cultural dynamics and community needs. Utilizing a case study in Tataouine, Tunisia, the research employs parametric mapping and user experience mapping to analyze interactions with heritage sites and public spaces. This approach captures qualitative data on user experiences and overlays it with spatial context, enabling the identification of patterns and relationships between cultural practices and territorial dynamics. The study aims to identify key factors for citizen participation, analyze user experiences in relation to cultural dynamics, and formulate recommendations for integrating participatory design principles. By aligning urban development with a dynamic culture and user-centric design, the study envisions urban spaces that are inclusive, sustainable, and reflective of local identities. The findings underscore the potential of participatory design to enhance the value of urban heritage and promote a more engaged and resilient urban community.

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Highlights:	Contribution to the field statement:
<ul style="list-style-type: none"> - Parametric models can effectively map user paths in Tataouine, providing detailed spatial analyses of urban interactions. - Innovative analytical tools can enhance the re-evaluation of architectural heritage, contributing to cultural preservation and urban renewal. - Participatory design is a critical component of architectural and urban planning processes, promoting inclusivity and sustainability. - Engaging stakeholders early in the planning process leads to the creation of cities that are organic, adaptable, and reflective of community needs. - Integrating dynamic culture with urban development can enrich the literature on cultural dynamics and algorithmic urbanism. 	<p>This article introduces a novel framework that combines cultural dynamics with participatory design, specifically applied to urban settings like Tataouine. By utilizing parametric modeling and user experience mapping, it pioneers new analytical tools for architectural heritage revaluation, offering scalable methodologies to redefine cities as algorithmic entities that adapt organically through community involvement.</p>

***Ines Sahtout Gaha:**
 Department of Design, Higher Institute of Fine Arts, University of Tunis, Tunisia
 Email address: ines.sahtout@isbat.u-tunis.tn

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1. Introduction

As a prelude for our investigation, let us take up Robert Fishman's inquiry, who proposed a fictitious story for defining and proposing new alternatives for building the cities of the future: What is the ideal city for the twentieth century, the one that would best express the study and beauty of modern technology and the most advanced ideals of social justice? (Fishman, 1982). The answer to this question was based on analyses of the work of urban planners such as Ebenezer Howard, Frank Lloyd Wright, and Corbusier, who produced detailed plans for factories, office buildings, schools, parks, and transportation systems; each plan introduced an innovation, and all the study are part of a revolutionary restructuring of urban form. The economic and political organization of the city, which was not easy to translate into drawings, was analyzed in the voluminous writings that each author attached to his projects (Fishman, 1982). Based on this perception, the study intends to develop an approach that resizes the configuration of today's city around new concepts such as participatory design, cultural dynamics, and parametric modelling. As the world becomes more urbanized and the human experience in urban environments becomes more diverse, the study is increasingly concerned about how the study creates, uses, and interacts in the built environment. In this context, cultural dynamics and participatory design have emerged as key concepts for understanding and embedding the city in a sustainable context, promoting the identification of uses and encouraging mutual appreciation. In this regard, there is an urgent need for governments to introduce and enforce processes that allow citizens, including vulnerable communities, to participate in development planning and policymaking. At present, there is a lack of guidance for practitioners regarding the definition of a clear purpose of community engagement and the selection of appropriate participatory methods to fulfil the set purpose (Devindi, Fernando, & Keraminiyage, 2021).

Participatory design involves the active collaboration of citizens, designers, and decision-makers in the creation and transformation of urban space. It transcends traditional design approaches by recognizing that end-users are in the best position to express their needs, preferences, and aspirations. The term participation is widely used to describe any practice or experience that involves citizens, but in most cases, neither the manner nor the degree of participation, nor the status of the people and the role given to them is defined (Croce, 2018). This democratic approach fosters greater ownership of public spaces and greater user satisfaction. Contemporary urban production and management is no longer just a matter for politicians and professionals in the field (decision-makers, architects and urban planners, construction companies, etc.). Nor is it just a matter of building buildings and roads. In the face of current social and urban changes and challenges (the need for more participatory democracy, the avoidance of urban sprawl, etc.), new "urban design cultures" are emerging, experimenting and, in some cases, ritualizing ways of saying, doing and experiencing today's city (Smail, 2021). At the same time, cultural dynamics play an essential role in the way the study perceives and interacts with our environment. Cultural values, social practices, and traditions shape our daily experience of the city.

The relationship between the study of regional culture and the city should have been a natural and smooth one of development or extinction, but rapid urbanization has upset the original equilibrium, thus restricting to a certain extent the development of a comfortable and personalized urban life (Sahari, Li, & Faridah, 2022).

By integrating these elements into the design process, the study can create spaces that reflect local identity, encourage diversity, and foster a sense of belonging. In practice, public participation is the key to the democratic process. This makes government institutions accountable to society, enables them to incorporate non-professional knowledge into decision-making, improves public policy support, and improves planning outcomes. Participation is valuable as a political goal, as it increases social capital and gives citizens more opportunities when they want a stronger voice in decision-making. (Jankauskaite, L, & Mlinkauskienė, 2021). In this paper, the study dives deep into the concepts of participatory design and cultural dynamics in the urban context. The study will present an approach to cartography based on urban and social

parameters. The cartography that is deployed as a result of our research will be integrated to redefine the context of the user experience in urban spaces. The study will also explore the challenges and opportunities that are associated with this approach, as the implications for sustainable urban planning.

This study will conduct a structured analysis of the literature and factual data based on concrete mapping and modelling to study the following questions:

- 1- What are the participatory methods that exist and are being used for community engagement?
- 2- In terms of real cultural dynamics, what level of engagement can parametric mapping methods achieve?
- 3- Are the proposed methods sufficient to support the engagement of the community throughout the urban design cycle, with a focus on a heritage specific to the city of Tataouine and with an emphasis on sustainability and resilience?

For the methodological needs of our research, the study has chosen a research project that explores the theory and epistemological needs to give us results in practice: a modelization visualized through a cartographic demonstration based on citizens' activities in the southern Tunisian city of Tataouine. Meanwhile, to better explain the goals of our research, other methods will be explored and analyzed as our research diagram evolves. In this sense, Figure 1 represents the process of our contribution and defines the specificity of our analysis.

2. Material and Methods

The aim of the systematic analysis of the user experience in the literature on the urban development of the city of Tataouine according to the location of its historical sites was to map and evaluate uses and interactions, and thus provide concrete answers to the research questions based on existing knowledge. Accordingly, the question of the study has been formulated as the study has previously specified and has been illustrated as follows: What existing participatory methods are used to engage communities, and how might Parametric Use Mapping be used to help envision a desirable architectural future?

The study proposes five distinct and complementary approaches in the diagram shown in Figure 1, which illustrates our research process. First, the study focuses on the identification of the foundations of cultural dynamics. This step is crucial to understanding the cultural foundations and the influences that shape the social interactions and behaviours in the city of Tataouine.

The study will then look at aspects of participatory design and its various forms and elements and the study will identify that Participation is often associated with the concept of democracy and it has a multidisciplinary, inclusive nature (Turken & Eyuboglu, 2021). Using parametric modelling, the study aims to create a new cartography of Tataouine that reflects the contributions and perspectives of its inhabitants, and which is defined as the dialogue between the study of a human and map, mediated through a computing device and is essential to the research into interactive cartography, visualization, and visual analytics (Roth, 2013). This participatory approach is essential to ensure that the cartography will be representative and inclusive. Third, the study presents examples of mapping methods, focusing on their conceptual and constructive aspects. These examples serve to illustrate how different techniques can be used to capture and represent urban complexity in innovative and effective ways. In the fourth section, the study presents the specifics of a cartographic case study carried out using parametric modelling. This process is a demonstration of the level of involvement of users with their immediate environment. An interpretation, adapted to the active data and the parametric parameters of the objects, will be developed to read these mapped paths. The presentation of the maps will also help us to revisit Tataouine's capacity for the reintegration of its historical sites in accordance with their uses. By analyzing the map through the activities of residents, the modelling process will be focused on concrete outcomes. These results will measure the level of involvement and interaction of users with their city and historic sites. They will identify the city's heritage and shared identity.

Finally, our conclusion offers a forward-looking perspective on urban development. The study postulates that the sustainability of architectural projects can be significantly enhanced through the interpretation and use of land-use mapping. By adopting a sustainable approach that considers the forming industry and sphere of activity for the territory (Vikhoreva, Malanina, & Ogloblin, 2020), the study aims to promote projects that respect and enhance local cultural and heritage dynamics. This approach not only preserves cultural heritage but also promotes harmonious interaction between studying residents and their urban environment. Furthermore, cartography and new technologies such as parametric design can be used to reinvent the city, reconstruct its urban fabric, and enhance its heritage.

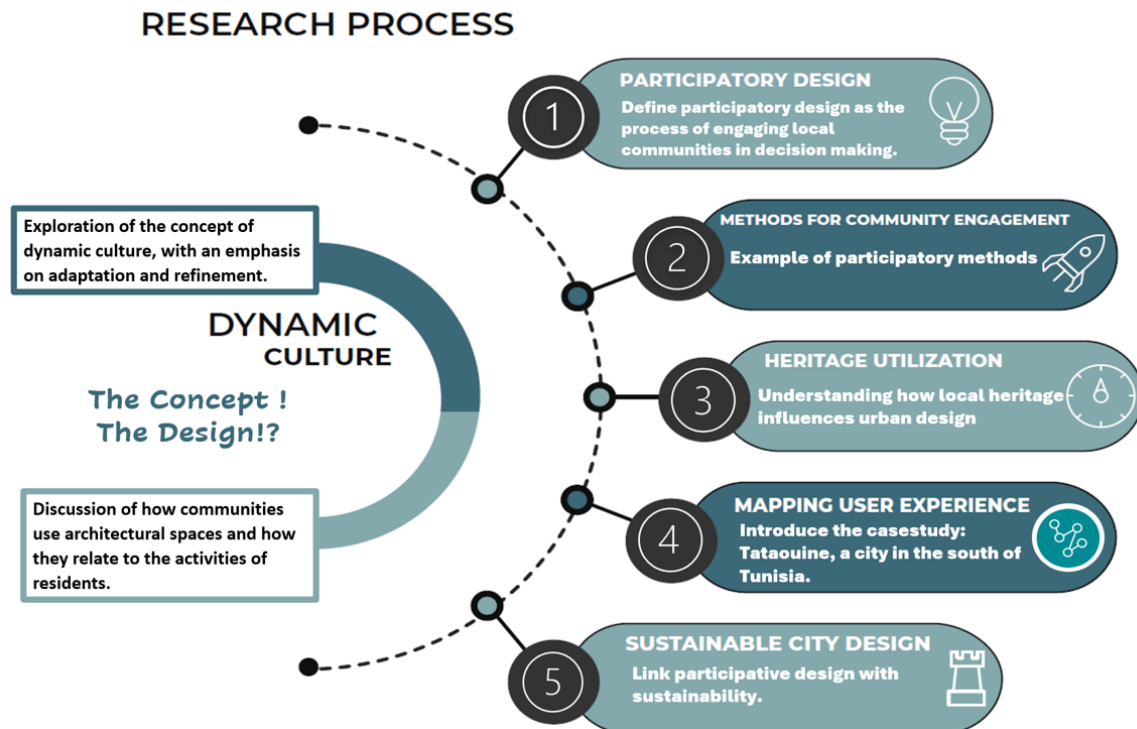


Figure 1. Research Process and Structure of the Study (Developed by Authors).

3. Theoretical Background: The fundamentals of participatory design

The approach advocated for applying our theoretical background is divided into three different interpretations. The first interpretation consists of a fundamental analysis that aims to identify the notions founded by design as a creative activity (Berger, 2004) in modelling solutions and alternatives for rereading a specific cultural heritage by and through user experience. This interpretation defines the theoretical foundations of cultural dynamics and demonstrates their relevance to participatory design. One of the techniques that has been used as a tool for urban development in recent years is that of cultural regeneration. This is seen as a means of restoring and improving the quality of urban life through the enhancement and development of the unique characteristics of a place and its people. (Wansborough & Mageean, 2000). To illustrate these foundations, an example of a pre-existing study will be presented. It will illustrate aspects of cultural dynamics and the participatory approach. Secondly, the mapping methods, tools, and resources that have been used so far for the improvement of the user experience through a spatial experience and a shaped urbanity are examined. The theoretical framework the study aims to establish in this section will serve as the foundation for our modelling and case study. It allows us to anticipate not only the impacts of urban concentration but also those of detachment. Our goal is to redefine cultural dynamics, considering novel public policy solutions and alternative approaches to

democratizing heritage sites. Additionally, the study will explore ways to establish stronger connections by better studying cultural practices, rituals, and consumer behaviours.

3.1. Cultural Dynamics' Participatory Design and Social Integration Characteristics

Dynamic culture refers to the constantly evolving, vibrant, and diverse fabric of human interactions, practices, and rituals within a city. It encompasses the ebb and flow of daily life, the varied rhythms of activity, and the collective experiences that shape urban spaces. To delve deeper, let's explore how dynamic culture intersects with participatory design, inspired by the words of J. Montgomery: Good cities tend to be a balance of a reasonably ordered and legible city form, and places of many and varied comings and goings, meetings and transactions. What might appear to some as disorder is very often simply the everyday rhythm of city life. In the absence of such activity, cities can lose their urbanity and eventually become suburban in character (Montgomery, 1998).

The study customizes Montgomery's vision in three fundamental ways:

- Urban Rhythms and Vibrancy
- Participatory Design as an Enabler
- Urbanity and Suburbanization

Table 1 illustrates the close relationship between the study's dynamic culture and participatory design. Both approaches celebrate the messy convergence of urban life, emphasizing the spontaneity of travel, unexpected encounters, and the dance of daily routines. When the study analyzes this dynamism, our cities thrive, bridging the gap between

the study disorder and vitality. Participatory design plays an essential role in this urban dynamic, cutting across cultural and local development to create a more vibrant pattern of place. It is above all a territorial design that unifies this idea of the adaptability of the city. The phenomenon of planning involving citizen's participation in planning literature has existed since the second half of the 20th century. Indeed, different methods and techniques have been used in the process. The study and participatory practices are time-consuming, and negotiations are tiresome. (Turken & Eyuboglu, 2021).

Territorial design is close to urban design, especially in its emphasis on the experience of the resident or user. There are two differences: The first is a difference in scale: urban design is localized (to the scale of the public square or the neighbourhood), whereas territorial design is part of a larger scale (which can include the neighbourhood, but also above all the city, the intercommunal area, even the region - all four can be considered simultaneously). (Jolivet, Safin, & Huron, 2021).

Table 1: Urban Dynamics: Unveiling the Heartbeat of Cities.

Urban Rhythms and Vibrancy	Participatory Design as an Enabler	Urbanity and Suburbanization
<p>Cities thrive on: <i>movement+ diversity+ interaction</i></p> <p>The comings and goings of people: Bustling through markets+ gathering in public squares+ engaging in spontaneous conversations</p> <p>=</p> <p><i>Creation of the heartbeat of urban life</i></p>	<p>Cities are not static entities but living organisms shaped by their inhabitants:</p> <p><i>Stakeholders + residents, architects + planners + community members + Designers</i></p> <p>=</p> <p>collaboration to shape urban spaces</p> <p>Knowledge experiences+ aspirations</p> <p>=</p> <p><i>Inform the design process</i></p>	<p>What makes a city truly urban</p> <p>Urbanity</p> <p>=</p> <p><i>Vibrance+ complexity+ adaptability</i></p> <p>It thrives on the interplay of people, activities, and cultural expressions.</p>
<p>What might initially appear as:</p> <p><i>disorder+ crowded streets+ impromptu street performances+ lively cafes</i></p> <p>=</p> <p>Dynamic culture</p>	<p>By involving End-users, Participatory design ensures that:</p> <p><i>Resulting spaces + city's unique cultural context</i></p> <p>=</p> <p>Empothes people to actively influence decisions Fostering a sense of ownership and pride</p>	<p>Cities lose their dynamic culture when:</p> <p><i>streets become sterile+ public spaces lack vitality+ interactions wane</i></p> <p>=</p> <p><i>Risk of slipping into suburban character</i></p> <p>Codesign revitalizes urbanity by infusing spaces with creativity inclusivity+ responsiveness to local needs.</p>
<p>Richness and Authenticity of Urban Experiences.</p>	<p>Participatory Design aligns with Dynamic Culture.</p>	<p>Participatory design acts as a counterbalance.</p>

Empowering Communities: Participatory Design in Action

3.2. Methods for Community Engagement

3.2.1. User experience-centered Approach Method

Using an experience-centered approach and mapping user journeys, the user is able to understand the importance of wayfinding and community collaboration for the "Entre les Ksour" project simulated by (Nesrine, 2019) in her study of the city of Tataouine. This simulation proposed public transportation solutions that would allow citizens and visitors to easily move between historic sites, providing a unique heritage experience and a greater appropriation of the urban environment. Exploring roads: These can be streets, pedestrian roads, public transport areas, canals, and railways. These elements are dominant in the image of many people. People observe the city on the move and perceive other environmental elements on these roads and relate to the whole. (Yavuz, Ataoğlu, & Acar, 2020).

This simulation aimed to improve the accessibility of the Ksour. It also actively involved the community. It adopts a pragmatic approach whose principles value experience, participatory processes of codesign, and project-grounded research.

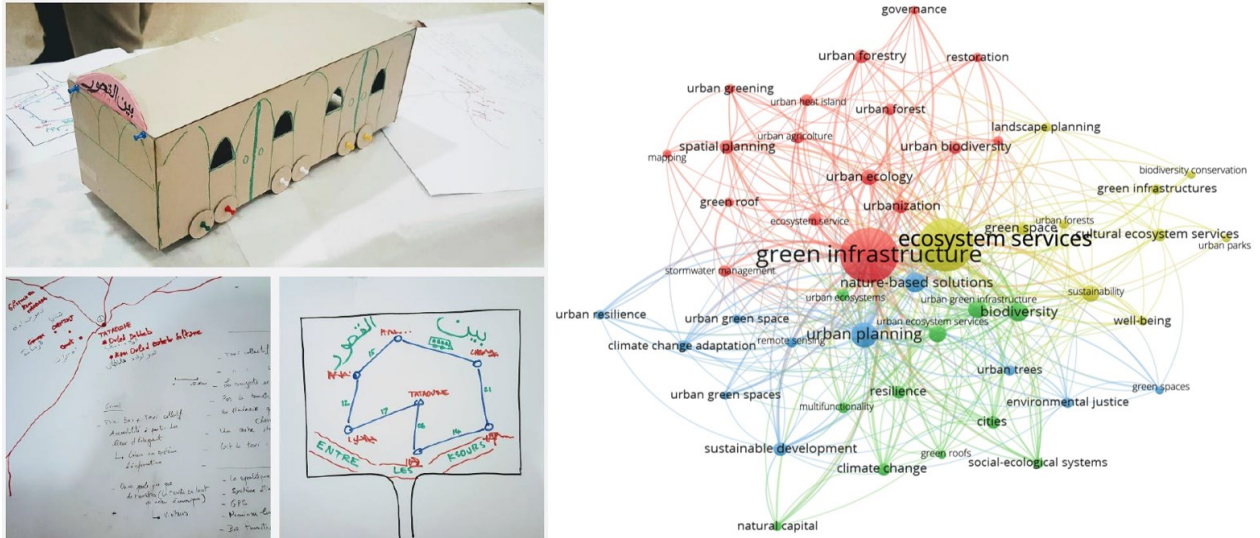


Figure 2. Project proposal of Between the Ksour (Ellouze, 2019).

Urban Mapping Tools & Techniques (URBAN DESIGN LAB)

To instantiate our co-design model, the initial idea and motivation came from a public integrator (Tataouine Governorate) who possessed an untapped resource (the Ksour) and wished to develop new services to strengthen regional attractiveness and promote local actors. As shown in Figure 2, the vision of the project was therefore to capitalize on the links established between institutions and to encourage cooperation and exchanges between professors and experts from different disciplines. (Ellouze, Ramseyer, & Brisolaro, 2021). The first idea is to bring conceptual features, as you can see through Figure 2, where a cluster of words and colours highlights urban planning and uses in terms of a specific vocabulary and convergent, interdisciplinary relationships. The second is a human-experienced concept delivered through between the ksour as a research project. Based on observing the lack of public transportation, signage, and difficulty of accessing without a guide, the simulation proposed tangible ways for citizens to connect with their cultural and natural heritage. By considering the lived experience of users and their uses, this approach proved viable and worthy of integration into the city's urban planning.

3.2.2. Design by and through citizen activities

To demonstrate that participatory design and cultural dynamics are two complementary and mutually stimulating concepts the study refers to the two methods developed by Ezio Manzini (2014) for Social dynamic Innovation.

Designing for the community: This design means looking at specific typologies of collaborative service and, after observing their strengths and the study weaknesses, intervening in the context of the services to make them more favourable, and developing solutions to increase their accessibility and effectiveness and therefore their replication. In this mode, designers have to conceptualize and develop solutions for specific collaborative services and other enabling artefacts (e.g., digital platforms, orienting scenarios, and catalyzing events, including exhibitions, festivals, and other cultural events) (Ezio, 2014).

Designing with the community: This means participating as peers with other actors involved in creative community building and collaborative service co-design. In this modality, designers must facilitate the convergence of different partners toward shared ideas and potential solutions. This kind of activity requires a set of new design skills: promoting collaboration among diverse social actors (local communities and companies, institutions, and research centres); participating in the construction of shared visions and scenarios; and

combining existing products and services to support the creative community members with whom they collaborate (Ezio, 2014). The study intends to go further than these two forms of participatory interpretation and develop a new approach Figure 3 based on designing through and by the interpretation of users' activities and real-life experiences.

- Cultural dynamics are shaped by the visibility of lived experience and represent the interaction between the study of a participative approach and the design of public policies.
- Cultural dynamics thus become a key element in making users aware of the heritage value of their sites and/or their region.

Innovation would be the organization of the city around all these elements that coordinate life and animate and co-animate urban development. Furthermore, it is possible to create solutions that meet users' real needs by involving the community in the design process. It can also foster a sense of pride and a sense of belonging to the cultural and natural heritage of the city. Cultural dynamics and community involvement are therefore key elements in architectural heritage conservation. By drawing on the experience and cooperation of residents, the study can enhance and preserve historic sites and monuments for future generations, while strengthening the social fabric and understanding of local history and culture. Liang, W., Ahmad, Y., & Mohidin, H. H. B. (2023), mentioned through their analysis demonstrating the correlation between user awareness and heritage enhancement of a community prescient that The conservation of architectural heritage in urban spaces is not only about preserving the historical buildings of the past but also about uniting stakeholder groups, identifying architectural heritage, gaining a collective cultural identity, finding a sense of place and civic pride for residents, allowing everyone to appreciate the cultural values of the city today, and creating a cultural identity for future urban planning through this process (Cauchi Santoro, 2016). As the study explores the convergence of dynamic culture and participatory design in the urban context, cartographic tools and mapping techniques emerge as powerful interpretive methods. They allow us to navigate and rethink the future of urban spaces. Here's how these tools and techniques can be defined according to our research study concept:

Modelling journeys

- Cartography transcends language and cultural barriers. It becomes a visual language shared by residents, planners, and decision-makers. As the study presents modelling 2 in Table 2 with a specific brainstorming technique in Figure 2 the study focuses our research on parametric visualization of user paths.
- The study can use maps to tell the story of how a city evolved, to reveal its dynamics, and to show how people interact with the environment in which they live.
- Route and wayfinding simulations help us anticipate user movements. They are essential for designing user-friendly routes and maintaining accessibility.
- By integrating historical and cultural data, these models can guide visitors to heritage sites while promoting an evocative experience.

Participatory mapping

- It is essential to involve the local community in the interpretation of the mapping of their city. Residents know the hidden places, the informal paths, and the daily anecdotes that are the foundation of their sense of place.

Utility Mapping

- Beyond streets and buildings, usage mapping explores how people interact with space. Where do they congregate? What are their habits?
- By identifying pedestrian flows, meeting places, and underutilized spaces, the study can design urban interventions that are more relevant and tailored to the real needs of residents: the study engaged a mapping in the field of participatory design creating

value for urban societies. The study wanted to look at theories and models that have the capability to generate measurable impact on urban challenges and stimulate sustainable urban transformation. (Von, T, S Verhagen, S, & Loorbach, 2019).

3.3. Heritage Utilization for a Designed Dynamic Culture

Notice that by exploring the traditions, know-how, lifestyles, and habits of a community, it is possible to discover other architectural and urban interpretations through daily activities and uses. Through the schematization Figure 3, the study explores the hidden meanings that use can have; Manzini discovered that social design is done with or for the community, but to evoke and integrate citizen practices, the study emphasizes and engages in a cartographic process to promote design through activities.

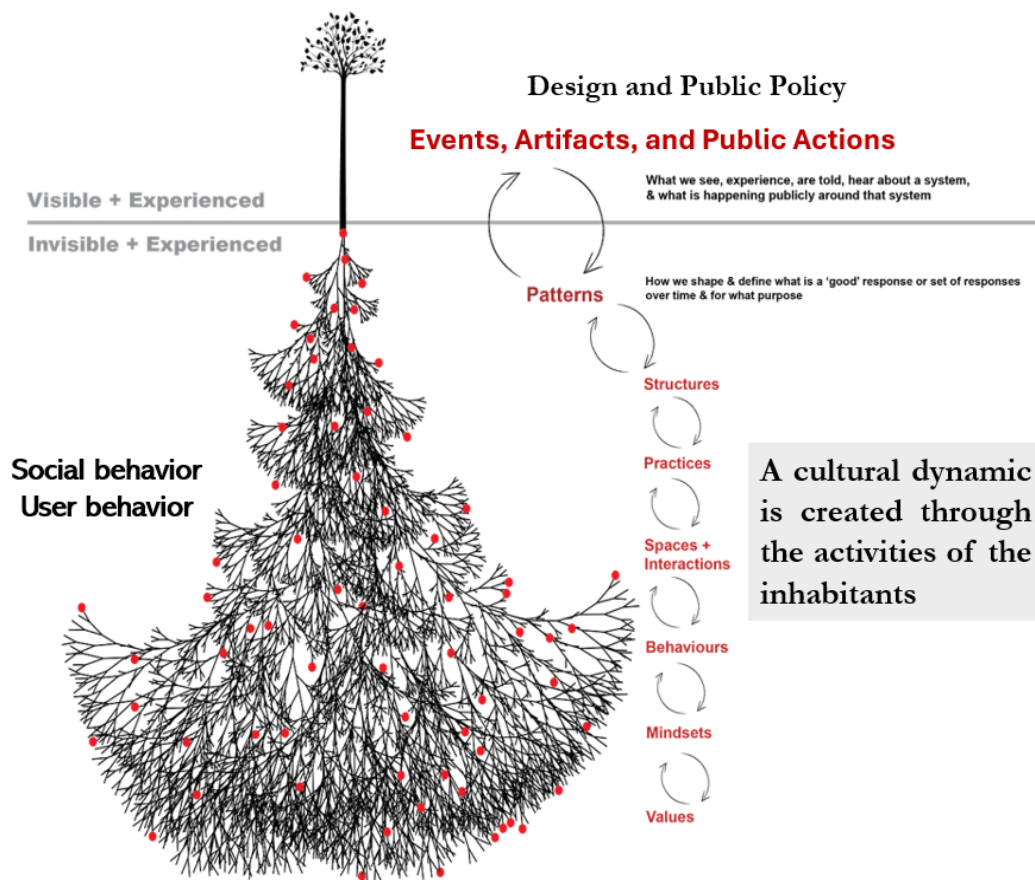


Figure 3. Changed by Authors, Inspired by the organic patterns of systems.

Analyzing Urban Activities and Experiences: Movement mapping

In our cities, every interaction and movement creates data that reflects how the study lives and uses our urban spaces. By analyzing this data, the study can uncover patterns in how spaces are utilized and understand the relationship better between people's behaviours and the environment. This analysis is crucial for designing urban spaces that are tailored to the specific needs of the community.

- Cities generate a vast amount of data from participatory activities and experiences that can be analyzed to provide information about spatial experiences and dynamic behaviours Figure 3.
- This can include information about how people move, what they do, and how they use spaces.

- This data can be useful for understanding patterns of place use and the relationship between citizens/habits/behaviours and the environment. Modelling 2, Table 2. It can be used for planning that is tailored to the needs of regional and specific users.

In essence, dynamic use mapping becomes a means of interpreting the city as it adapts to current needs. It invites us to explore narrow streets, lively squares, and changing spaces while keeping an eye on the future. This approach, rooted in citizen participation, allows us to rethink housing from a more social and even more economic point of view. It also allows us to rethink the enhancement of historic sites. Thus, in our second phase, the study intends to demonstrate through parametric modelling how the Ksour of Tataouine are detached from the city and its central activities. modelling that maps the relationship between users and the convergence of their experiences.

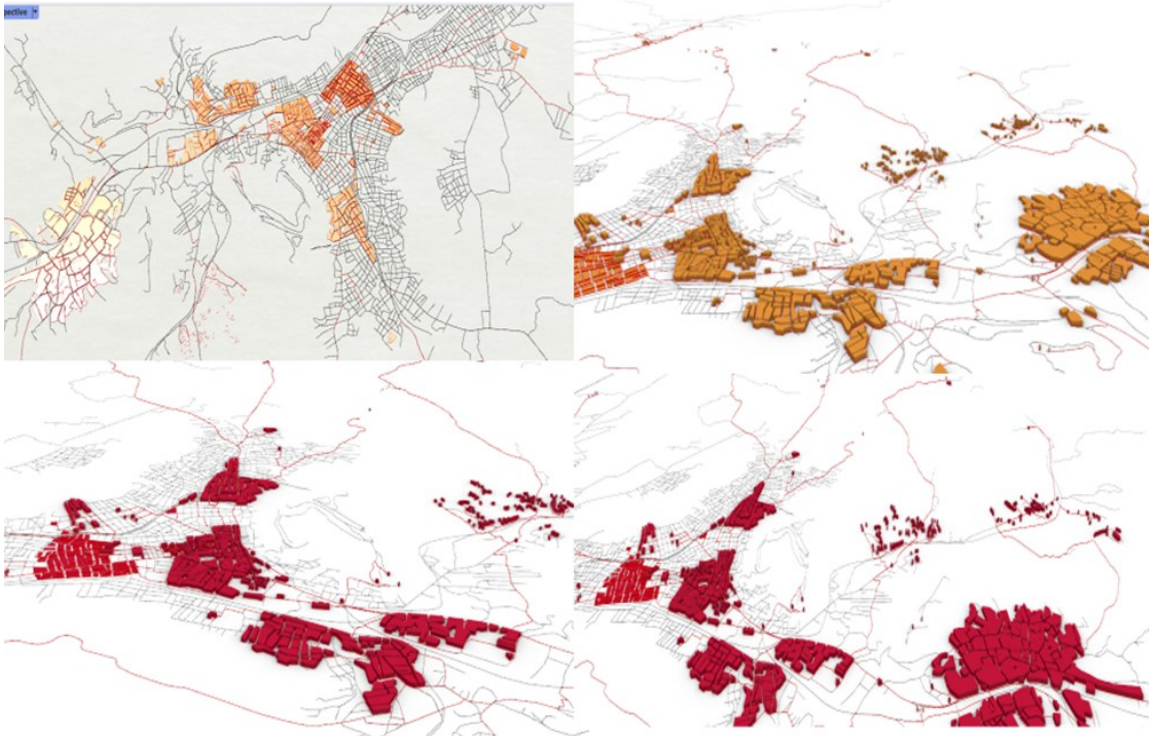
4. Mapping User Experience: Case study- TATOUINE

Second, an urban meaning that considers the tangible, social dimension of the city and, combined with the innovation of technology, configures the needs of users. The second type invites us to become part of an intelligent schematization that advocates new readings and interpretations of the complex system that is the city. Its optimization depends not only on the will of a community but above all on new reading and interpretation tools.

Bernard Stiegler (Stiegler, 2016) emphasizes the importance of inventing a new urban intelligence and confirms that the study must invent a new urban intelligence. The study needs to use digital platforms to organize local deliberations and give citizens the ability to take control of their city's technological destiny (Anne, 2017).


For this reason, the study proposes to model the activities and routes of the citizens of Tataouine for a simulation of the journeys to the ksour, to progress towards our case study. The integration of an interactive and specifically parametric component is essential for the emergence of new ideas. A contemporary urban design process demands human-centred development where future technologies intertwine with traditional approaches to generate a sustainable, liveable environment while saving time and resources (Fink & Reinhard, 2019). A map of the cultural dynamics of the city of Tataouine was created using this parametric modelling approach.

Table 2: Setting Orientation Parameters.

Modelling 1	
Adding OSM (Open-Street-Map) geographic data for the city of Tataouine and setting orientation parameters	
1- Import OpenStreetMap (OSM) geographic data for the city of Tataouine.	
2- This data includes detailed information about the topography of the city, its streets, buildings, and other geographic features.	
3- Customize and adjust parameters to orient the map according to the daily activities of residents.	
4- Focus on the essential amenities for citizens.	
5- Customize the map to better meet needs, functions, and uses.	
Modulization Results	
	

Participatory design is inextricably linked to urban development and the methods advocated for its implementation. Furthermore, technological advances offer new experiences in spatial exploration. The models the study intends to use to analyze our case study are combinations of parameterized objects that exhibit a form of spatio-temporal interoperability. In this way, a primary reading of the urban and topographical context of the city of Tataouine is developed, offering a static vision of places, environments, and constructions. This parametric modelling allows for an in-depth, dynamic understanding of the interactions between different urban elements while integrating the perspectives and needs of residents into the urban planning process. Exploring Tataouine virtually allows us to uncover the essential amenities that significantly impact the daily lives of its residents. This virtual journey helps us decode the city's concealed features and understand what truly matters to the local community. Table 2 outlines the procedures required to obtain a specific map of Tataouine and a justified description of its functions. Parametric design mapping enabled us to virtually penetrate the city and decipher its algorithms and organic value.

Table 3: Exploring the map with programs and algorithms.

Modelling 2	
Minimizing mass addition distances, the blue paths shown on the map below are modelled.	
1-	Entering the city virtually
2-	Deciphering its hidden characteristics: to discover the amenities that are particularly important in the daily life of the inhabitants of Tataouine.
Modelisation Results	
	

By minimizing the distances for mass addition, the study revealed that user activities are centered around a focal point, identified as ELECTROSAYEH, a sales area. As demonstrated through the model presented in Table 3, the study illustrates how these activities are organized according to a program that highlights the city's central point. The pathways connecting various activities at different times are mapped out by connecting lines. The study employed parametric modeling to calculate and visualize spatial movements within Tataouine, leading to the identification of ELECTROSAYEH as the barycenter. This point is recognized as the core of the city's dynamics, providing unique insights into the urban structure and the daily flow of its inhabitants' activities.

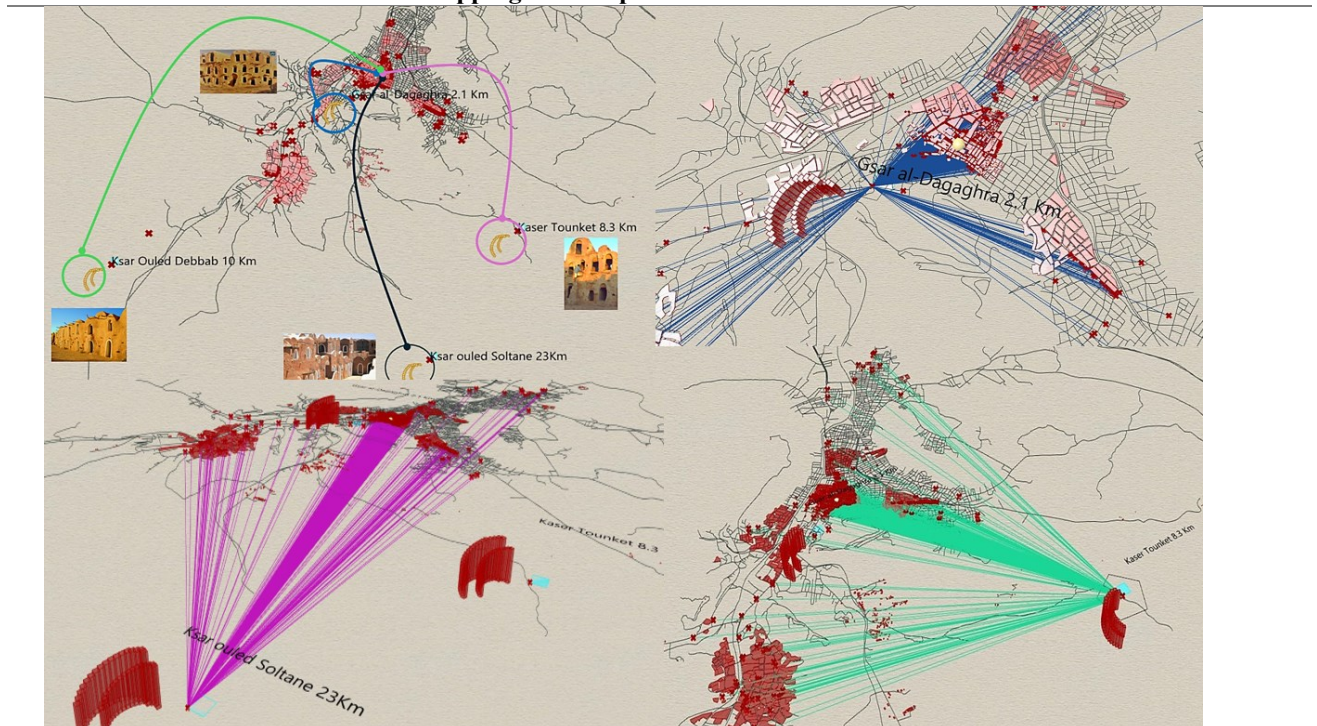
To further illustrate this, the activities modeled in Table 3 are linked to the functional diagram of the ksour. The study simulated the placement of the ksour in Tataouine by accurately managing the real distances between them and the city, particularly their relationship to the ELECTROSAYEH barycenter. This modeling, as shown in Table 4, enables a deeper understanding of the city's layout based on both common and uncommon patterns of use. The value of the ksour is enhanced by synchronizing user activities according to their locations (maximizing distances) and by creating a network of routes distinguished by different colors and connections between the sites themselves.

The study will now present the cartographic results, displaying user routes by minimizing and maximizing the distances between the Tataouine barycenter and various ksour, providing estimates of visit frequencies.

Table 4: Mapping the detailed user experience.

Modelling 3
Minimizing and maximizing mass addition distances, the coloured paths shown on the map below illustrate the location of the ksour and their relationship to the center of Tataouine.
1- Ksour Locations: Ksar Dghaghra, Ksar Ouled Debbab, Ksar Ouled Soltane, and Ksar Tounket
2- Calculate the distance of arrival and departure
3- Calculate route values
4- Walk the map, Discover the Ksour, and Color the routes.

Mapping User Experience Results



Urban designers draw inspiration from a variety of principles to create sustainable, user-centred spaces in harmony with community lifestyles. One of these guiding principles could be the new cartographies that have emerged as an alternative with the birth of Generative Design. This new cartographic experiment emphasizes citizen participation, seeing through the social understandings of individuals to relational bases that evoke meaning. In the context of our project, the installation of ksour as a functional unit within the central activity of ELECTROSAYEH in Tataouine Table 2 is a fascinating exploration. By modelling activities and travel distances, the user is able to optimize routes to key ksour, including Ksar Dghaghra, Ksar Ouled Debbab, Ksar Ouled Soltane, and Ksar Tounket Table 4. This approach is consistent with a new mapping goal of creating vibrant, well-connected communities.

5. Findings and Discussion: The rhythm city, the algorithmic city

The theoretical fundamentals of this research project were developed by identifying ancient cartographic methods such as the "between the ksour" exploration developed by Nesrine Elllouze (Nesrine, 2019). It focuses on the fundamental aspects of participatory design and cultural dynamics. As for our case study, which took place in Tataouine, the study tried to

model the city according to its uses, to penetrate it and bring out the degrees to which its citizens belong. In this way, the study understood that the population is a good variable to measure the importance and the success of a city, that the city is a whole system, and that the study can identify the science of the city. This is the controversial issue the study has tried to address in this study by approaching Tataouine's activities as a function of its historical sites and its dominant interurban displacements. In this way, and according to our modelling, the study has come to understand that the design of a city is determined by external interventions and urban problems are complex issues whereby social, economic, and environmental dimensions are intertwined. (Pertoldi, Fioretti, Busti, & Van Heerden, 2020). The city is not a fixed design, which is positive for territorial planning. A model is an abstract and partial representation of some aspect or aspects of the world "that can be manipulated to analyze the past, define the present, and consider possibilities for the future (Couclelis, 2002). Thus, mapped models of cities, which show the use of citizens as an essential component, also allow us to decode the city and read its components, focusing on its strengths and weaknesses to write an impressive future.

To analyze and discuss the results of our modelling and our approach, the study will base our analysis on the question the study posed in the introduction of our article, which is formulated in the following way: Are the proposed methods sufficient to support the engagement of the community throughout the urban design cycle, with a focus on a heritage specific to the city of Tataouine and with an emphasis on sustainability and resilience?

Mapping experiences through urban development is a complex field that translates actions into our cities. To answer our question, the study will look at two emerging approaches: The "Rhythm City" and the "Algorithmic City", which are mapped via uses and calculated via parameters. The study will explore these two concepts and their implications for the design of sustainable, user-centered cities. Therefore, to propose possible future solutions, the study breaks down our modelling results according to these two readings.

- **The Rhythm City**

As configured in Figure 4 the rhythm city is inspired by the rhythms of travel, way findings, and movement Table 1. It is a view of the city as a dynamic composition in which human activities create rhythms and harmonies. The city of Tataouine, as revealed by user journeys in parametric modelling, does not connect its historic sites through activities. Although their territorial presence differs from the overall schematization of the centre, these sites reflect an enduring heritage entity. In this sense, the study proposes to design our cities and territories in a way that promotes reconciliation, regularity, and civic expression. The models presented in Table 4 show that the study is not faced with a simple problem of geometric design, but rather with a question of the geographical enhancement of places. It's about finding a balance between centralization and decentralization, between concentration and diversity. All these elements contribute to the urban design of the city. The rhythm of the city will come from the layout of the streets and the uniqueness of the places. A rhythmic city adapts to the actions of its citizens, to the climate and the paths they take, as the study of public policies. On the other hand, it is essential to involve citizens in the creation of their living spaces. Urban strategies can be seen as collective roadmaps, aimed at triggering a desired change. (Pertoldi, Fioretti, Busti, & Van Heerden, 2020). This becomes an essential value. In other words, the city of Tataouine will be described as "rhythmic" if its inhabitants truly decide to work together to revitalize their cultural and heritage identity. It's no longer a question of style and modeling, but of compositions based on use and usability.

- **The Algorithmic- Organic City**

The study shows that the city of Tataouine can be organized in an organic manner by utilizing data related to its usage patterns. So, before developing the concept of the algorithmic city, it would be better to know what the organic city is. To define the organic city, the study

agrees with Harpet and Pincetl (2019), who point out that the city is an organization that not only mobilizes architectural and urban planning knowledge, but above all requires knowledge of human neuro-cerebral functioning and interactions. (Harpet & Pincetl, 2019). Organic urban planning is based on the ability to make the knowledge of project managers and designers available to residents as owners. These specialists provide tailor-made solutions to specific needs, mirroring the unique persona of each inhabitant. Otherwise, we are asking the same question as Pumain (2006) who states that: could the algorithmic city be the reunification of the concept of the city-object, understood both as a particular form of land use and as differentiated clusters of buildings, activities, and population on a territory, or can it emerge from a reflection on the fractal structure of cities, taken in their materiality? (Pumain, 2006). Thus, in the context of our research, the algorithmic city is defined as an organic city that is well developed in urban terms and that takes urban data as its primary component because when data is analyzed, it provides us with highly fractalized details about lifestyles and the territorial nuances of the inhabited space:

Data Analysis: The study collects data on travel patterns, consumption habits, and social interactions. Algorithms are used to analyze this data to identify trends and opportunities for improvement.

Personalization: The "Algorithmic City" identifies urban interoperability. Itineraries are tailored to individual preferences, recommendations, and neighbourhood associations. Parametric design is the ultimate enabling technology for this focus. It allows the morpho structural and morphological possibilities of the city to be deciphered, updated and brought to life. In contemporary architectural Design, the study speaks of a parametric structural design. A design that integrates new functionalities crossed with the spatial geometry of objects. It has been considered structured because it optimizes combinations that integrate a minimum of materials and data to respond to functions, uses, and needs more adapted to a society in perpetual evolution. (Sahtout, 2023). The preservation of cultural heritage and the revitalization of territories are major issues for urban planners and decision-makers. Through this discussion, the study will explore three key aspects: knowledge of the risks of heritage loss, the role of participatory and territorial design, and the integration of technological values for the revitalization of our local spaces.

5.1. Understanding the risks of heritage loss

According to our analysis, the location of the Ksour in Tatouine is not related to the activity of the city and, as the study has shown in Table 3, Electrosayeh is the focal point of the city. The risk would then be that these sites could only be visited as a function of ephemeral events and tourist seasons. On the other hand, what the study calls an organic and algorithmic city is one that redraws its urban contours as a function of the revalorization of its heritage. Heritage loss is a global challenge. Planners need to understand the factors that threaten our heritage: rapid urbanization, conflict, neglect, and changing lifestyles.

5.2. Rethinking Redevelopment with Participatory and Territorial Design

The phenomenon of participation has been an essential component of the globally accepted sustainable city concept since the 1970s (Turken & Eyuboglu, 2021), so the study strongly believes that community involvement, as shown in Table 3 is essential to creating sustainable and resilient cities, and for this to happen, the study need to think about

- ✓ Involve the community from the start: Involve residents from the planning stage. Their local knowledge and specific needs are invaluable in designing urban spaces adapted to their reality.

- ✓ Participatory Consultations and Workshops: Organize public consultations, workshops, and information sessions. This helps to gather ideas, solve problems, and create a sense of ownership.
- ✓ Participatory mapping: Use participatory mapping tools to identify vulnerable areas, local resources, and opportunities for sustainable development. Residents can contribute to the collection of geospatial data.
- ✓ Narratives and Awareness Raising: Tell stories about sustainability and urban resilience. Stories can inspire action and mobilize the community.
- ✓ Ongoing evaluation: Engage the community throughout the design process, from planning to implementation. Ongoing evaluation ensures that projects meet changing needs.

5.3. Integrating technological values

Our survey revealed that the use of parametric modelling enables us to generate designs that are better adapted to the specific needs of users while considering environmental and economic constraints. This design approach also enables better integration of the various disciplines involved in the design process, such as architecture, engineering, and construction. (Sahtout, 2023). Digital and parametric mapping technologies offer opportunities to revitalize our territories. Parametric urban modelling can be used to reconstruct and simulate design scenarios for redevelopment experiments and assess their impact on heritage. In Figure 4, the results of the five user journeys intersect, further highlighting the disconnect between the Ksour site and the city. Table 4 also defines our first exploration of the analysis, confirming our main concern: to regenerate the city of Tataouine by highlighting its historical identity and promoting civic action. The model presented in Figure 5 traces the periphery of the city concerning the Ksour, while maintaining the relationship with the central focus of citizens' daily activities.

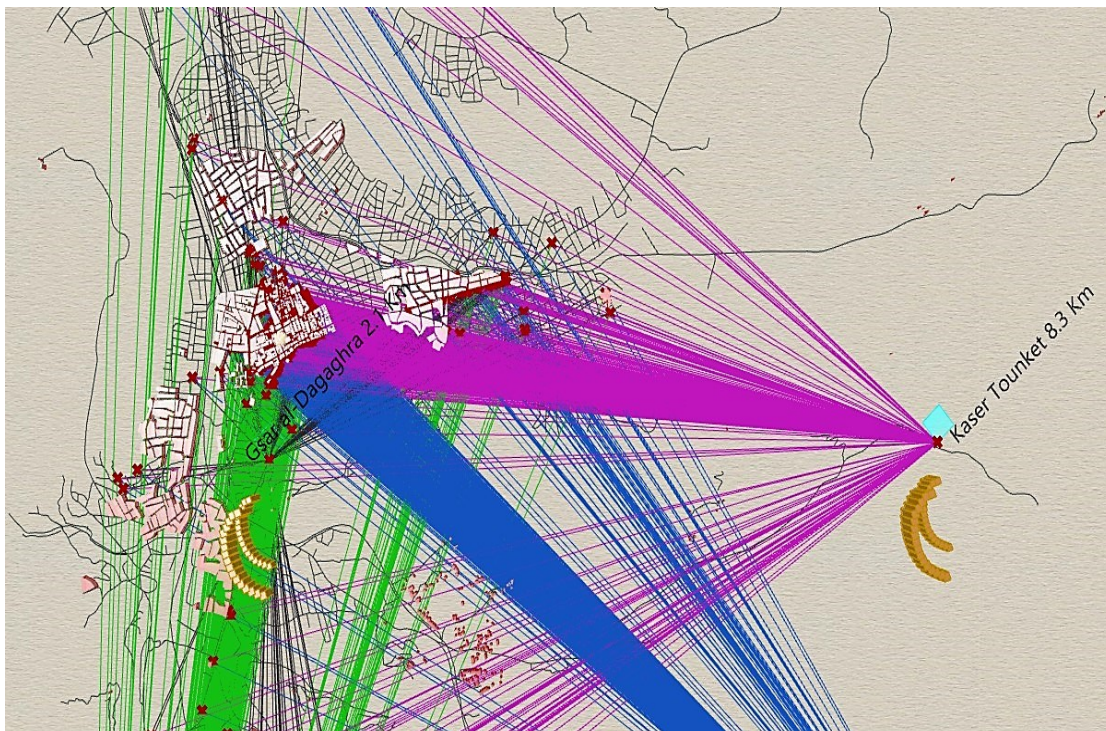


Figure 4. Result Mapping In-between the Ksour- Tataouine Ksour's.

5. Conclusions and Future Research Directions

In conclusion, this study presents a personalized framework inspired by Tim Brown's concepts (Lina, 2015). As shown in Figure 5, the research proposes a trilogy that outlines the deployment of a usage map based on cultural dynamics. This framework emphasizes the resilient enhancement of cultural heritage, with a focus on sustainable preservation and the maintenance of its legacy. Developed through a participatory methodology, it calls for the inclusion of case studies that capture the evolving nature of user experiences, regional distinctions, and, crucially, sustainable urban development. This approach aims to ensure that cultural heritage remains vibrant and sustainably integrated into urban environments, promoting a resilient, user-centered future.

The concept of livability introduces a practical perspective to the broader philosophical goals of sustainability. While sustainability tends to focus on long-term objectives, livability addresses immediate, tangible conditions and interventions, making it appear more achievable (Ruth & Franklin, 2014). Understanding how livability aligns with sustainability can help urban planners reconcile the present-day needs and preferences of residents with the longer-term goals of sustainable development (Farzaneh, 2017).

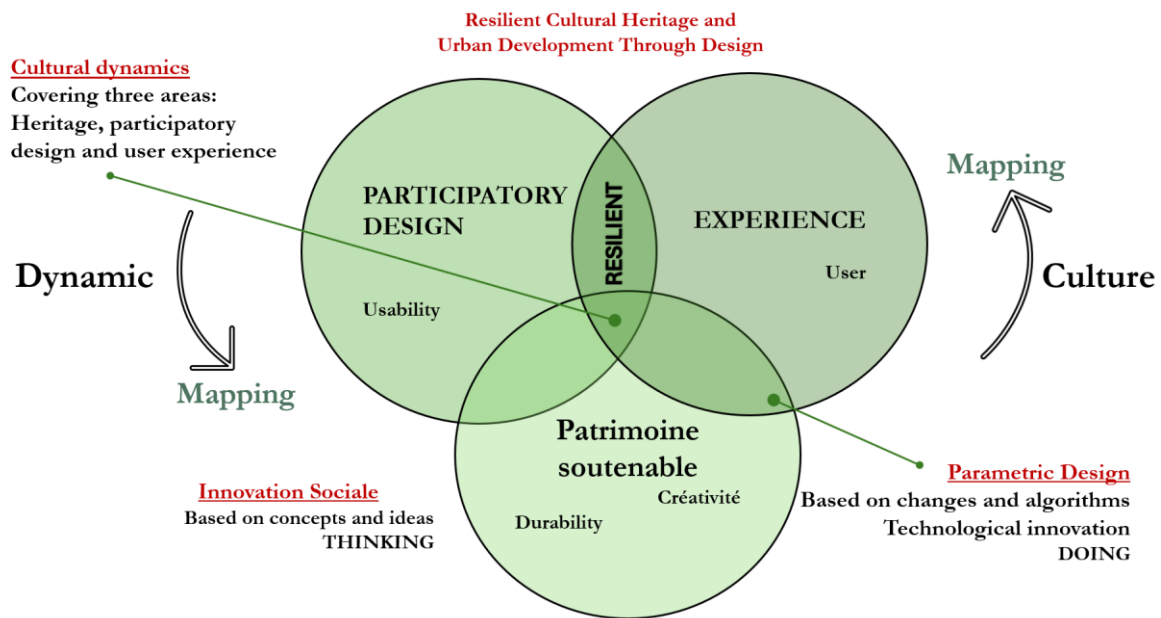


Figure 5. Mapping User Experience: The Dynamic Cultural Process.

More specifically than these examples of sublimating cartography, new models can be designed to answer the complex questions raised by the development of urban dynamics in cities, and above all to enhance the value of a heritage as unique as that of the city of Tataouine. To resemble participatory experiences and paths, a "parametric" solution would be to combine algorithms specific to shared living spaces, circulation and moldability of uses, and experiences to be commissioned and composed in city centres. Several methods will be innovated in a participatory and transdisciplinary way. Although institutional actors admit the existence of a generalized urban crisis because of real estate speculation and deregulated urban development, they also advocate that it can be treated as a temporary crisis that shall be resolved through targeted technical and policy measures that fall under the umbrella of sustainable urban development. However, the complexity of contemporary territories requires an approach that can address the numerous economic, ecological, technological, and cultural links between urban development and sustainable planning. (Antonios, 2020). Codesign and parametric design can provide new technical and

technological solutions to these crucial issues of urban development and participatory living. Cartography is only a medium that can facilitate the dialogue between stakeholders in an alternative of co-construction, sustainability, and longevity. Working on the issue of the smart city operatively involves systemic approaches to transformation, and the challenge would be to find a way to link technology to use through design. There is no such thing as a model smart city. But there are different uses to be observed, and complex realities to be discovered, there is a growing movement towards viewing cities and regions as complex and sociotechnical with people and communities interacting with one another and with objects, such as roads, buildings, transport links, etc, within a range of urban and regional settings or contexts. (Robert, 2022). In a way, design organizes the encounter of space and objects with the individual. Thanks to its interdisciplinary approach, it can be a catalyst for urbanity in this "smart city". Today, the smart city is a fiction that hasn't met the user. Urbanity is a question of friction, of understanding, of creating a common language. It is on this condition - the condition of design - that the connected city will be truly intelligent. (Orsoni, 2016). The complexity inherent in projects to create cultural dynamics, characterized by their multidisciplinary and historical nature, highlights the need for in-depth collaboration and innovative tools, including parameterized, technical, and technological dynamics. When it comes to preserving a particular heritage, there are many issues at stake. Historical, architectural, cultural, and environmental aspects interact in a complementary way, requiring a territorial innovation approach. What's more, uncertainty is often a feature of these projects, whether due to the demanding nature of the heritage elements or to budgetary and logistical constraints. By integrating new technologies, advanced modelling, parametric design, and urban mapping, this dynamic approach offers powerful solutions to the complex challenges of preserving and developing our heritage. It enables professionals from multiple disciplines - archaeologists, architects, curators, designers, and digital technology specialists - to work synergistically through design and the lived experience of users.

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Conflict of Interests

The Author declares that there is no conflict of interest.

Data availability statement

Data is openly available in a public repository that issues datasets with DOIs.

CRedit author statement:

Conceptualization, data curation, and formal analysis were conducted by Ines Sahtout Gaha, with additional data curation by Imen Ben Youssef Zorgati and Zoubeir Lafhaj. The methodology was developed by Ines Sahtout Gaha, Imen Ben Youssef Zorgati, and Zoubeir Lafhaj. Software utilized includes Rhino 3D, Grasshopper, and Adobe Illustrator, with contributions from Ines Sahtout Gaha and Hafedh Gaha. Writing, review, and editing were carried out by Ines Sahtout Gaha. The author has read and approved the published version of the manuscript.



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Original scientific paper

Integrating Dynamic Culture and Participatory Design in Urban Spaces for Sustainable Futures

*¹ Assoc. Prof. Dr. **Ines Sahtout Gaha** , ² Prof. Dr. **Imen Ben Youssef Zorgati** , ³ Prof. **Zoubeir Lafhaj**

¹ Department of Design, Higher Institute of Fine Arts, University of Tunis, Tunisia
² School of Design, Faculty of Planning, University of Montreal, Montreal, Canada
² Department of Science and Technologies, Lille University, France

¹ E-mail: ines.sahtout@isbat.u-tunis.tn, ² E-mail: imen.ben.youssef.zorgati@umontreal.ca, ³ E-mail: zoubeir.lafhaj@gmail.com

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ABSTRACT

This study explores the intersection of dynamic culture and participatory design in urban spaces, emphasizing the role of user experiences in shaping urban environments. By integrating residents' input in the design and planning processes, this research aims to foster sustainable, viable urban futures that reflect local cultural dynamics and community needs. Utilizing a case study in Tataouine, Tunisia, the research employs parametric mapping and user experience mapping to analyze interactions with heritage sites and public spaces. This approach captures qualitative data on user experiences and overlays it with spatial context, enabling the identification of patterns and relationships between cultural practices and territorial dynamics. The study aims to identify key factors for citizen participation, analyze user experiences in relation to cultural dynamics, and formulate recommendations for integrating participatory design principles. By aligning urban development with a dynamic culture and user-centric design, the study envisions urban spaces that are inclusive, sustainable, and reflective of local identities. The findings underscore the potential of participatory design to enhance the value of urban heritage and promote a more engaged and resilient urban community.

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Highlights:	Contribution to the field statement:
<ul style="list-style-type: none"> - Parametric models can effectively map user paths in Tataouine, providing detailed spatial analyses of urban interactions. - Innovative analytical tools can enhance the re-evaluation of architectural heritage, contributing to cultural preservation and urban renewal. - Participatory design is a critical component of architectural and urban planning processes, promoting inclusivity and sustainability. - Engaging stakeholders early in the planning process leads to the creation of cities that are organic, adaptable, and reflective of community needs. - Integrating dynamic culture with urban development can enrich the literature on cultural dynamics and algorithmic urbanism. 	<p>This article introduces a novel framework that combines cultural dynamics with participatory design, specifically applied to urban settings like Tataouine. By utilizing parametric modeling and user experience mapping, it pioneers new analytical tools for architectural heritage revaluation, offering scalable methodologies to redefine cities as algorithmic entities that adapt organically through community involvement.</p>

***Ines Sahtout Gaha:**
Department of Design, Higher Institute of Fine Arts, University of Tunis, Tunisia
Email address: ines.sahtout@isbat.u-tunis.tn

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1. Introduction

As a prelude for our investigation, let us take up Robert Fishman's inquiry, who proposed a fictitious story for defining and proposing new alternatives for building the cities of the future: What is the ideal city for the twentieth century, the one that would best express the study and beauty of modern technology and the most advanced ideals of social justice? (Fishman, 1982). The answer to this question was based on analyses of the work of urban planners such as Ebenezer Howard, Frank Lloyd Wright, and Corbusier, who produced detailed plans for factories, office buildings, schools, parks, and transportation systems; each plan introduced an innovation, and all the study are part of a revolutionary restructuring of urban form. The economic and political organization of the city, which was not easy to translate into drawings, was analyzed in the voluminous writings that each author attached to his projects (Fishman, 1982). Based on this perception, the study intends to develop an approach that resizes the configuration of today's city around new concepts such as participatory design, cultural dynamics, and parametric modelling. As the world becomes more urbanized and the human experience in urban environments becomes more diverse, the study is increasingly concerned about how the study creates, uses, and interacts in the built environment. In this context, cultural dynamics and participatory design have emerged as key concepts for understanding and embedding the city in a sustainable context, promoting the identification of uses and encouraging mutual appreciation. In this regard, there is an urgent need for governments to introduce and enforce processes that allow citizens, including vulnerable communities, to participate in development planning and policymaking. At present, there is a lack of guidance for practitioners regarding the definition of a clear purpose of community engagement and the selection of appropriate participatory methods to fulfil the set purpose (Devindi, Fernando, & Keraminiyage, 2021).

Participatory design involves the active collaboration of citizens, designers, and decision-makers in the creation and transformation of urban space. It transcends traditional design approaches by recognizing that end-users are in the best position to express their needs, preferences, and aspirations. The term participation is widely used to describe any practice or experience that involves citizens, but in most cases, neither the manner nor the degree of participation, nor the status of the people and the role given to them is defined (Croce, 2018). This democratic approach fosters greater ownership of public spaces and greater user satisfaction. Contemporary urban production and management is no longer just a matter for politicians and professionals in the field (decision-makers, architects and urban planners, construction companies, etc.). Nor is it just a matter of building buildings and roads. In the face of current social and urban changes and challenges (the need for more participatory democracy, the avoidance of urban sprawl, etc.), new "urban design cultures" are emerging, experimenting and, in some cases, ritualizing ways of saying, doing and experiencing today's city (Smail, 2021). At the same time, cultural dynamics play an essential role in the way the study perceives and interacts with our environment. Cultural values, social practices, and traditions shape our daily experience of the city.

The relationship between the study of regional culture and the city should have been a natural and smooth one of development or extinction, but rapid urbanization has upset the original equilibrium, thus restricting to a certain extent the development of a comfortable and personalized urban life (Sahari, Li, & Faridah, 2022).

By integrating these elements into the design process, the study can create spaces that reflect local identity, encourage diversity, and foster a sense of belonging. In practice, public participation is the key to the democratic process. This makes government institutions accountable to society, enables them to incorporate non-professional knowledge into decision-making, improves public policy support, and improves planning outcomes. Participation is valuable as a political goal, as it increases social capital and gives citizens more opportunities when they want a stronger voice in decision-making. (Jankauskaite, L, & Mlinkauskienė, 2021). In this paper, the study dives deep into the concepts of participatory design and cultural dynamics in the urban context. The study will present an approach to cartography based on urban and social

parameters. The cartography that is deployed as a result of our research will be integrated to redefine the context of the user experience in urban spaces. The study will also explore the challenges and opportunities that are associated with this approach, as the implications for sustainable urban planning.

This study will conduct a structured analysis of the literature and factual data based on concrete mapping and modelling to study the following questions:

- 1- What are the participatory methods that exist and are being used for community engagement?
- 2- In terms of real cultural dynamics, what level of engagement can parametric mapping methods achieve?
- 3- Are the proposed methods sufficient to support the engagement of the community throughout the urban design cycle, with a focus on a heritage specific to the city of Tataouine and with an emphasis on sustainability and resilience?

For the methodological needs of our research, the study has chosen a research project that explores the theory and epistemological needs to give us results in practice: a modelization visualized through a cartographic demonstration based on citizens' activities in the southern Tunisian city of Tataouine. Meanwhile, to better explain the goals of our research, other methods will be explored and analyzed as our research diagram evolves. In this sense, Figure 1 represents the process of our contribution and defines the specificity of our analysis.

2. Material and Methods

The aim of the systematic analysis of the user experience in the literature on the urban development of the city of Tataouine according to the location of its historical sites was to map and evaluate uses and interactions, and thus provide concrete answers to the research questions based on existing knowledge. Accordingly, the question of the study has been formulated as the study has previously specified and has been illustrated as follows: What existing participatory methods are used to engage communities, and how might Parametric Use Mapping be used to help envision a desirable architectural future?

The study proposes five distinct and complementary approaches in the diagram shown in Figure 1, which illustrates our research process. First, the study focuses on the identification of the foundations of cultural dynamics. This step is crucial to understanding the cultural foundations and the influences that shape the social interactions and behaviours in the city of Tataouine.

The study will then look at aspects of participatory design and its various forms and elements and the study will identify that Participation is often associated with the concept of democracy and it has a multidisciplinary, inclusive nature (Turken & Eyuboglu, 2021). Using parametric modelling, the study aims to create a new cartography of Tataouine that reflects the contributions and perspectives of its inhabitants, and which is defined as the dialogue between the study of a human and map, mediated through a computing device and is essential to the research into interactive cartography, visualization, and visual analytics (Roth, 2013). This participatory approach is essential to ensure that the cartography will be representative and inclusive. Third, the study presents examples of mapping methods, focusing on their conceptual and constructive aspects. These examples serve to illustrate how different techniques can be used to capture and represent urban complexity in innovative and effective ways. In the fourth section, the study presents the specifics of a cartographic case study carried out using parametric modelling. This process is a demonstration of the level of involvement of users with their immediate environment. An interpretation, adapted to the active data and the parametric parameters of the objects, will be developed to read these mapped paths. The presentation of the maps will also help us to revisit Tataouine's capacity for the reintegration of its historical sites in accordance with their uses. By analyzing the map through the activities of residents, the modelling process will be focused on concrete outcomes. These results will measure the level of involvement and interaction of users with their city and historic sites. They will identify the city's heritage and shared identity.

Finally, our conclusion offers a forward-looking perspective on urban development. The study postulates that the sustainability of architectural projects can be significantly enhanced through the interpretation and use of land-use mapping. By adopting a sustainable approach that considers the forming industry and sphere of activity for the territory (Vikhoreva, Malanina, & Ogloblin, 2020), the study aims to promote projects that respect and enhance local cultural and heritage dynamics. This approach not only preserves cultural heritage but also promotes harmonious interaction between studying residents and their urban environment. Furthermore, cartography and new technologies such as parametric design can be used to reinvent the city, reconstruct its urban fabric, and enhance its heritage.

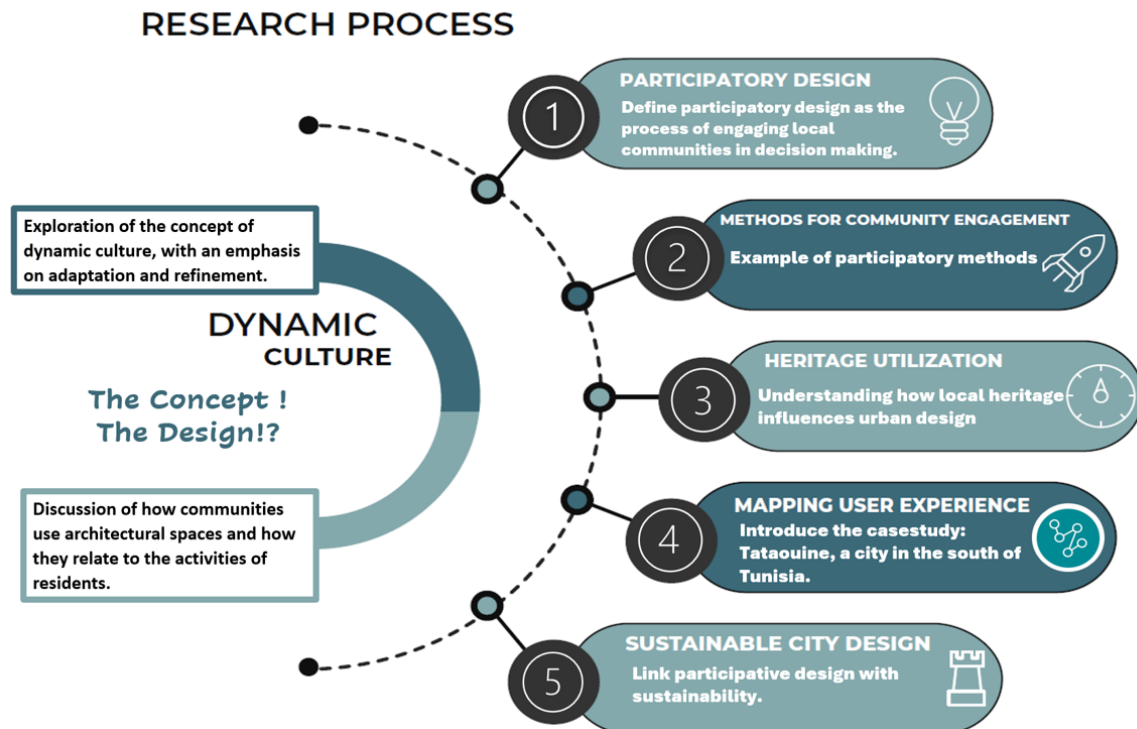


Figure 1. Research Process and Structure of the Study (Developed by Authors).

3. Theoretical Background: The fundamentals of participatory design

The approach advocated for applying our theoretical background is divided into three different interpretations. The first interpretation consists of a fundamental analysis that aims to identify the notions founded by design as a creative activity (Berger, 2004) in modelling solutions and alternatives for rereading a specific cultural heritage by and through user experience. This interpretation defines the theoretical foundations of cultural dynamics and demonstrates their relevance to participatory design. One of the techniques that has been used as a tool for urban development in recent years is that of cultural regeneration. This is seen as a means of restoring and improving the quality of urban life through the enhancement and development of the unique characteristics of a place and its people. (Wansborough & Mageean, 2000). To illustrate these foundations, an example of a pre-existing study will be presented. It will illustrate aspects of cultural dynamics and the participatory approach. Secondly, the mapping methods, tools, and resources that have been used so far for the improvement of the user experience through a spatial experience and a shaped urbanity are examined. The theoretical framework the study aims to establish in this section will serve as the foundation for our modelling and case study. It allows us to anticipate not only the impacts of urban concentration but also those of detachment. Our goal is to redefine cultural dynamics, considering novel public policy solutions and alternative approaches to

democratizing heritage sites. Additionally, the study will explore ways to establish stronger connections by better studying cultural practices, rituals, and consumer behaviours.

3.1. Cultural Dynamics' Participatory Design and Social Integration Characteristics

Dynamic culture refers to the constantly evolving, vibrant, and diverse fabric of human interactions, practices, and rituals within a city. It encompasses the ebb and flow of daily life, the varied rhythms of activity, and the collective experiences that shape urban spaces. To delve deeper, let's explore how dynamic culture intersects with participatory design, inspired by the words of J. Montgomery: Good cities tend to be a balance of a reasonably ordered and legible city form, and places of many and varied comings and goings, meetings and transactions. What might appear to some as disorder is very often simply the everyday rhythm of city life. In the absence of such activity, cities can lose their urbanity and eventually become suburban in character (Montgomery, 1998).

The study customizes Montgomery's vision in three fundamental ways:

- Urban Rhythms and Vibrancy
- Participatory Design as an Enabler
- Urbanity and Suburbanization

Table 1 illustrates the close relationship between the study's dynamic culture and participatory design. Both approaches celebrate the messy convergence of urban life, emphasizing the spontaneity of travel, unexpected encounters, and the dance of daily routines. When the study analyzes this dynamism, our cities thrive, bridging the gap between

the study disorder and vitality. Participatory design plays an essential role in this urban dynamic, cutting across cultural and local development to create a more vibrant pattern of place. It is above all a territorial design that unifies this idea of the adaptability of the city. The phenomenon of planning involving citizen's participation in planning literature has existed since the second half of the 20th century. Indeed, different methods and techniques have been used in the process. The study and participatory practices are time-consuming, and negotiations are tiresome. (Turken & Eyuboglu, 2021).

Territorial design is close to urban design, especially in its emphasis on the experience of the resident or user. There are two differences: The first is a difference in scale: urban design is localized (to the scale of the public square or the neighbourhood), whereas territorial design is part of a larger scale (which can include the neighbourhood, but also above all the city, the intercommunal area, even the region - all four can be considered simultaneously). (Jolivet, Safin, & Huron, 2021).

Table 1: Urban Dynamics: Unveiling the Heartbeat of Cities.

Urban Rhythms and Vibrancy	Participatory Design as an Enabler	Urbanity and Suburbanization
<p>Cities thrive on: <i>movement+ diversity+ interaction</i></p> <p>The comings and goings of people: Bustling through markets+ gathering in public squares+ engaging in spontaneous conversations</p> <p>=</p> <p><i>Creation of the heartbeat of urban life</i></p>	<p>Cities are not static entities but living organisms shaped by their inhabitants:</p> <p><i>Stakeholders + residents, architects + planners + community members + Designers</i></p> <p>=</p> <p>collaboration to shape urban spaces</p> <p>Knowledge experiences+ aspirations</p> <p>=</p> <p><i>Inform the design process</i></p>	<p>What makes a city truly urban</p> <p>Urbanity</p> <p>=</p> <p><i>Vibrance+ complexity+ adaptability</i></p> <p>It thrives on the interplay of people, activities, and cultural expressions.</p>
<p>What might initially appear as:</p> <p><i>disorder+ crowded streets+ impromptu street performances+ lively cafes</i></p> <p>=</p> <p>Dynamic culture</p>	<p>By involving End-users, Participatory design ensures that:</p> <p><i>Resulting spaces + city's unique cultural context</i></p> <p>=</p> <p>Empothes people to actively influence decisions Fostering a sense of ownership and pride</p>	<p>Cities lose their dynamic culture when:</p> <p><i>streets become sterile+ public spaces lack vitality+ interactions wane</i></p> <p>=</p> <p><i>Risk of slipping into suburban character</i></p> <p>Codesign revitalizes urbanity by infusing spaces with creativity inclusivity+ responsiveness to local needs.</p>
<p>Richness and Authenticity of Urban Experiences.</p>	<p>Participatory Design aligns with Dynamic Culture.</p>	<p>Participatory design acts as a counterbalance.</p>
<p>Empowering Communities: Participatory Design in Action</p>		

3.2. Methods for Community Engagement

3.2.1. User experience-centered Approach Method

Using an experience-centered approach and mapping user journeys, the user is able to understand the importance of wayfinding and community collaboration for the "Entre les Ksour" project simulated by (Nesrine, 2019) in her study of the city of Tataouine. This simulation proposed public transportation solutions that would allow citizens and visitors to easily move between historic sites, providing a unique heritage experience and a greater appropriation of the urban environment. Exploring roads: These can be streets, pedestrian roads, public transport areas, canals, and railways. These elements are dominant in the image of many people. People observe the city on the move and perceive other environmental elements on these roads and relate to the whole. (Yavuz, Ataoğlu, & Acar, 2020).

This simulation aimed to improve the accessibility of the Ksour. It also actively involved the community. It adopts a pragmatic approach whose principles value experience, participatory processes of codesign, and project-grounded research.

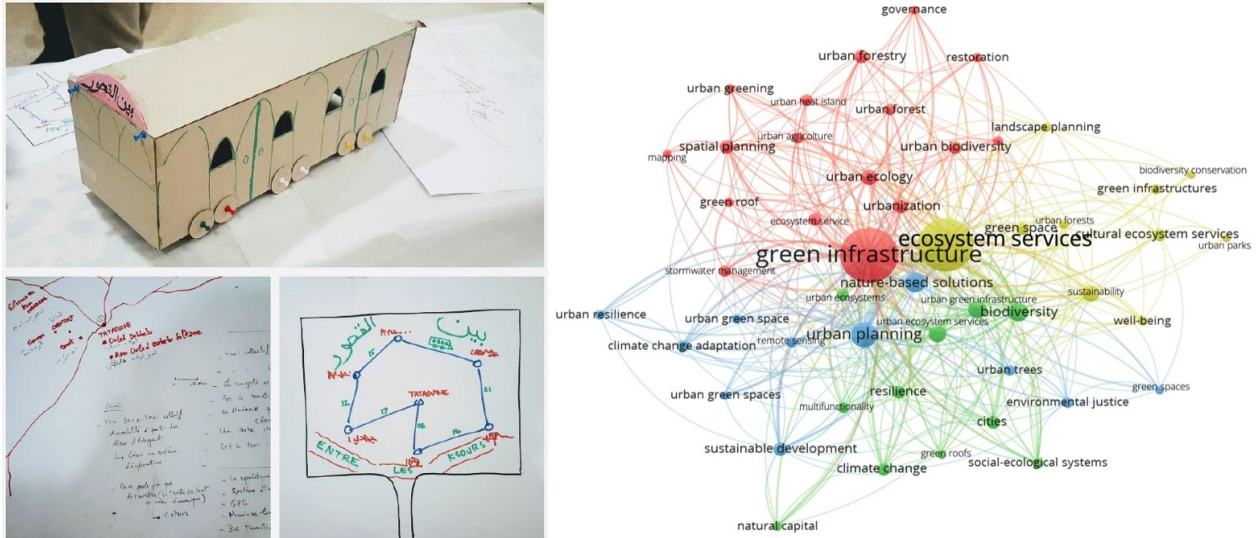


Figure 2. Project proposal of Between the Ksour (Ellouze, 2019).

Urban Mapping Tools & Techniques (URBAN DESIGN LAB)

To instantiate our co-design model, the initial idea and motivation came from a public integrator (Tataouine Governorate) who possessed an untapped resource (the Ksour) and wished to develop new services to strengthen regional attractiveness and promote local actors. As shown in Figure 2, the vision of the project was therefore to capitalize on the links established between institutions and to encourage cooperation and exchanges between professors and experts from different disciplines. (Ellouze, Ramseyer, & Brisolaro, 2021). The first idea is to bring conceptual features, as you can see through Figure 2, where a cluster of words and colours highlights urban planning and uses in terms of a specific vocabulary and convergent, interdisciplinary relationships. The second is a human-experienced concept delivered through between the ksour as a research project. Based on observing the lack of public transportation, signage, and difficulty of accessing without a guide, the simulation proposed tangible ways for citizens to connect with their cultural and natural heritage. By considering the lived experience of users and their uses, this approach proved viable and worthy of integration into the city's urban planning.

3.2.2. Design by and through citizen activities

To demonstrate that participatory design and cultural dynamics are two complementary and mutually stimulating concepts the study refers to the two methods developed by Ezio Manzini (2014) for Social dynamic Innovation.

Designing for the community: This design means looking at specific typologies of collaborative service and, after observing their strengths and the study weaknesses, intervening in the context of the services to make them more favourable, and developing solutions to increase their accessibility and effectiveness and therefore their replication. In this mode, designers have to conceptualize and develop solutions for specific collaborative services and other enabling artefacts (e.g., digital platforms, orienting scenarios, and catalyzing events, including exhibitions, festivals, and other cultural events) (Ezio, 2014).

Designing with the community: This means participating as peers with other actors involved in creative community building and collaborative service co-design. In this modality, designers must facilitate the convergence of different partners toward shared ideas and potential solutions. This kind of activity requires a set of new design skills: promoting collaboration among diverse social actors (local communities and companies, institutions, and research centres); participating in the construction of shared visions and scenarios; and

combining existing products and services to support the creative community members with whom they collaborate (Ezio, 2014). The study intends to go further than these two forms of participatory interpretation and develop a new approach Figure 3 based on designing through and by the interpretation of users' activities and real-life experiences.

- Cultural dynamics are shaped by the visibility of lived experience and represent the interaction between the study of a participative approach and the design of public policies.
- Cultural dynamics thus become a key element in making users aware of the heritage value of their sites and/or their region.

Innovation would be the organization of the city around all these elements that coordinate life and animate and co-animate urban development. Furthermore, it is possible to create solutions that meet users' real needs by involving the community in the design process. It can also foster a sense of pride and a sense of belonging to the cultural and natural heritage of the city. Cultural dynamics and community involvement are therefore key elements in architectural heritage conservation. By drawing on the experience and cooperation of residents, the study can enhance and preserve historic sites and monuments for future generations, while strengthening the social fabric and understanding of local history and culture. Liang, W., Ahmad, Y., & Mohidin, H. H. B. (2023), mentioned through their analysis demonstrating the correlation between user awareness and heritage enhancement of a community prescient that The conservation of architectural heritage in urban spaces is not only about preserving the historical buildings of the past but also about uniting stakeholder groups, identifying architectural heritage, gaining a collective cultural identity, finding a sense of place and civic pride for residents, allowing everyone to appreciate the cultural values of the city today, and creating a cultural identity for future urban planning through this process (Cauchi Santoro, 2016). As the study explores the convergence of dynamic culture and participatory design in the urban context, cartographic tools and mapping techniques emerge as powerful interpretive methods. They allow us to navigate and rethink the future of urban spaces. Here's how these tools and techniques can be defined according to our research study concept:

Modelling journeys

- Cartography transcends language and cultural barriers. It becomes a visual language shared by residents, planners, and decision-makers. As the study presents modelling 2 in Table 2 with a specific brainstorming technique in Figure 2 the study focuses our research on parametric visualization of user paths.
- The study can use maps to tell the story of how a city evolved, to reveal its dynamics, and to show how people interact with the environment in which they live.
- Route and wayfinding simulations help us anticipate user movements. They are essential for designing user-friendly routes and maintaining accessibility.
- By integrating historical and cultural data, these models can guide visitors to heritage sites while promoting an evocative experience.

Participatory mapping

- It is essential to involve the local community in the interpretation of the mapping of their city. Residents know the hidden places, the informal paths, and the daily anecdotes that are the foundation of their sense of place.

Utility Mapping

- Beyond streets and buildings, usage mapping explores how people interact with space. Where do they congregate? What are their habits?
- By identifying pedestrian flows, meeting places, and underutilized spaces, the study can design urban interventions that are more relevant and tailored to the real needs of residents: the study engaged a mapping in the field of participatory design creating

value for urban societies. The study wanted to look at theories and models that have the capability to generate measurable impact on urban challenges and stimulate sustainable urban transformation. (Von, T, S Verhagen, S, & Loorbach, 2019).

3.3. Heritage Utilization for a Designed Dynamic Culture

Notice that by exploring the traditions, know-how, lifestyles, and habits of a community, it is possible to discover other architectural and urban interpretations through daily activities and uses. Through the schematization Figure 3, the study explores the hidden meanings that use can have; Manzini discovered that social design is done with or for the community, but to evoke and integrate citizen practices, the study emphasizes and engages in a cartographic process to promote design through activities.

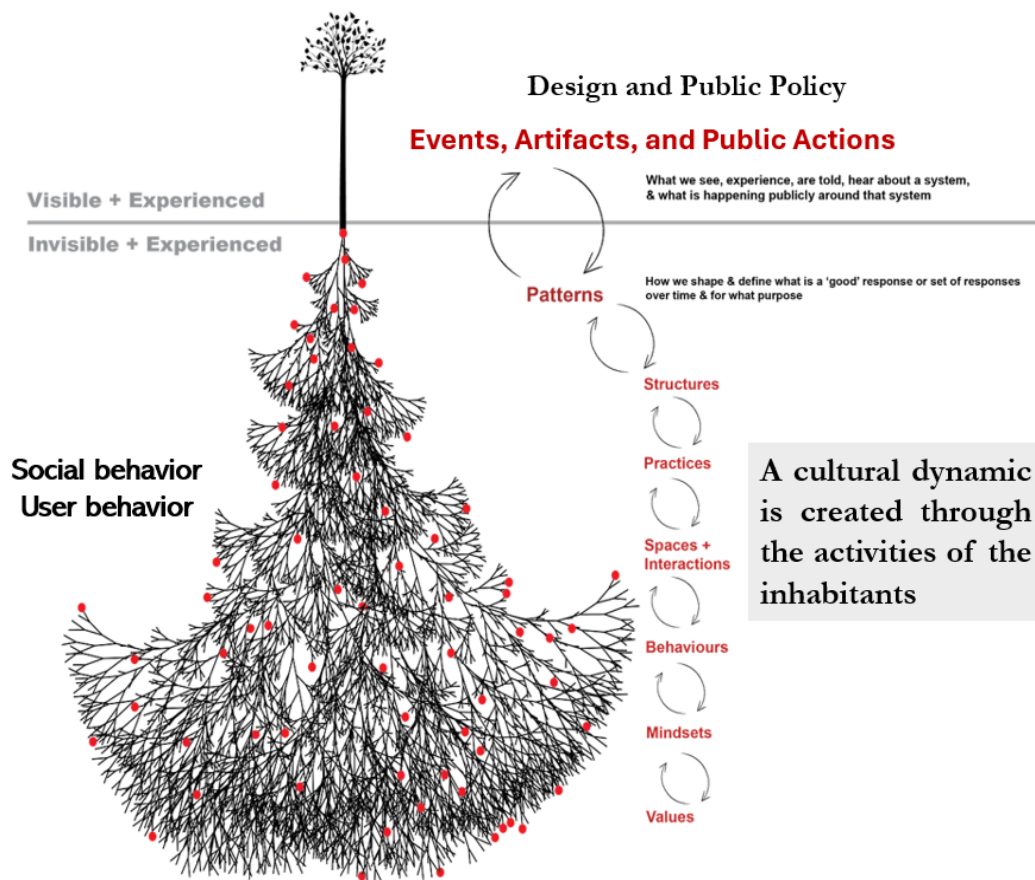


Figure 3. Changed by Authors, Inspired by the organic patterns of systems.

Analyzing Urban Activities and Experiences: Movement mapping

In our cities, every interaction and movement creates data that reflects how the study lives and uses our urban spaces. By analyzing this data, the study can uncover patterns in how spaces are utilized and understand the relationship better between people's behaviours and the environment. This analysis is crucial for designing urban spaces that are tailored to the specific needs of the community.

- Cities generate a vast amount of data from participatory activities and experiences that can be analyzed to provide information about spatial experiences and dynamic behaviours Figure 3.
- This can include information about how people move, what they do, and how they use spaces.

- This data can be useful for understanding patterns of place use and the relationship between citizens/habits/behaviours and the environment. Modelling 2, Table 2. It can be used for planning that is tailored to the needs of regional and specific users.

In essence, dynamic use mapping becomes a means of interpreting the city as it adapts to current needs. It invites us to explore narrow streets, lively squares, and changing spaces while keeping an eye on the future. This approach, rooted in citizen participation, allows us to rethink housing from a more social and even more economic point of view. It also allows us to rethink the enhancement of historic sites. Thus, in our second phase, the study intends to demonstrate through parametric modelling how the Ksour of Tataouine are detached from the city and its central activities. modelling that maps the relationship between users and the convergence of their experiences.

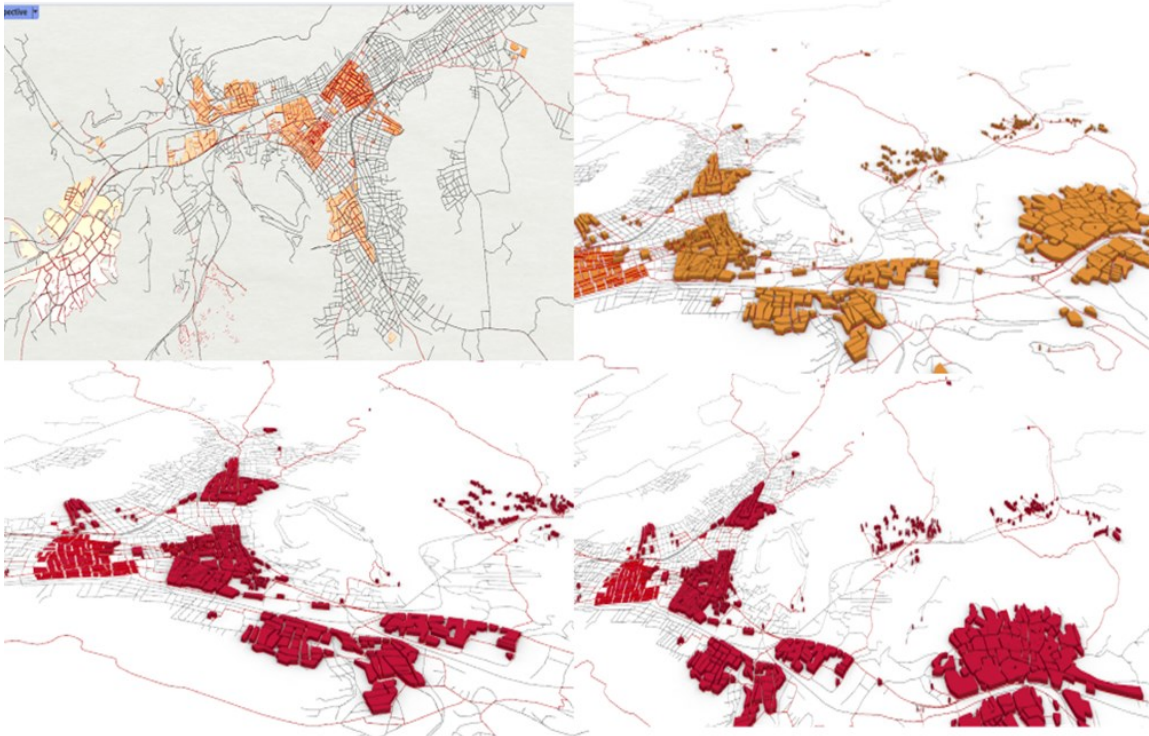
4. Mapping User Experience: Case study- TATOUINE

Second, an urban meaning that considers the tangible, social dimension of the city and, combined with the innovation of technology, configures the needs of users. The second type invites us to become part of an intelligent schematization that advocates new readings and interpretations of the complex system that is the city. Its optimization depends not only on the will of a community but above all on new reading and interpretation tools.

Bernard Stiegler (Stiegler, 2016) emphasizes the importance of inventing a new urban intelligence and confirms that the study must invent a new urban intelligence. The study needs to use digital platforms to organize local deliberations and give citizens the ability to take control of their city's technological destiny (Anne, 2017).


For this reason, the study proposes to model the activities and routes of the citizens of Tataouine for a simulation of the journeys to the ksour, to progress towards our case study. The integration of an interactive and specifically parametric component is essential for the emergence of new ideas. A contemporary urban design process demands human-centred development where future technologies intertwine with traditional approaches to generate a sustainable, liveable environment while saving time and resources (Fink & Reinhard, 2019). A map of the cultural dynamics of the city of Tataouine was created using this parametric modelling approach.

Table 2: Setting Orientation Parameters.

Modelling 1	
Adding OSM (Open-Street-Map) geographic data for the city of Tataouine and setting orientation parameters	
1- Import OpenStreetMap (OSM) geographic data for the city of Tataouine.	
2- This data includes detailed information about the topography of the city, its streets, buildings, and other geographic features.	
3- Customize and adjust parameters to orient the map according to the daily activities of residents.	
4- Focus on the essential amenities for citizens.	
5- Customize the map to better meet needs, functions, and uses.	
Modulization Results	
	

Participatory design is inextricably linked to urban development and the methods advocated for its implementation. Furthermore, technological advances offer new experiences in spatial exploration. The models the study intends to use to analyze our case study are combinations of parameterized objects that exhibit a form of spatio-temporal interoperability. In this way, a primary reading of the urban and topographical context of the city of Tataouine is developed, offering a static vision of places, environments, and constructions. This parametric modelling allows for an in-depth, dynamic understanding of the interactions between different urban elements while integrating the perspectives and needs of residents into the urban planning process. Exploring Tataouine virtually allows us to uncover the essential amenities that significantly impact the daily lives of its residents. This virtual journey helps us decode the city's concealed features and understand what truly matters to the local community. Table 2 outlines the procedures required to obtain a specific map of Tataouine and a justified description of its functions. Parametric design mapping enabled us to virtually penetrate the city and decipher its algorithms and organic value.

Table 3: Exploring the map with programs and algorithms.

Modelling 2	
Minimizing mass addition distances, the blue paths shown on the map below are modelled.	
1-	Entering the city virtually
2-	Deciphering its hidden characteristics: to discover the amenities that are particularly important in the daily life of the inhabitants of Tataouine.
Modelisation Results	
	

By minimizing the distances for mass addition, the study revealed that user activities are centered around a focal point, identified as ELECTROSAYEH, a sales area. As demonstrated through the model presented in Table 3, the study illustrates how these activities are organized according to a program that highlights the city's central point. The pathways connecting various activities at different times are mapped out by connecting lines. The study employed parametric modeling to calculate and visualize spatial movements within Tataouine, leading to the identification of ELECTROSAYEH as the barycenter. This point is recognized as the core of the city's dynamics, providing unique insights into the urban structure and the daily flow of its inhabitants' activities.

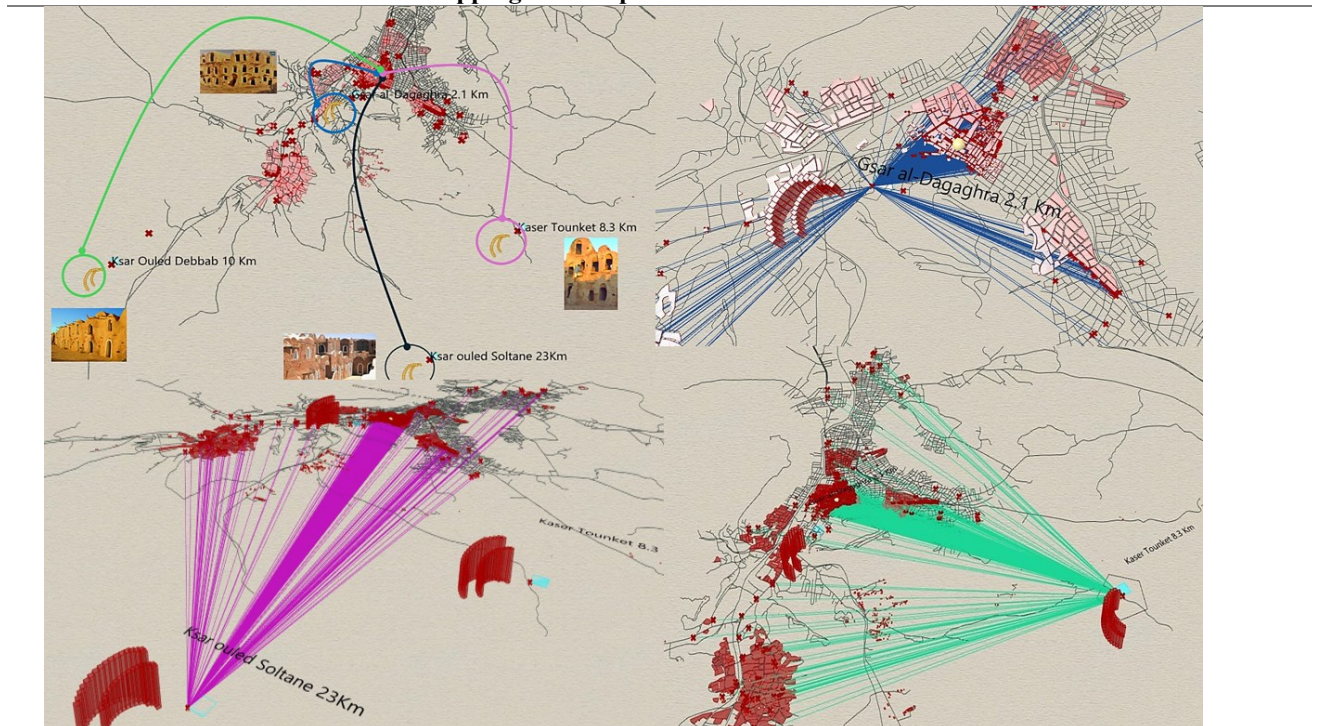
To further illustrate this, the activities modeled in Table 3 are linked to the functional diagram of the ksour. The study simulated the placement of the ksour in Tataouine by accurately managing the real distances between them and the city, particularly their relationship to the ELECTROSAYEH barycenter. This modeling, as shown in Table 4, enables a deeper understanding of the city's layout based on both common and uncommon patterns of use. The value of the ksour is enhanced by synchronizing user activities according to their locations (maximizing distances) and by creating a network of routes distinguished by different colors and connections between the sites themselves.

The study will now present the cartographic results, displaying user routes by minimizing and maximizing the distances between the Tataouine barycenter and various ksour, providing estimates of visit frequencies.

Table 4: Mapping the detailed user experience.

Modelling 3
Minimizing and maximizing mass addition distances, the coloured paths shown on the map below illustrate the location of the ksour and their relationship to the center of Tataouine.
1- Ksour Locations: Ksar Dghaghra, Ksar Ouled Debbab, Ksar Ouled Soltane, and Ksar Tounket
2- Calculate the distance of arrival and departure
3- Calculate route values
4- Walk the map, Discover the Ksour, and Color the routes.

Mapping User Experience Results



Urban designers draw inspiration from a variety of principles to create sustainable, user-centred spaces in harmony with community lifestyles. One of these guiding principles could be the new cartographies that have emerged as an alternative with the birth of Generative Design. This new cartographic experiment emphasizes citizen participation, seeing through the social understandings of individuals to relational bases that evoke meaning. In the context of our project, the installation of ksour as a functional unit within the central activity of ELECTROSAYEH in Tataouine Table 2 is a fascinating exploration. By modelling activities and travel distances, the user is able to optimize routes to key ksour, including Ksar Dghaghra, Ksar Ouled Debbab, Ksar Ouled Soltane, and Ksar Tounket Table 4. This approach is consistent with a new mapping goal of creating vibrant, well-connected communities.

5. Findings and Discussion: The rhythm city, the algorithmic city

The theoretical fundamentals of this research project were developed by identifying ancient cartographic methods such as the "between the ksour" exploration developed by Nesrine Elllouze (Nesrine, 2019). It focuses on the fundamental aspects of participatory design and cultural dynamics. As for our case study, which took place in Tataouine, the study tried to

model the city according to its uses, to penetrate it and bring out the degrees to which its citizens belong. In this way, the study understood that the population is a good variable to measure the importance and the success of a city, that the city is a whole system, and that the study can identify the science of the city. This is the controversial issue the study has tried to address in this study by approaching Tataouine's activities as a function of its historical sites and its dominant interurban displacements. In this way, and according to our modelling, the study has come to understand that the design of a city is determined by external interventions and urban problems are complex issues whereby social, economic, and environmental dimensions are intertwined. (Pertoldi, Fioretti, Busti, & Van Heerden, 2020). The city is not a fixed design, which is positive for territorial planning. A model is an abstract and partial representation of some aspect or aspects of the world "that can be manipulated to analyze the past, define the present, and consider possibilities for the future (Couclelis, 2002). Thus, mapped models of cities, which show the use of citizens as an essential component, also allow us to decode the city and read its components, focusing on its strengths and weaknesses to write an impressive future.

To analyze and discuss the results of our modelling and our approach, the study will base our analysis on the question the study posed in the introduction of our article, which is formulated in the following way: Are the proposed methods sufficient to support the engagement of the community throughout the urban design cycle, with a focus on a heritage specific to the city of Tataouine and with an emphasis on sustainability and resilience?

Mapping experiences through urban development is a complex field that translates actions into our cities. To answer our question, the study will look at two emerging approaches: The "Rhythm City" and the "Algorithmic City", which are mapped via uses and calculated via parameters. The study will explore these two concepts and their implications for the design of sustainable, user-centered cities. Therefore, to propose possible future solutions, the study breaks down our modelling results according to these two readings.

- **The Rhythm City**

As configured in Figure 4 the rhythm city is inspired by the rhythms of travel, way findings, and movement Table 1. It is a view of the city as a dynamic composition in which human activities create rhythms and harmonies. The city of Tataouine, as revealed by user journeys in parametric modelling, does not connect its historic sites through activities. Although their territorial presence differs from the overall schematization of the centre, these sites reflect an enduring heritage entity. In this sense, the study proposes to design our cities and territories in a way that promotes reconciliation, regularity, and civic expression. The models presented in Table 4 show that the study is not faced with a simple problem of geometric design, but rather with a question of the geographical enhancement of places. It's about finding a balance between centralization and decentralization, between concentration and diversity. All these elements contribute to the urban design of the city. The rhythm of the city will come from the layout of the streets and the uniqueness of the places. A rhythmic city adapts to the actions of its citizens, to the climate and the paths they take, as the study of public policies. On the other hand, it is essential to involve citizens in the creation of their living spaces. Urban strategies can be seen as collective roadmaps, aimed at triggering a desired change. (Pertoldi, Fioretti, Busti, & Van Heerden, 2020). This becomes an essential value. In other words, the city of Tataouine will be described as "rhythmic" if its inhabitants truly decide to work together to revitalize their cultural and heritage identity. It's no longer a question of style and modeling, but of compositions based on use and usability.

- **The Algorithmic- Organic City**

The study shows that the city of Tataouine can be organized in an organic manner by utilizing data related to its usage patterns. So, before developing the concept of the algorithmic city, it would be better to know what the organic city is. To define the organic city, the study

agrees with Harpet and Pincetl (2019), who point out that the city is an organization that not only mobilizes architectural and urban planning knowledge, but above all requires knowledge of human neuro-cerebral functioning and interactions. (Harpet & Pincetl, 2019). Organic urban planning is based on the ability to make the knowledge of project managers and designers available to residents as owners. These specialists provide tailor-made solutions to specific needs, mirroring the unique persona of each inhabitant. Otherwise, we are asking the same question as Pumain (2006) who states that: could the algorithmic city be the reunification of the concept of the city-object, understood both as a particular form of land use and as differentiated clusters of buildings, activities, and population on a territory, or can it emerge from a reflection on the fractal structure of cities, taken in their materiality? (Pumain, 2006). Thus, in the context of our research, the algorithmic city is defined as an organic city that is well developed in urban terms and that takes urban data as its primary component because when data is analyzed, it provides us with highly fractalized details about lifestyles and the territorial nuances of the inhabited space:

Data Analysis: The study collects data on travel patterns, consumption habits, and social interactions. Algorithms are used to analyze this data to identify trends and opportunities for improvement.

Personalization: The "Algorithmic City" identifies urban interoperability. Itineraries are tailored to individual preferences, recommendations, and neighbourhood associations. Parametric design is the ultimate enabling technology for this focus. It allows the morpho structural and morphological possibilities of the city to be deciphered, updated and brought to life. In contemporary architectural Design, the study speaks of a parametric structural design. A design that integrates new functionalities crossed with the spatial geometry of objects. It has been considered structured because it optimizes combinations that integrate a minimum of materials and data to respond to functions, uses, and needs more adapted to a society in perpetual evolution. (Sahtout, 2023). The preservation of cultural heritage and the revitalization of territories are major issues for urban planners and decision-makers. Through this discussion, the study will explore three key aspects: knowledge of the risks of heritage loss, the role of participatory and territorial design, and the integration of technological values for the revitalization of our local spaces.

5.1. Understanding the risks of heritage loss

According to our analysis, the location of the Ksour in Tatouine is not related to the activity of the city and, as the study has shown in Table 3, Electrosayeh is the focal point of the city. The risk would then be that these sites could only be visited as a function of ephemeral events and tourist seasons. On the other hand, what the study calls an organic and algorithmic city is one that redraws its urban contours as a function of the revalorization of its heritage. Heritage loss is a global challenge. Planners need to understand the factors that threaten our heritage: rapid urbanization, conflict, neglect, and changing lifestyles.

5.2. Rethinking Redevelopment with Participatory and Territorial Design

The phenomenon of participation has been an essential component of the globally accepted sustainable city concept since the 1970s (Turken & Eyuboglu, 2021), so the study strongly believes that community involvement, as shown in Table 3 is essential to creating sustainable and resilient cities, and for this to happen, the study need to think about

- ✓ Involve the community from the start: Involve residents from the planning stage. Their local knowledge and specific needs are invaluable in designing urban spaces adapted to their reality.

- ✓ Participatory Consultations and Workshops: Organize public consultations, workshops, and information sessions. This helps to gather ideas, solve problems, and create a sense of ownership.
- ✓ Participatory mapping: Use participatory mapping tools to identify vulnerable areas, local resources, and opportunities for sustainable development. Residents can contribute to the collection of geospatial data.
- ✓ Narratives and Awareness Raising: Tell stories about sustainability and urban resilience. Stories can inspire action and mobilize the community.
- ✓ Ongoing evaluation: Engage the community throughout the design process, from planning to implementation. Ongoing evaluation ensures that projects meet changing needs.

5.3. Integrating technological values

Our survey revealed that the use of parametric modelling enables us to generate designs that are better adapted to the specific needs of users while considering environmental and economic constraints. This design approach also enables better integration of the various disciplines involved in the design process, such as architecture, engineering, and construction. (Sahtout, 2023). Digital and parametric mapping technologies offer opportunities to revitalize our territories. Parametric urban modelling can be used to reconstruct and simulate design scenarios for redevelopment experiments and assess their impact on heritage. In Figure 4, the results of the five user journeys intersect, further highlighting the disconnect between the Ksour site and the city. Table 4 also defines our first exploration of the analysis, confirming our main concern: to regenerate the city of Tataouine by highlighting its historical identity and promoting civic action. The model presented in Figure 5 traces the periphery of the city concerning the Ksour, while maintaining the relationship with the central focus of citizens' daily activities.

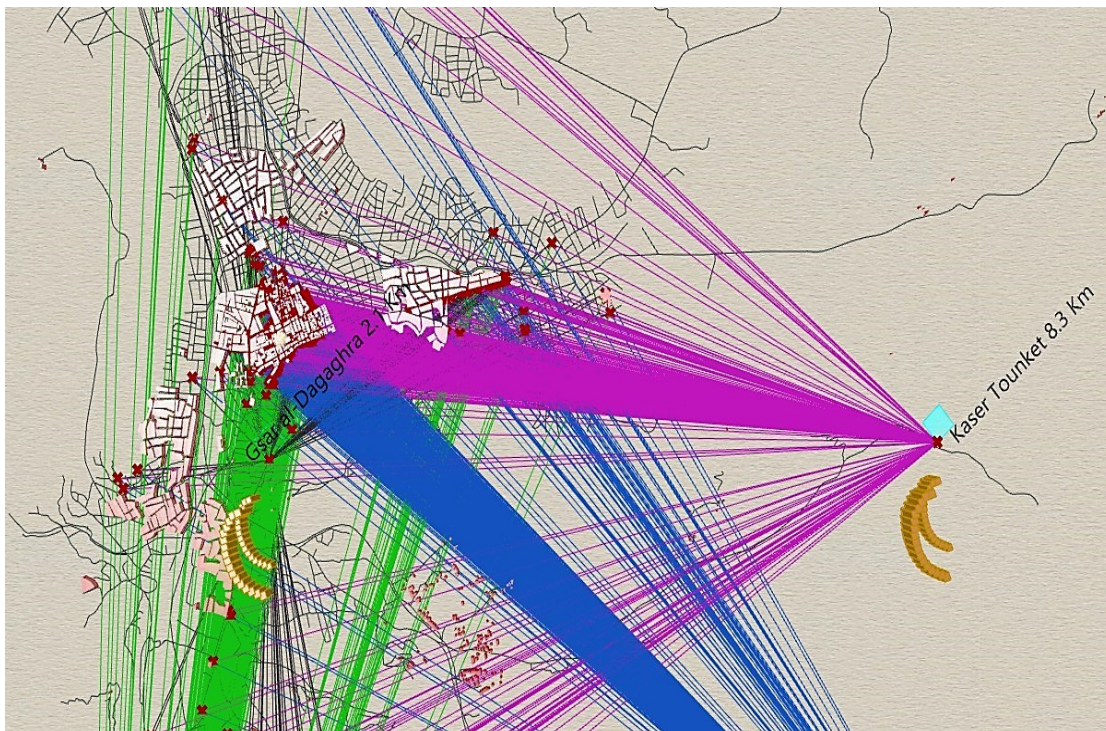


Figure 4. Result Mapping In-between the Ksour- Tataouine Ksour's.

5. Conclusions and Future Research Directions

In conclusion, this study presents a personalized framework inspired by Tim Brown's concepts (Lina, 2015). As shown in Figure 5, the research proposes a trilogy that outlines the deployment of a usage map based on cultural dynamics. This framework emphasizes the resilient enhancement of cultural heritage, with a focus on sustainable preservation and the maintenance of its legacy. Developed through a participatory methodology, it calls for the inclusion of case studies that capture the evolving nature of user experiences, regional distinctions, and, crucially, sustainable urban development. This approach aims to ensure that cultural heritage remains vibrant and sustainably integrated into urban environments, promoting a resilient, user-centered future.

The concept of livability introduces a practical perspective to the broader philosophical goals of sustainability. While sustainability tends to focus on long-term objectives, livability addresses immediate, tangible conditions and interventions, making it appear more achievable (Ruth & Franklin, 2014). Understanding how livability aligns with sustainability can help urban planners reconcile the present-day needs and preferences of residents with the longer-term goals of sustainable development (Farzaneh, 2017).

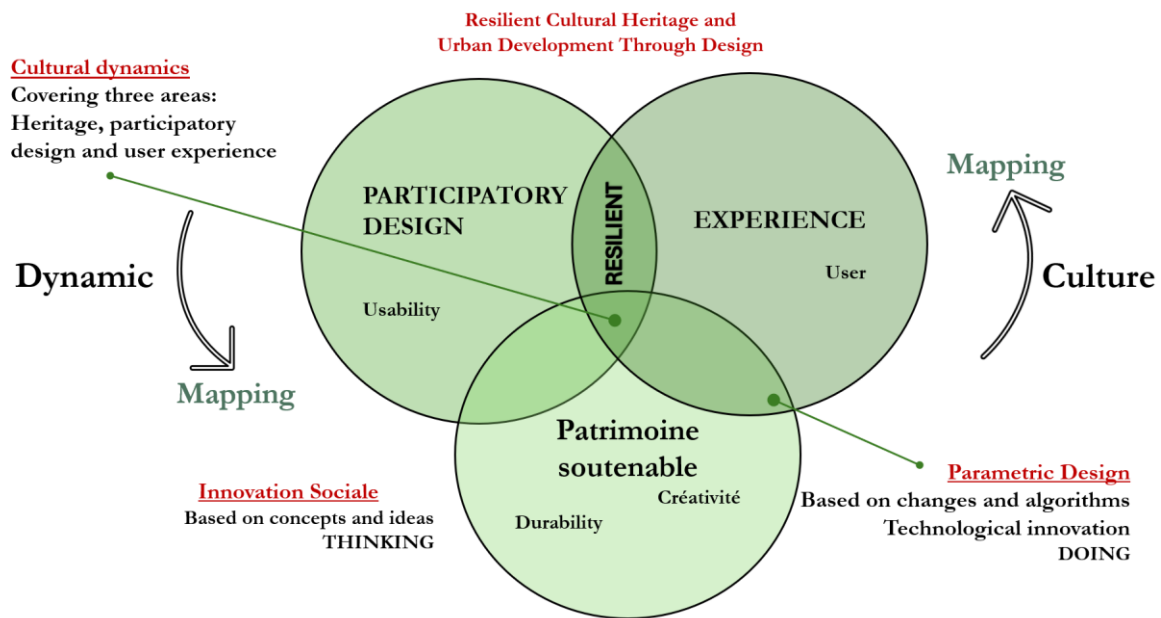


Figure 5. Mapping User Experience: The Dynamic Cultural Process.

In summary, developing new models that address the complexities of urban dynamics is crucial, particularly to enhance the unique heritage of cities like Tataouine. A parametric approach, combining algorithms that optimize shared spaces, circulation, and adaptable uses, offers significant potential for urban centers. Participatory and interdisciplinary methods will be vital in innovating solutions to current urban challenges. While institutional perspectives often treat the urban crisis as a temporary phenomenon that can be resolved with targeted measures, the complexity of contemporary urban territories demands a more integrated approach that considers economic, ecological, technological, and cultural dimensions (Antonios, 2020).

Codesign and parametric design provide promising avenues for developing new technical and technological strategies for sustainable urban development and participatory living. As a medium, cartography can facilitate dialogue among stakeholders, fostering co-construction, sustainability, and longevity. The pursuit of a smart city requires systemic approaches that link technological innovation with practical use, recognizing that there is no

one-size-fits-all model but rather diverse applications and complex realities to explore (Robert, 2022).

Design plays a critical role in mediating the relationship between space, objects, and users. Through its interdisciplinary nature, design can act as a catalyst for urban development within the framework of the smart city. Achieving true urban intelligence requires creating a shared language and understanding among all stakeholders, which is essential for the city's connectivity and adaptability (Orsoni, 2016).

The multidisciplinary and historically complex nature of cultural dynamics further emphasizes the need for collaboration and innovative tools, such as advanced modeling, parametric design, and urban mapping. When preserving heritage, we must consider historical, architectural, cultural, and environmental dimensions, each interacting within a territorial innovation framework. Given the uncertainties associated with heritage projects, whether due to their inherent complexities or logistical constraints, integrating new technologies and dynamic approaches offers robust solutions for both preservation and development. This strategy allows diverse professionals—including archaeologists, architects, curators, designers, and technology specialists—to collaborate effectively, ensuring that heritage conservation and urban development are aligned with sustainable practices. Future research should focus on developing adaptable frameworks that further integrate technological innovation with participatory design, allowing cities to evolve as living, dynamic systems that respond to the complex needs of their inhabitants.

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Conflict of Interests

The Author declares that there is no conflict of interest.

Data availability statement

Data is openly available in a public repository that issues datasets with DOIs.

CRedit author statement:

Conceptualization, data curation, and formal analysis were conducted by Ines Sahtout Gaha, with additional data curation by Imen Ben Youssef Zorgati and Zoubeir Lafhaj. The methodology was developed by Ines Sahtout Gaha, Imen Ben Youssef Zorgati, and Zoubeir Lafhaj. Software utilized includes Rhino 3D, Grasshopper, and Adobe Illustrator, with contributions from Ines Sahtout Gaha and Hafedh Gaha. Writing, review, and editing were carried out by Ines Sahtout Gaha. The author has read and approved the published version of the manuscript.

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Original scientific paper

Parental Preferences and Non-Spatial Factors Influencing Home-to-school Distance in Urban India: Insights From Visakhapatnam

*¹ Rohinikumar Reddy , ² Assoc. Prof. Dr. Ram Sateesh Pasupuleti 

¹ & ² Department of Architecture and Planning, Indian Institute of Technology Roorkee, India

¹ E-mail: rohinikumar@ar.iitr.ac.in, ² E-mail: ram.pasupuleti@ar.iitr.ac.in



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Multinomial Logistic Regression,
Visakhapatnam.

ABSTRACT

The school in the neighbourhood unit has been a significant and irreplaceable element in promoting active school commutes, and physical activity needs for children. However, urban areas in India are currently witnessing long school commutes. This study explores parental preferences for school selection in an urban Indian context, focusing on non-spatial attributes of schools associated with home-to-school distance. A questionnaire-based cross-sectional survey was conducted in Visakhapatnam, Andhra Pradesh, with a sample size of 409 families. Data were collected under four parameters: family demographics, socio-economics, neighbourhood environment, and non-spatial attributes of the schools. Pearson's chi-square (χ^2) test of independence was adopted to identify the association between the dependent and predictor variables. Further, a multinomial logistic regression model was employed to predict the odds in home-to-school distance. These methods were chosen for their ability to provide robust and reliable results. The findings, which indicate that child age, number of school-going children, annual household income, school's board of affiliation, and education level significantly predict home-to-school distance, have practical implications. They suggest that policy interventions aimed at reducing school commute times should consider these non-spatial factors. Enhancing local school attributes could encourage shorter commutes, promoting healthier lifestyles for children. This understanding can guide the development of policies and interventions that effectively reduce school commute times.

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Highlights:

- The school's non-spatial attributes are contextually specific. This study is the first attempt to investigate the role of non-spatial factors affecting home-to-school distance in India.
- The non-spatial attributes of school environments significantly influence parents' preferences in school selection.
- Statistical methods χ^2 test of independence and MNL Regression analysis provide robust results in preferential choice studies.

Contribution to the field statement:

This study expands theoretical perspectives on the neighbourhood school concept by incorporating non-spatial attributes of schools and socio-economic factors in parents' school selection preferences, emphasizing the need for integrated urban planning and community engagement to ensure equitable education access in developing urban areas.

*Rohinikumar Reddy:

Department of Architecture and Planning, Indian Institute of Technology Roorkee, India

Email address: rohinikumar@ar.iitr.ac.in

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1. Introduction

1.1 Background and Context

Distance of the school plays a significant role in progressing a child's physical and cognitive development and overall well-being (Faulkner et al., 2009; Macdonald et al., 2019). Starting in the early 2000s neighbourhood concept, the element of the school in the neighbourhood unit has played an instrumental role in fostering urban planning and neighbourhood unit sustainability in many developed and developing nations (Glazer, 1959; Lawhon, 2014). Over the period, the consistent efforts and educational reforms in providing access to education in India have facilitated a school provision in almost all neighbourhoods within a walkable distance of 1km (Tucker Shailey, 2012). However, the dynamic nature of urbanisation, available school choices, affordable transportation conveniences, and ever-changing preferences encourage parents to choose various schools and shift away from local schools for their children's education. In urban areas, this has exacerbated challenges in the transportation infrastructure, with studies indicating that nearly 30% of road traffic congestion is caused by school trips during school operating hours (Srinivasan, 2010; W. Sun et al., 2021). This situation is particularly concerning for children, who are a highly vulnerable age group. Longer school commutes expose them to increased risk of road traffic accidents (Singh, 2017), air pollution, obesity, and cardiovascular diseases (Sabin et al., 2005). Additionally, these extended commutes result in a significant loss of active time for physical activity, which is crucial for children's overall health and well-being.

1.2 Literature Study

The literature in this paper consists of two major aspects. It begins with a brief overview of understanding Indian school education and concludes with a review of parental school preferences.

1.2.1 Understanding the Indian School Education

The Ministry of Education under the Ministry of Human Resource Development (MHRD), Government of India, is India's apex body of school education. It controls the funding, framing of policies, and execution, and it ensures uniformity at national and regional levels for education improvement and overall development (Krishna & Naidu, 2005). According to (Parruck Chanda & Ghosh, 2014), School education in India can broadly be segmented by three key factors: level of education, ownership, and board of affiliation. Level of education is further categorised into four phases: lower primary (class 1-5), upper primary/elementary (class 6-8), secondary (class 9-10), and higher secondary (class 11-12) (see figure 1) for clear understanding about the type of school and level of education. School ownership is categorised into three types: public, semi-public and private. Government-operated schools are called government/municipal public schools and offer formal schooling. Semi-public schools are aided by the government and managed by the private, whereas private schools are funded and managed by the private. Most urban neighbourhood schools are municipal schools affiliated with a respective state board of education. Besides the state board, two other prominent school boards are in India: the Central Board of Secondary Education (CBSE) and the Council for the Indian School Certificate Examinations (ICSE). The CBSE and ICSE share a very minimal number among the total school share (nearly 28,000 schools out of a total of 1.5 million), yet they are prevalent across the country. The curriculum, teaching/learning methods, infrastructure facilities, and site areas of these boards are different.

1.2.2 Parents Preferences

Proponents contend that parents are the key decision-makers in school selection and their children's commuting mode (Alsuiadi, 2015; Burgess et al., 2015; Joshi, 2014; Schneider & Buckley, 2002). A recent study by (Joshi, 2014) in Nepal says location, quality of education, and financial consideration are the utmost factors parents rank when selecting a school for their children. Similarly, many U.S. studies identified the convenient location as the primary parental preference in choosing a school for ease of dropping and picking up their children (Hastings et al., 2005). A study by (Schneider & Buckley, 2002) based on an internet search of parental preference about schooling in Washington, DC, found that location



is the second most common keyword in school selection concerning distance from home and access to public transportation. Location preferences vary based on parents' socio-economic background, built environment attributes and political governance (Joshi, 2014).

School quality is a complex variable and challenging to describe and quantify. Parents consider higher academic attainments (Burgess et al., 2015), quality of instruction and innovative teaching methods, discipline, school management and results of board examinations (Joshi, 2014), class size, quality of instruction and student-teacher relationship (Alaiyadi, 2015) are major attributes of the school quality. (Woessmann, L. 2000) Defines such factors based on the resources and management of the school, which are the two fundamental elements that shape the school's functioning. Based on the above two elements, (Klees, 2010) categorised a school's mechanism into four types, i.e., funded and managed by the public, funded and managed by private, funded by public and managed by private, and funded by private and managed by public. Further, (Woessmann, 2000) study finds that the operation of schools with public funding and public management is associated with lower outcomes, but public funding and private management are associated with better student outcomes and are most efficient. However, private funding and management schools result in higher student outcomes. Parents also consider reputation as another attribute of the school's quality, and school achievements further define its reputation.

Dissatisfaction over failing public schools has motivated parents to choose private schools in many places (Beavis, 2004; Kingdon, 2007; Mousumi & Kusakabe, 2022; A. Singh, 2015; Woodhead et al., 2013). Conversely, globalisation in developing countries has resulted in citizens accessing and affording private schools that teach English, a globally important language (Joshi, 2014), rather than public schools that predominantly teach local or regional languages. Parents who choose private schools in non-native English-speaking countries value English medium instruction, quality of English teaching and teachers' professional expertise (Joshi, 2014). Few studies (Iram Naila et al., 2008; Woodhead et al., 2013) reported that household factors might influence school selection criteria, like the number of children in the family, birth order, and gender of the siblings, have a substantial impact on school selection, particularly in marginal economic families.

1.3 Research Gap

Globally, a vast number of studies exist on children's school commute modes concerning home-to-school distance. Such studies are based on children's age, gender, demographic, socio-economic, neighbourhood environment, social and cultural setting, urban form, distance, walkability, safety, school location, transit access, traffic danger, car ownership, season, and other explanatory factors. These studies focus on the various commute modes and their association with children's health and the built environment (Broberg & Sarjala, 2015; Chica-Olmo et al., 2018; Chillón et al., 2015; Crane & Crepeau, 1998; McDonald, 2007; Mitra, 2013; Sidharthan et al., 2011; Y. Sun et al., 2015). A few studies have attempted to investigate parental preferential factors when selecting a school for their children, mainly considering the distance of the school from home.

1.4 Objectives

Motivated by the above discussion, this research aims to determine the role of a school's non-spatial attributes that influence the parents' preferences in school selection concerning home-to-school distance in urban areas. This study is based on the primary data gathered from a representative sample of parents (of children aged 5-14 years) in Visakhapatnam, India. Further, this study provides insights into school commute typologies of children and home-to-school distance concerning varied socio-demographic settings and further attempts to understand the parent's preferences on school selection criteria based on household characteristics, SES, and school's non-spatial and built-environment factors.

1.5 Significance and Structure of the Paper

This study highlights the critical role of non-spatial attributes in parental school selection and its impact on home-to-school distance in urban India. By understanding these preferences, policymakers can design interventions to reduce school commute times, alleviate traffic congestion, and promote healthier lifestyles for children. The findings provide a basis for enhancing local school attributes and inform the development of more effective urban education policies.

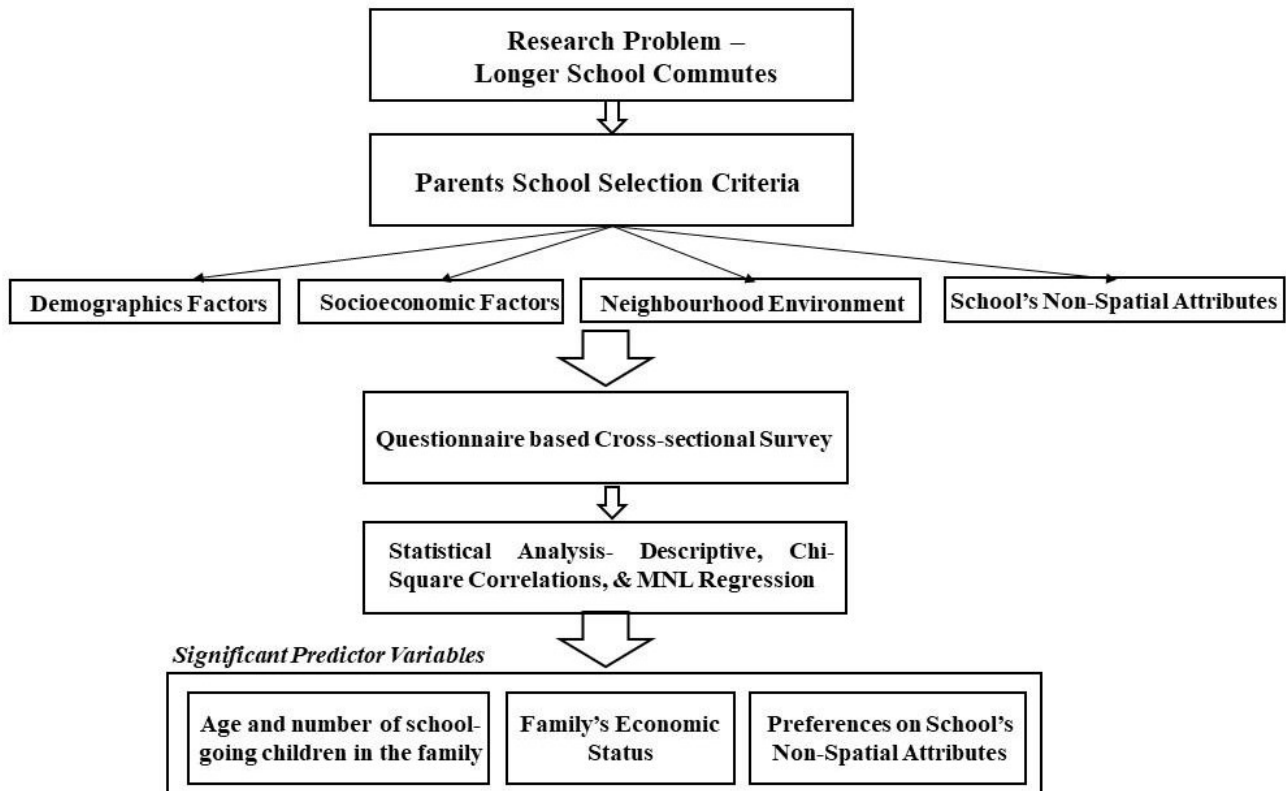


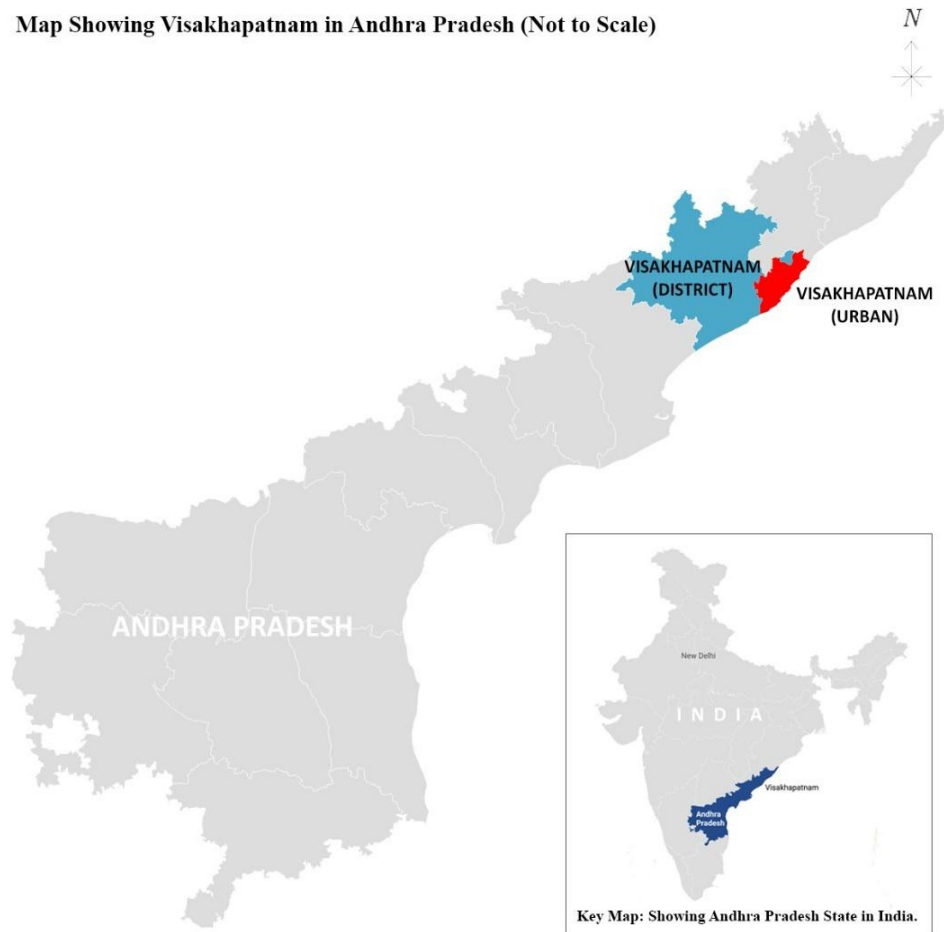
Figure 1. Structure of the Study (Developed by the Authors).

2. Materials and Methods

2.1 Study Setting

A questionnaire-based cross-sectional survey was conducted in Visakhapatnam (GVMC –Greater Visakhapatnam Municipal Corporation), a metropolitan city (with a population of more than 1 million people) in Andhra Pradesh, India (see Figure 2). Visakhapatnam is the first largest city and a proposed executive capital city of the newly bifurcated state of Andhra Pradesh. The city has a population of 1.7 million, a core urban area of 122 km² and a total metropolitan area of 539.95 km²; the city is administratively organised into six zones and 72 wards. Further, the city consists of major ports, industries, and educational institutions in the state, attracting many migrants from the neighbouring regions.

Map Showing Visakhapatnam in Andhra Pradesh (Not to Scale)



Map: Reedy Rohinikumar | IIT Roorkee | 2022 . Map data: © OSM . Created with Datawrapper . Edited in PSD

Figure 2. Map representing the location of Visakhapatnam city in Andhra Pradesh, India.

2.2 Participants

The targeted respondents were the parents of elementary school pupils (5-14 years old). Two sampling methods were used to collect the data and received 247 samples from a non-probabilistic snowball sampling technique (circulating questionnaire link/QR code through SMS and WhatsApp) and 220 samples from a simple random sampling (Circulating questionnaire form at the neighbourhood parks) during April 2021 to August 2021. Out of 467 observations, 409 valid responses are retained for the analysis. The purpose of the study was communicated, and informed consent was obtained from the participants.

2.3 Materials, Equipment, Procedures and Protocols

Indicators identified from previous studies to formulate the questionnaire and discussed with subject experts, i.e., school teachers and school-going children's parents, to contextualize the instrument. The questionnaire involves demographic, socio-economic, neighbourhood environment, and spatial and non-spatial parameters of schools. Microsoft Forms (an online survey tool) is used to prepare a questionnaire form for distribution to the targeted respondents. Each question in the questionnaire form was asked in two languages, English and Telugu (a regional language in the study context), for the convenience of the participant. The author has sufficient knowledge of both languages. Hence, the translation of the questionnaire reflects the same meaning in both languages. The data types collected are nominal, ordinal, and interval/ratio with a structured closed-ended and open-ended questionnaire. In this paper, only a selected closed-ended questionnaire is taken into consideration.



2.4 Data Analysis

Descriptive statistics were used to represent the characteristics of the overall sample in frequencies and percentages. Variables like home-to-school distance, commute mode, and school availability in the neighbourhood have been cross-tabulated with frequencies. It has provided information about the proportion of children studying within the neighbourhood and commuting outside with varied distances and commute modes. The Chi-square test is a distribution-free non-parametric test; when the Level of measurement of variables is nominal/ordinal, the sample size of the study groups is unequal, and the distribution is non-normal, this test gives robust results and detailed information about the interdependency of the variables (Mchugh, 2013). The variables in our study satisfy the (Mchugh, 2013) chi-square test criteria and do not require preliminary tests to check the normality. Hence, further analysis was conducted in non-parametric tests using Pearson's chi-square (χ^2) test of independence to investigate the significant relations between the dependent and independent variables. After obtaining the significant variables, a multinomial logistic regression analysis was conducted using the forward method with the significant variables to predict the odds ratios of the home-to-school distance. All the statistical tests were conducted using IBM® SPSS® Statistics Version 27.

3. Results

3.1 Children studying within the neighbourhood vs outside

As shown in Table 2, out of 409 parents' responses, 362 parents reported school availability within the range of 1km from their home, and the remaining 47 parents reported unavailability or unaware of the school in the 1km vicinity. However, out of 362 parents, only 136 parents (i.e., 59 parents with single children, 69 parents having two children, and 8 parents having three children) reported that their children are studying at the same school, and 193 parents (i.e., 144 parents with single children, 45 parents having two children, and 4 parents having three children) reported that they are sending their children outside the neighbourhood for school. Surprisingly, 33 parents said at least one of their children is at the neighbourhood school, and the rest are studying outside the neighbourhood.

Table 1: Characteristics of the sample.

Characteristics of the sample			Characteristics of the sample		
Variable	Frequency	Percentage	Variable	Frequency	Percentage
Number of Respondents	409	100%	Board of Child School		
Gender of the Child			Local / State govt. board	297	72.60%
Male	230	56.20%	CBSE	82	20.00%
Female	179	43.80%	ICSE	30	7.40%
Level of Education of the Child			Medium of instruction		
Primary	208	50.90%	Regional language	48	11.70%
High School	201	49.10%	English	361	88.30%
Number of Children in the Home			Type of management of the school		
1	232	56.70%	Public	108	26.40%
2	160	39.10%	Semi-public	60	14.70%
3	17	4.20%	Private	241	58.90%
Education of the parent			Level of education of the school		
Did not attend the school	22	5.40%	Up to Primary	83	20.30%
Up to matriculation	46	11.20%	Up to Upper-Primary	70	17.10%
Graduate	194	47.40%	Up to Secondary (High School)	256	62.60%
Above graduation	147	35.90%	Type of education of the school		
Occupation of the Parent			Co-Education	380	92.90%
Both are not working	26	6.40%	Only Girls	20	4.90%
Single parent working	290	70.90%	Only Boys	9	2.20%
Both are working	93	22.70%	Teaching Methods		



Annual income of the family (Indian Rupees)			Traditional	140	34.20%
< 3,00,000	101	24.70%	Modern / Digital	36	8.80%
3,00,001 - 6,00,000	133	34.00%	Combined	233	57.00%
6,00,001 - 12,00,000	123	30.10%			
> 12,00,000	46	11.20%			

Table 2: Children studying within the neighbourhood vs outside.

	Is the school within 1km of your residence available?		If yes, is your child studying at the same school?			
	Yes	No	Yes, all my children study at the same school	Yes, one of my child studying at the same school	No	
Number of School Children in the Family	1	204	28	59 (59)	1(1)	144 (144)
	2	143	17	69 (138)	29 (29)	45 (90)
	3	15	2	8 (24)	3 (3)	4 (12)
	Total	362	47	136 (221)	33 (33)	193 (46)

3.2 Mode of the school commute and home-to-school distance

As shown in Table 3, children travel to school by active modes (walking and bicycling) up to the range of 2km from home; as the distance increases, the mode of commute changes to the motorised vehicle. However, the commute mode may vary according to the child's gender and level of education. The Pearson correlation results indicate a significant relationship between the variables of the child's school commute mode and the distance of the school from home ($\chi^2 = 250.078$, $df = 15$, $p\text{-value} < 0.001$).

Table 3: Mode of school commute vs home-to-school distance.

Mode of School Commute	Distance of the child's school from home				Total
	< 1 km	1-2 km	2-5 km	> 5 km	
Walking	45	13	0	0	58
Bicycling	25	2	2	0	29
Rickshaw/Auto	47	45	22	13	127
Dropping/Pick-up by parent or caretaker	11	21	27	6	65
School van/bus	7	13	45	51	116
Public transport	0	0	2	12	14

3.3 Correlation among variables (Refer to Table 4)

3.3.1 Demographic factors vs home-to-school distance

Gender

Our sample of responses represents 43.8% girls and 56.2% boys school admissions. Regarding the distance of the school from home, girls were slightly lower compared to boys in the school admissions, whereas, while distance increased from home to school, boys' numbers slightly increased. However, the difference was not statistically significant ($\chi^2 = 0.646$, $df = 3$, $p\text{-value} = 0.886$). (Easton & Ferrari, 2015) reported that gender moderated with age could significantly affect the commute distance as a girl's age may increase commute distance.

Age / Level of the child's education

Parents of primary school children were more likely to send their children to schools near home (39.4%, 23.6%, 20.2%, and 16.8% in <1km, 1-2km, 2-5km, and above 5km, respectively). Whereas in high-school children, the number of children was significantly increasing in comparison to primary-level children as the distance increased from the home (26.4%, 22.4%, 27.9%, and 23.4%, in <1km, 1-2km, 2-5km, above



5km, respectively). There is a significant difference in the Level of the child's education and the distance of the school from home ($\chi^2 = 10.039$, $df = 3$, p -value < 0.05). The results correlate with (Easton & Ferrari, 2015) findings, where a child's age/level of education is very consistent and significant in association with home-to-school distance.

Number of children in the family

Regarding the number of school-going children in the family, our sample reported 232 (56.7%) families having a single child, 160 (39.1%) families having two children and the rest 17 (4.2%) families having three children. Our results describe that families with two or more children prefer schools within 2km from home, whereas single-child parents' preferences vary regardless of the distance. Our findings report a significant difference in the number of school children in the family and home-to-school distance ($\chi^2 = 21.040$, $df = 6$, p -value < 0.05).

3.3.2 Socio-economic factors vs home-to-school distance

Parent's educational qualification

Of all the 409 observations, 174 (35.9%) respondents are above graduation; among them, 37 parents (25.2%) are sending their children to the school in the neighbourhood, another 105 parents (71.4%), including the above 37 respondents' children are studying at the school within 5km from home, and 42 parents (28.6%) are sending their children to the school above 5km from home. Similarly, 194 (47.4%) respondents are graduates; among them, 72 parents (37.1%) are sending their children to the school in the neighbourhood, 166 parents (85.4%), including the above 72 respondents' children are studying at the school within 5km from home, and 28 parents (14.4%) are sending their children to the school above 5km from home. Likewise, 46 (11.2%) respondents are up to matriculation; among them, 17 parents (37%) are sending their children to the school in the neighbourhood, and the rest 29 parents (63%) are sending their children to the school outside the neighbourhood. Lastly, 22 (5.4%) respondents did not attend schooling; among them, 9 parents (40.9%) are sending their children to the school in the neighbourhood, and the 18 parents (81.8%) children including above 9 are studying within the 5km, and the remaining 4 parents (18.2%) are sending their children above 5km. These results describe a slight relation between an increase in the parent's education level to the Distance of the children's school from home; however, the difference was not statistically significant ($\chi^2 = 14.991$, $df = 9$, p -value = 0.091).

Annual income of the family

Of all the 409 observations, 101 respondents (24.7%) have income below 3,00,000 and send their 45 (44.6%) children to the school in the neighbourhood, 92 (91.1%) children are studying the range of 5km from home, and only 9 (8.9%) children are travelling more than 5km from home for schooling. Similarly, 139 respondents (34%) have an income between 3,00,001-6,00,000 and send their 52 (37.4%) children to the school in the neighbourhood, 115 (82.7%) children are studying the range 5km from home, and 24 (17.3%) children are travelling more than 5km. Likewise, 123 respondents (30.1%) have an income of 6,00,001-12,00,000 and send their 25 (20.3%) children to the school in the neighbourhood, 82 (66.7%) children are studying in the range of 5km from home, and 41 (24.7%) children are travelling more than 5km from home for schooling. And finally, 46 respondents (11.2%) have an income of above 12,00,000; among them, 13 (28.3%) parents send their children to the school in the neighbourhood, 38 (82.6%) are within the range of 5km from home, and the rest 8 (17.4%) of them are travelling more than 5km. Pearson correlation suggests a significant correlation between the annual income of the family and the Distance of the children from home ($\chi^2 = 40.251$, $df = 9$, p -value < 0.001).

Parents occupation

In our sample, 290 (70.9%) respondents reported single parents are working, 93 (22.7%) said both parents are working, and only 26 (6.4%) reported not working anywhere. The correlation between parents' occupation and home-to-school distance did not show any statistical significance ($\chi^2 = 1.290$, $df = 6$, p -value = 0.972).



3.3.3 School's non-spatial factors vs home-to-school distance

Board of the school

Of all the 409 observations, 297 parents (72.6%) are sending their children to the Local / State government board schools; among them, 117 (39.4%) parents send their children to the neighbourhood school, 257 (86.5%) children are studying in the range of 5km from home, and only 40 (13.5%) children are travelling more than 5km from home. Similarly, 82 parents (20.1%) are sending their children to CBSE schools; among them, 13 (15.9%) parents send their children to the neighbourhood school, 52 (63.4%) children are studying in the range of 5km from home, and 30 (36.6%) children are travelling more than 5km from home. Finally, 30 parents (7.3%) are sending their children to the ICSE schools; among them, 5 (16.7%) parents send their children to the neighbourhood school, 18 (60%) children are studying in the range of 5km from home, and 12 (40%) children are travelling more than 5km from home. These results show that most children studying in local/state govt board schools travel less than 5km for schooling from their home, whereas children studying at CBSE and ICSE schools travel more than 5km. Although most children study at local schools, there is a significant difference in the distance of the school from home and the board of children's school ($\chi^2 = 39.256$, $df = 6$, $p\text{-value} < 0.001$).

Our statistical model (see table 5) presents the probability of preference for CBSE schools compared to the local board having 1.198, 4.118, and 6.721 times in 1-2km, 2-5km and above 5km categories, respectively, with the base category of home-to-school distance below 1km. Similarly, the probability of preference for ICSE schools compared to the local board having 1.200, 2.370, and 6.669 times in 1-2km, 2-5km and above 5km categories, respectively, with the base category of home-to-school distance below 1km.

Medium of instruction

The majority of the parents choose English as an instruction language rather than a local/regional language; out of 409 observations, 361 (88.3%) parents sending their children to schools of English language instruction, and only 48 (11.7%) parents are sending to the schools of local/regional language instruction. Though the majority prefer English instruction as a major criterion for their children's school, the distance of the school from home and the medium of instruction does not significantly differ ($\chi^2 = 6.789$, $df = 3$, $p\text{-value} = 0.079$).

School management

Nearly two-thirds of the sample represents private schools over public and semi-public together. Public school students decrease as home-to-school distance increases, whereas private school children remain consistent. However, the home-to-school distance over school management is not statistically significant at 95% CI ($\chi^2 = 12.132$, $df = 6$, $p\text{-value} = 0.059$).

Level of education offered by the school

Our sample represents primary school children with 208 members. However, only 83 (40%) were enrolled in schools offering primary education, and the rest, 125 (60%), were enrolled in schools that offer up to elementary and secondary level. Chi-square statistics show the association between home-to-school distance and the level of education offered by the school in school selection ($\chi^2 = 18.043$, $df = 6$, $p\text{-value} < 0.05$). However, the child's education level needs further examination of this significance.

Type of education offered by the school

In the type of schooling, 93% of the sample represents co-education schools, and only 7% represents only girls and only boys schools together. The chi-square statistic is not significant on home-to-school distance and type of school ($\chi^2 = 3.464$, $df = 6$, $p\text{-value} = 0.749$).



Table 4: Correlation among variables.

Variable	Descriptive statistics (frequency)				Pearson Chi-Square analysis		
	Distance of the child's school from home				χ^2	df	Sig.
	< 1 km	1-2 km	2-5 km	> 5 km			
Gender of the Child					0.686	3	0.886
Male	74	51	58	47			
Female	61	43	40	35			
Level of Education of the Child					10.039	3	< 0.05 (0.018)
Primary	82	49	42	35			
High School	53	45	56	47			
Number of Children in the family					21.040	6	< 0.05 (0.002)
1	58	57	70	47			
2	69	32	26	33			
3	8	5	2	2			
Education of the parent					14.991	9	0.091
Did not attend the school	9	3	6	4			
Up to matriculation	17	10	11	8			
Graduate	72	44	50	28			
Above graduation	37	37	31	42			
Occupation of the Parent					1.290	6	0.972
Both are not working	9	6	7	4			
Single parent working	96	68	70	56			
Both are working	30	20	21	22			
Annual income of the family					40.251	9	< 0.001 (0.000)
< 3,00,000	45	27	20	9			
3,00,001 - 6,00,000	52	25	38	24			
6,00,001 - 12,00,000	25	24	33	41			
> 12,00,000	13	18	7	8			
Board of child school					39.256	6	< 0.001 (0.000)
Local / State govt. board	117	72	68	40			
CBSE	13	15	24	30			
ICSE	5	7	6	12			
Medium of instruction					6.789	3	0.079
Regional language	19	16	7	6			
English	116	78	91	76			
Type of management of the school					12.132	6	< 0.05 (0.059)
Public	36	32	21	19			
Semi-public	16	12	12	20			
Private	83	50	65	43			
Education offered by the school					18.043	6	< 0.05 (0.006)
Up to Primary	41	11	13	18			
Up to Upper-Primary	19	22	18	11			
Up to Secondary (High School)	75	61	67	53			
Type of education of the school					3.464	6	0.749
Co-Education	128	85	91	76			
Only Boys	4	7	4	5			
Only Girls	3	2	3	1			
Teaching Methods					3.589	6	0.732
Traditional	52	34	32	22			
Modern / Digital	11	9	8	8			
Combined	72	51	58	52			



3.4 Results of Multinomial Logistic Regression Analysis: (Refer to Table 5)

After identifying the significant predictor variables using Pearson Chi-Square correlation, a multinomial logistic regression model was performed to predict the odds of parental preferences on school selection (dependent variable: the distance of the child's school from home 1 = <1km, 2 = 1-2km, 3 = 2-5km, 4 = above 5km. and independent/predictor variables are the number of school children at home, the child's education level, the family's annual income and the board of education of the child's school). The model was performed using the stepwise method of forward entry.

3.4.1 Model Fitting Information

The model fitness was measured using the likelihood ratio (LR) chi-square test, comparing the model's fitness with the complete set of predictors with an intercept-only, or null, model (no predictors). Based on the LR test, the model containing the complete set of predictors represents a significant improvement in fit relative to a null model (LR $\chi^2(21) = 97.796, P < 0.001$). This result proves at least one population slope is non-zero. The Pearson (0.933) and Deviance (0.851) statistics prove that the model is fit since the P-value is > 0.05 . The Pseudo R-square measures are Cox and Snell (0.289), Nagelkerke (0.310) and Mc Fadden (0.128), which implies a moderately strong model referencing to the odds ratio scale in the results (Bo Hu, et.al., 2006). The model accounts for 20% to 33% of the variance and represents relatively decent-sized effects. The likelihood ratio test provides that the independent or predictor variables, number of school children at home, education level of the child, board of education and family's annual income are significant contributors.

3.5 Predictors of the home-to-school distance

Table 5 shows the predicted statistics of the model concerning the base category as the distance of the school from home is less than 1km. In the 1-2 km category, none of the predictor variables is statistically significant at $p < 0.05$. Only the board of education CBSE & ICSE positively correlates with the dependent category. In contrast, the remaining predictor variables negatively correlate to the home-to-school distance. Similarly, in the 2-5 km category, board of education CBSE & ICSE, number of children and Level of child education are statistically significant at $p < 0.05$ except for the family's annual income. Among them, the child's board of education and education level have a positive correlation, and the number of school children has a negative correlation. Finally, in the category above 5km, the board of education CBSE and education level are statistically significant at $p < 0.05$.

Table 5: Results of Multinomial Logistic Regression.

Variables	B	(S.E)	P - Value	Odds	Ra	95% C.I (Exp . B)
						Lower Upper
Distance of the school from home = 1-2km						
Board of Child's School = Local/State Govt	-	-	-	-	-	-
Board of Child's School = CBSE	0.181	0.499	0.717	1.198	0.451	3.185
Board of Child's School = ICSE	0.182	0.697	0.794	1.200	0.306	4.703
Number of School Children	-0.529	0.237	0.025	0.589	0.370	0.937
Education Level of the Child	0.419	0.279	0.134	1.520	0.879	2.628
Annual income of the family = Below 3,00,000	-	-	-	-	-	-
Annual income of the family = 3,00,001 - 6,00,000	-0.311	0.350	0.374	0.733	0.369	1.454
Annual income of the family = 6,00,001 - 12,00,000	0.412	0.399	0.302	1.510	0.691	3.303
Annual income of the family = Above 12,00,000	0.652	0.560	0.244	1.919	0.641	5.745



Distance of the school from home = 2-5km

Board of Children's School = Local/State Govt	-	-	-	-	-	-
Board of Children's School = CBSE	1.415	0.471	0.003	4.118	1.636	10.366
Board of Children's school = ICSE	0.863	0.726	0.235	2.370	0.571	9.828
Number of School Children	-1.046	0.263	0.000	0.351	0.210	0.589
Education Level of the Child	0.813	0.285	0.004	2.254	1.290	3.938
Annual income of the family = Below 3,00,000	-	-	-	-	-	-
Annual income of the family = 3,00,001 - 6,00,000	0.257	0.358	0.473	1.293	0.641	2.610
Annual income of the family = 6,00,001 - 12,00,000	0.584	0.427	0.171	1.793	0.777	4.140
Annual income of the family = Above 12,00,000	-0.958	0.671	0.154	0.384	0.103	1.431

Distance of the school from home = >5km

Board of Children's School = Local/State Govt	-	-	-	-	-	-
Board of Children's School = CBSE	1.905	0.468	0.000	6.721	2.688	16.804
Board of Child's School = ICSE	1.898	0.671	0.005	6.669	1.789	24.859
Number of School Children	-461	0.268	0.086	0.631	0.373	1.067
Education Level of the Child	0.829	0.310	0.008	2.290	1.247	4.205
Annual income of the family = Below 3,00,000	-	-	-	-	-	-
Annual income of the family = 3,00,001 - 6,00,000	0.589	0.452	0.193	1.803	0.743	4.376
Annual income of the family = 6,00,001 - 12,00,000	1.303	0.497	0.009	3.681	1.390	9.746
Annual income of the family = Above 12,00,000	-0.517	0.703	0.462	0.596	0.150	2.364

-: **Bold** figures are significant at $p < 0.05$

4. Discussion Summary

Many researchers used cross-sectional research design and multinomial logistic analysis to model the school commute distances and mode of commute assessment. In this research, we have used the same methods for investigating parental preferences and analysing how demographic, socio-economic, and school non-spatial attributes are instrumental to home-to-school distance in an urban context in India. Our preliminary results found that many parents send their children to schools outside their neighbourhood, though there is a school facility within their neighbourhood. And it has also shown a significant association between home-to-school distance and the mode of school commute. These findings are similar to previous studies in similar Indian urban contexts (Tetali et al., 2016; N. Singh & Vasudevan, 2018).

As explained in 4.3.1 (Age / Level of the child's education), parents of primary school children prefer schools near home, whereas high school children in our study travelled long distances for schooling. The results correlate with (Easton & Ferrari, 2015) findings, where a child's age/level of education is very consistent and significant in association with home-to-school distance. Regarding a child's gender role, this variable does not directly affect the home-to-school distance in our findings. (Easton & Ferrari, 2015) reported that gender moderated with age could significantly affect the girl's age as the commute distance may increase. We further analysed the influence of the number of children in the family associated with home-to-school distance. In our findings, the number of school-going children in the family negatively correlates with school distance. Families with two or more children send their children to schools within 2km, whereas single-child families' preferences vary with mixed responses. This finding is close to the earlier study by (Ota & Moffatt, 2006) in rural Andhra Pradesh. It talks about opportunities based on family size and birth order, where the younger child in siblings receive privileges over the firstborn and elder children. Such studies were initial and focused on only schooling opportunities, and did not explore any



relation to home-to-school distance. recent times, increased access and opportunities in school education have given numerous opportunities to parents in urban areas for various school choices.

Parents' perceived specific non-spatial attributes define the quality of the school. Previous studies focused on school management, medium of instruction, smaller class sizes, teaching methods, and academic attainments are found to be significant factors in parental preferences (Alsuiadi, 2015). In addition to the above factors, the board of education is crucial in school selection in the Indian context, mainly the social construct over the impression of school boards. Usually, neighbourhood schools are local/state board schools that consist of basic infrastructure and facilities and offer application-based learning. In contrast, CBSE and ICSE are magnet schools with higher infrastructure standards, equipped with facilities, laboratories, and libraries, and offer application-based and problem-solving pedagogy. Such schools are mainly located in suburban areas, and very few are in core urban neighbourhoods since they require a more extensive site area. Such schools are accessible to financially resourced families with better parent education levels in urban areas.

5. Conclusion

The findings of this research study highlight that parents' preferences are instrumental in the non-spatial attributes of the school environments. This study explains how the role of demographic, socio-economic factors and school's non-spatial attributes influences the parents' preferences in school selection concerning home-to-school distance in urban areas. In this regard, the findings from the case of Visakhapatnam show that significant determinants of home-to-school distance are

- Age and the number of school children in the family (demographic),
- family income (socio-economic), and
- attitude toward the board of education and management of the school (non-spatial attributes of the school).

These findings offered a new dimension to rethink the theoretical perspectives that have defined the traditional neighbourhood concepts of Clarence Artur Perry (Aronovici, C. 1939) and (Mumford, 1949), on the importance of school in neighbourhood unit design whilst investigating from a developing country's position. The fact is that cities are ever-changing with their demographic and socio-economic needs. The infrastructure setups for education resources within the urban areas are also drastically changing for the development causes with a competitive spirit. The availability of land resources and affordability have become the open and often latent drivers in the cities. For instance, this study has shown that demographics, socio-economic factors and attitudes toward the school's board of education (non-spatial attributes of the school) have driven parents' preferences in selecting the schools for their children in the case of Visakhapatnam City.

From a methodological position, this study adopted a cross-sectional research design for collecting data and a multinomial logistic model to predict the factors determining the parents' preferences in selecting the schools for their children with respect to home-to-school distance. However, this study has shown a direction for collating and analysing the data on parents' preferences towards school selection. Such models need to be developed from a multi-disciplinary perspective that can assimilate the spatial distribution of such non-spatial parameters in an integrated manner. Nevertheless, this study showed that ongoing and future school revamping schemes are often limited only to the physical and educational aspects of the schools. Instead, it should be a holistic approach scaling from the school setting, creating a sense of neighbourhood unit, and even planning the city transport network.

This study contributes to the existing literature by expanding the theoretical understanding of neighbourhood design, particularly in the context of developing countries. It challenges traditional theories by incorporating the influence of non-spatial attributes of schools and socio-economic factors on parents' preferences, thereby offering a more holistic view of urban educational infrastructure. It highlights the need for policymakers to consider the Integrated Urban Planning and Development policies that integrate educational infrastructure within neighbourhood planning, ensuring accessible schooling options. Socio-economic Support: Implement programs that address the socioeconomic



disparities influencing school selection, such as subsidies or financial aid for lower-income families. Community Engagement: Foster a collaborative approach involving parents in the educational policies and school management decision-making process.

This study acknowledges several limitations: Contextualization of the findings is specific to Visakhapatnam City and may not be generalizable to other urban areas with different socio-economic contexts. The cross-sectional nature of the study limits the ability to observe changes over time in contrast to longitudinal studies. Moreover, the snowball sampling method and self-reported data from parents may affect the results in potential biases.

In conclusion, this study highlights the critical need for a holistic approach to urban planning and school infrastructure development. Policymakers, urban planners, and educators must collaborate to create neighbourhood-level interventions that provide quality education and foster a sense of community. By addressing the demographic, socio-economic, and non-spatial attributes influencing school selection, we can ensure equitable access to education and contribute to the sustainable development of urban areas.

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Conflicts of Interest

The author(s) declare(s) no conflicts of interest.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author, Ram Sateesh Pasupuleti.

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Not applicable.

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Original scientific paper

Investigating the Linkages Between Migration and Image of the City

*¹ Samruddhi Purohit , ² Vaishnavi Shevde , ³ Prof. Dr. Shruti Joshi , ⁴ Prof. Dr. Amruta Garud ,
⁵ Prof. Surbhi Gadkari , ⁶ Prof. Mandar Athavale

¹⁻⁶ Department of Architecture, MKSSS' Dr. Bhanuben Nanavati College of Architecture for Women, India
¹ E-mail: a19104.samruddhip@bnca.ac.in, ² E-mail: a19137.vaishnavis@bnca.ac.in, ³ E-mail: shruti.joshi@bnca.ac.in,
⁴ E-mail: amruta.garud@bnca.ac.in, ⁵ E-mail: surbhi.gadkari@bnca.ac.in, ⁶ E-mail: mandar.athavale@bnca.ac.in

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ABSTRACT



This study explores the complex interplay between migration and the image of the city, with a focus on the Hadapsar-Magarpatta area of Pune, India. Using Kevin Lynch's theoretical framework of urban elements—districts, paths, nodes, landmarks, and edges—combined with Geographic Information System (GIS) analysis, the research investigates how migration reshapes urban form and identity. The study employs a decadal analysis of urban transformation, identifying key changes driven by migration patterns. Findings reveal that migration significantly influences the development of new urban nodes, alters paths, and affects the overall spatial structure, leading to evolving city identities. The influx of migrants is found to enhance the functional complexity of urban districts, impact the hierarchy of nodes, and reconfigure the prominence of paths within the city's spatial organization. This transformation contributes to socio-economic shifts, influencing local economies, labor markets, and resource distribution patterns. The study underscores the importance of integrating migration dynamics into sustainable urban planning, promoting the need for resilient infrastructure and inclusive policies to accommodate demographic changes. This research contributes to urban morphology literature by providing new insights into how migration drives urban transformation, reshaping the image and functionality of cities in a rapidly urbanizing world.

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Highlights:

- Migration drives the evolution of urban districts along the Pune-Solapur Highway, altering Hadapsar's socio-economic landscape.
- Kevin Lynch's framework reveals how migration reshapes urban nodes and paths, affecting city identity.
- Road hierarchy mapping reduces vehicle-pedestrian conflicts, improving urban safety and accessibility.
- GIS analysis offers a novel method for examining migration's impact on urban transformation.
- Migration influences local economies by changing labor markets and resource distribution patterns.

Contribution to the field statement:

This study contributes to urban morphology literature by analyzing the urban transformation of Hadapsar, Pune, through migration dynamics using Kevin Lynch's framework. It reveals how migration reshapes urban form and identity, highlighting new nodes and paths, thereby offering insights into sustainable urban planning and the socio-economic impacts of contemporary urbanization.

*Samruddhi Purohit:

Department of Architecture, MKSSS' Dr. Bhanuben Nanavati College of Architecture for Women, India
Email address: a19104.samruddhip@bnca.ac.in

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1. Introduction

1.1 Background and Context

Cities are complex, dynamic entities that continuously evolve under the influence of social, economic, political, and environmental factors. This evolution shapes the unique image of each city, which emerges as an ever-changing expression of its material and immaterial conditions. As urban populations grow and migration patterns intensify, cities undergo significant transformations in their physical form and socio-cultural identity (United Nations, 2019). Migration, in particular, plays a critical role in shaping urban landscapes, often driving changes in land use, infrastructure, and social dynamics. Human activity is a primary driver of these landscape transformations, making demographic shifts closely linked to changes in the urban environment (Egidi et al., 2021). Globalization has accelerated these changes, leading to uneven development in many countries. Resources tend to concentrate in a few urban centers, exacerbating regional inequalities—an issue more pronounced in the Global South than in the Global North (Hassanzadehkermanshahi et al., 2022). Within this context, migration can reshape the image of the city by altering its spatial, social, and economic landscapes. The intention to migrate and residents' satisfaction levels are crucial indicators for predicting development trends in both expanding and shrinking cities (Fu & Zheng, 2021).

In many cities, especially in the Global South, rapid urbanization has pushed development beyond traditional urban boundaries, creating new peri-urban areas characterized by rapid physical, social, and economic changes (Woltjer, 2014). These dynamics are particularly evident in overpopulated cities where expansion into rural areas transforms the city-countryside relationship, creating a new kind of peri-urbanity (Ticau et al., 2023). Concurrently, the migration of urban residents from city centers to inner suburbs in search of improved living conditions contributes to further urban sprawl (Qin & Deng, n.d.).

Given these transformations, the integration of migrants presents significant challenges. Rapid and poorly managed migration can lead to social fragmentation, resource disparities, and economic inequalities, which undermine societal stability and hinder progress towards sustainable development goals (Zhang & Li, 2024). Shaw's (1975) definition of migration as "the comparatively permanent movement of individuals over a considerable distance" highlights both the spatial and temporal dimensions of this phenomenon. Migrants often settle in peripheral urban areas, addressing labor shortages and mitigating human capital deficits, thereby influencing the socio-economic fabric of their new localities (Kowalewska, 2024).

1.2 Problem Statement and Research Gap

Pune, a rapidly growing city in the state of Maharashtra, India, exemplifies the complex interplay between migration and urban development. Known as the "Oxford of the East" due to its educational institutions, Pune is also one of the largest IT hubs in India. The city offers a combination of economic opportunities, quality infrastructure, and a favorable living environment, making it a magnet for talent and business operations across the country. This concentration of resources has led to rapid population growth, driven by both in-migration from neighboring areas and the internal movement of residents within the city. However, this growth has also exacerbated various urban challenges, including inadequate housing, traffic congestion, pollution, waste management, and the proliferation of informal settlements or slums (Kateja & Jha, 2021; Sorolla Edo, 2014). These issues make it difficult to maintain sustainable urban expansion and resilience in the face of ongoing growth pressures (Garcia-López & Muñiz, 2020). Migration-driven changes are particularly evident in areas like Hadapsar-Magarpatta, where the influx of new residents has reshaped urban form and functionality.

Despite the significant impact of migration on the city's development, there remains a limited understanding of how migration specifically influences the urban image and spatial structure of Pune. While studies have explored various aspects of urban transformation, there is a noticeable gap in research that integrates migration dynamics with urban morphology, particularly using frameworks like Kevin Lynch's urban elements theory combined with Geographic Information System (GIS) analysis. This study



seeks to fill this gap by examining the interplay between migration and the city's evolving image, providing new insights into sustainable urban planning and development.

By focusing on the Hadapsar-Magarpatta area of Pune, this research aims to analyze how migration reshapes urban nodes, paths, and overall spatial organization, influencing the city's identity and socio-economic landscape. Through a decadal analysis of urban transformation, this study offers a novel perspective on the role of migration in urban morphology and contributes to the broader discourse on urban development in rapidly urbanizing contexts.

2. Materials and Methods

2.1 Literature Review

2.1.1 Why People Migrate

People migrate for a multitude of reasons, driven by a combination of push and pull factors. Push factors, such as economic hardship, political instability, social discrimination, and environmental degradation, compel individuals to leave their current locations in search of better opportunities or safer environments. Conversely, pull factors like improved economic prospects, political stability, social acceptance, and favorable living conditions in potential destinations attract people to new areas. These motivations are often intertwined, with individuals weighing the challenges of their current circumstances against the perceived benefits of moving to a new place. Migration is not solely a response to adverse conditions; it is also a proactive choice driven by aspirations for a better life, access to education, healthcare, and social services, or the desire to reunite with family and friends.

The dynamics of migration are complex and influenced by both long-term trends and sudden events. For example, economic downturns, political upheavals, natural disasters, or social conflicts can create immediate pressures for migration. On the other hand, gradual changes, such as economic development in a destination country or demographic shifts, can encourage steady flows of migrants over time. Additionally, migration is often a multi-stage process where initial moves may lead to subsequent migrations as people adjust their strategies based on new experiences and information. Understanding why people migrate requires examining these diverse factors and recognizing the fluid and evolving nature of migration patterns.

2.1.2 Migration Theories and Models

Over the past decades, researchers have developed various theories and models to explain migration. These theories highlight the complex interplay of multiple factors that influence migration decisions. Neoclassical migration theory, based on (Sjaastad, 1962) cost-benefit model and Lee's push-pull model (Lee, 1980) suggests that individuals migrate due to economic discrepancies between their current location and potential destinations. According to this theory, people tend to move if the expected benefits of migrating outweigh the costs. The decision to migrate is often linked to substantial differences in income or utility between places.

While Lee's push-pull model and the augmented gravity model explain overall migration flows relatively well, they have been criticized for not accounting for why the majority of people do not migrate despite significant income disparities. One reason for immobility is that migration decisions are influenced by individual agency and self-determination, rather than being solely driven by economic factors.

Critics of the neoclassical migration model argue that it suffers from methodological individualism, assuming that individuals are the main decision-makers. However, individuals are part of households and communities that influence, or even make, migration decisions. Scholars have therefore urged a reconsideration of migration decision-making, highlighting the role of households and families.

Two perspectives on the role of households have emerged. First, family structure and functions have both direct and indirect effects on migration decision-making, with the individual remaining the decision-maker. Second, the family is seen as the ultimate migration decision-making unit. Families transmit information, shape motivations, and influence migration norms, thereby directly and



indirectly affecting migration decisions. Structural and functional family characteristics also affect perceptions of the costs and benefits associated with migration.

2.1.3 New Economics of Labour Migration

The new economics of labour migration, proposed by (Bloom, 1985) places households at the center of migration decision-making. This theory argues that households can diversify income risks and control uncertainty by allocating members to different income sources, including migration. Family ties, representing social externalities, significantly impact migration decisions. Strong ties to the place of origin can decrease the likelihood of migration, while connections with family and friends elsewhere can provide valuable information that reduces migration-related uncertainty.

2.1.4 Modern Migration Models

More recent migration models combine individual factors with a focus on the family or household. These models consider the temporality, selectivity, and geography of migration drivers. Temporality refers to whether a driver is permanent or transitory. Selectivity acknowledges that broader social, economic, or political transformations affect societal groups differently. Geography considers the location and scope of migration drivers, from local to global levels. Migration is a multifaceted phenomenon driven by a complex interplay of push and pull factors. Economic disparities, political instability, environmental challenges, social inequalities, and lack of services push individuals to migrate, while better economic opportunities, political stability, higher quality of life, social networks, and cultural attractions pull them towards new destinations. Understanding the intricate dynamics of migration requires a holistic approach that considers individual, household, and broader structural factors.

2.1.5 Migration Driver Taxonomy: Driver Dimensions and Driving Factors

The motivations behind migration are varied and complex, influenced by an array of factors that can be both structural and event-driven. (Czaika & de Haas, 2022) categorizes these motivations into different dimensions and factors that drive migration. These include the quality of public infrastructure, educational opportunities, labor market conditions, and the interrelation of migration with spatial policy. Each of these factors can either encourage or deter migration, depending on their specific context and impact.

The impact of public infrastructure on migration is somewhat ambiguous. On one hand, a well-developed and efficient public infrastructure can lower transportation costs, thereby facilitating migration and increasing overall mobility. On the other hand, improved infrastructure can also reduce the propensity to migrate by enhancing local economic opportunities (Gachassin, 2013). For example, educational infrastructure, particularly the quality of higher education, plays a significant role in student mobility. Students are drawn to regions or countries with reputable universities, available scholarships, and manageable living costs (Beine et al., 2012; Findlay & King, 2011). Cities with good universities not only attract students but also retain graduates, partly due to job availability and strong employer-university relationships (Ciriaci, 2014). The lack of educational opportunities in one's home country can drive international migration for students, unaccompanied minors, and asylum seekers (McAuliffe & Ruhs, 2018). However, educational opportunities often rank secondary to factors like security, labor market prospects, and residency or citizenship opportunities (Dimitriadi, 2017). High-skilled migrants, such as health professionals (Awases et al., 2004) and academics, often migrate for professional training and career advancement (Bartolini et al., 2017).

2.1.6 Labour Migration

Labour migration is heavily influenced by economic factors. The neoclassical approach views migration in macroeconomic terms, as a means of redistributing the workforce from low productivity areas to high productivity ones (Lewis, 1954). This perspective sees migration as instrumental in



balancing economic disparities on regional, national, and global scales. At the micro level, neoclassical theory defines migration as the outcome of individual decisions based on a rational assessment of the costs and benefits of moving, aiming to achieve higher returns (Todaro, 1970) (Sjaastad, 1962);. This approach frames migration as an investment in human capital closely tied to labor market conditions. Push factors in the regions of origin, such as unemployment and low incomes, combined with pull factors in the destination areas, like job opportunities and higher wages, underscore the rational decision-making process of migrants (Lee, 1980).

2.1.7 Migration and Spatial Policy Interrelation

Migration patterns are also shaped by spatial policies and the distribution of urban and rural populations. Large-scale changes are occurring as households move away from rural areas plagued by poverty, unemployment, violence, and environmental collapse, towards new localities with better prospects. Survey data from the Development Bank of South Africa (DBSA) indicate that migration is now common among the rural population of South Africa's coastal provinces. Infrastructure development plays a significant role in these migration processes, prompting population movements when previous livelihoods become unsustainable despite the absence of jobs. This highlights the importance of spatial planning and infrastructure delivery in managing migration. Policies must account for population movements to ensure effective public spending, development delivery, and social justice. Infrastructure must be strategically placed to support these movements and ensure cost-effective, sustainable delivery that enhances livelihoods.

Migration flows generally move from overcrowded, economically depressed rural interiors to coastal areas with more economic activity. However, migrants tend to prefer shorter moves that maintain their social capital and support networks. These population flows are substantial enough to reshape rural economies and necessitate new paradigms for high-density rural settlement development. The affordability of infrastructure for these trends poses challenges, especially for smaller towns with deteriorating existing infrastructure. Even relatively prosperous urban centers like Cape Town struggle to accommodate high levels of rural inflow, demonstrating that transferring rural poor to cities does not solve housing and service delivery crises. The rural poor often do not see their future in urban areas, and the government faces challenges in providing housing and infrastructure within budget constraints.

Migration is driven by a multitude of factors that interact in complex ways. Public infrastructure can both facilitate and deter migration, depending on how it impacts local opportunities. Educational opportunities are a major driver for student mobility, but security, labor market prospects, and residency options are often more critical factors. Labour migration is influenced by economic disparities and labor market conditions, with individuals making rational decisions based on expected benefits. Spatial policies and infrastructure development also play crucial roles in shaping migration patterns, particularly in rural areas facing economic and environmental challenges. Effective management of migration requires a comprehensive understanding of these driving factors and strategic planning to support sustainable development and social equity.

2.2 Method

2.2.1 Districts

Figure 1 denotes the Built-Unbuilt Ratio for the city of Pune. A district's physical characteristics include texture, space, form, detail, symbol, building type, use, activity, inhabitants, degree of maintenance and topography. They are elements that define districts as the primary components of large urban areas. Each element contributes to the district's identity and plays a key role in shaping the character of the place; together they create a unique sense of place which is easily identifiable. The spatial patterns that emerge from these elements influence how people move and interact with the district: form (which closely relates

to space) determines the shape while building type and use define function and activity within the area. Figure 2 includes the Building Height Mapping done using QGIS Software.

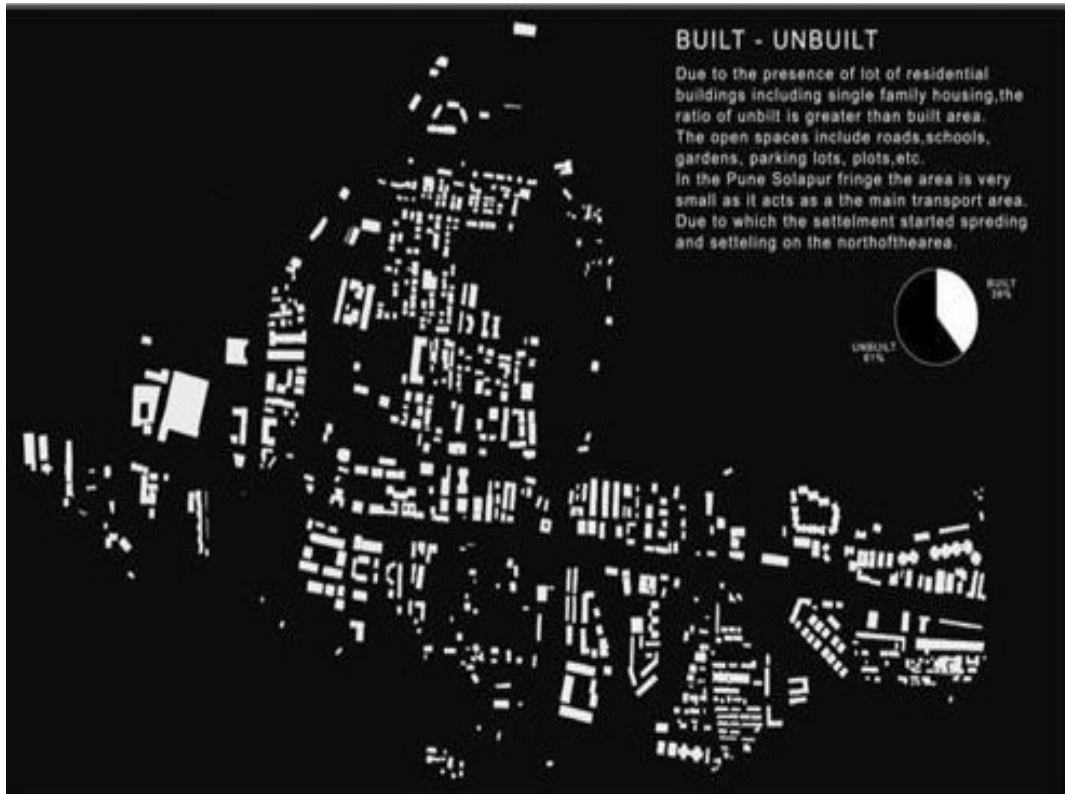


Figure 1. Figure Ground showing Built-Unbuilt Ratio.



Figure 2. Number of floors Mapping on QGIS.

Form is closely related to space; it refers to the shape and configuration of the buildings and structures within the district. It encompasses scale, height, massing of buildings, public spaces' layout and other urban elements that constitute it. Type of building closely relates with functional activity in the district: different types like residential or commercial have different roles which lead them into different patterns of use in the district area. The people living in a district are key players in defining its character— they infuse cultural and social aspects into it which further develop its identity. The population's demography, their ways of life, and cultural rituals that portray the people in the district are what give the place its unique character and dynamics of activities. The degree of maintenance is an indicator showing how well the district is taken care of in terms of keeping the built environment. The upkeep on public spaces plus

buildings besides other urban materials significantly contributes to establishing a safe, friendly, and attractive district. Figure 3 maps the Building Age within the selected District consisting of four spans.

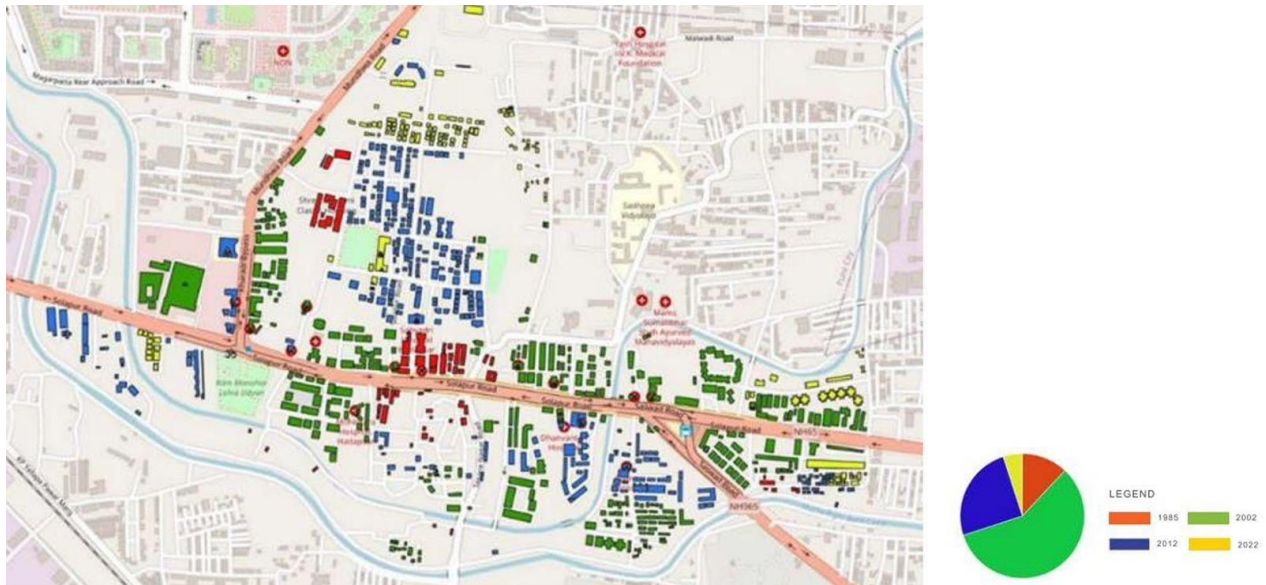


Figure 3. Building Age Mapping on QGIS.

Ultimately, land topography is pivotal in defining physical characteristics for any district including building arrangements intertwined with streetscapes; it also dictates what should be incorporated into the landscape design due to natural features within an area. Districts may have different kinds of boundaries, including hard, definite, and precise boundaries that create clear edges, or soft, uncertain boundaries that gradually fade away into surrounding areas. Some districts may stand alone, while others are connected to each other, creating a complex network of interconnected urban areas. In conclusion, districts are complex and multifaceted urban areas defined by a range of physical characteristics that create a unique and recognizable sense of place. These features are shaped by the built environment, the people who live and work within the district, and the cultural and social practices that define the community. Understanding these elements is essential for creating vibrant and sustainable urban areas that meet the needs of residents and visitors alike.

2.2.2 Path

Paths play a significant role in urban design by influencing how people move through the city and interact with its built environment. As Kevin Lynch suggests, paths are channels along which the observer moves either customarily, occasionally, or potentially. In Hadapsar, certain paths have gained importance due to the concentration of special use or activity along them, which gives them prominence for observers. The development of the IT hub of Magarpatta in Hadapsar has been a driving factor for the area's population growth over the last two decades, leading to changes in the urban environment and the paths people use to move through it. As the population has grown, the paths people take have become more diverse and complex. In some cases, customary travel patterns have emerged along certain paths, while in others, potential paths have been created to accommodate new developments. Figure 4 highlights the identifiable Paths according to Kevin Lynch's theory within the Hadapsar-Magarpatta area.



Figure 4. Paths Mapping on QGIS.

In Hadapsar, paths leading to the IT hub of Magarpatta have become more important due to the concentration of technology-related businesses in the area. Similarly, paths leading to parks, schools, or other amenities can gain increased importance due to their proximity. Paths with clear and well-known origins and destinations tend to have stronger identities. In Hadapsar, paths leading to major landmarks or transportation hubs such as bus stops or train stations tend to have more defined identities, while other paths that lead to more generic destinations may be less well-defined. Overall, the growth of the population in Hadapsar has had a significant impact on the city's paths and urban environment. Figure 5 highlights customary travel paths identified after interviewing the residents of Hadapsar.

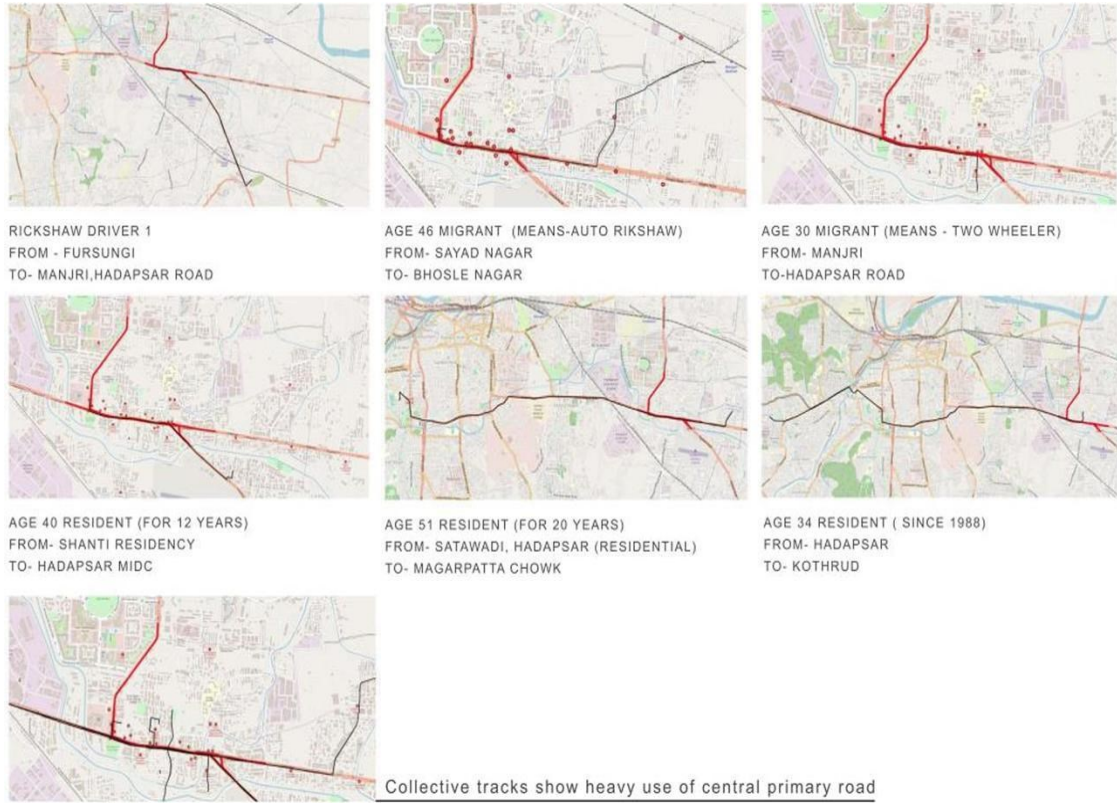


Figure 5. Interviews with Residents regarding paths.

As the city continues to evolve, it will be important for urban designers and planners to consider the role of paths in shaping the city's character and identity, and to ensure that the paths people take are safe, accessible, and well-connected to the rest of the urban fabric. Figure 6 highlights actively used paths by the immigrants of Hadapsar city.



Figure 6. Activity path used by Immigrants.

2.2.3 Nodes

Understanding the hierarchy of nodes and the order in which they occur is important for architects and planners when creating a functional and visually appealing space. Different nodes will have different levels of importance and their design will vary depending on their functions and the density of people using them. For example, bus stops may require a different design than residential or commercial areas. In order to create a space that meets the needs of its users, the type, importance and hierarchy of the nodes were taken into account and their effects on local behaviour and the physical characteristics of the area were determined. Figure 7 highlights identifiable Nodes according to Kevin Lynch's theory within the Hadapsar-Magarpatta area.



Figure 7. Nodes Mapping on QGIS.

To do this, designers need to consider important factors such as mobility and infrastructure, hierarchical and cross-sectional structures, the influence of the surrounding environment, and model work and operation. A variety of tools, including Google Maps and QGIS, as well as interviews and questions with local residents and immigrants of varying ages, can help map and understand walkable and walkable communities. By identifying and analyzing important and unimportant areas and their impact on society, designers can make informed decisions about their design and development. Street classes are an important part of city planning that separates streets according to their functions and capacities. Generally, it divides the road into three classes according to its width: primary, secondary and secondary. Figure 8 highlights changes in local nodes over the time span of the last two decades.

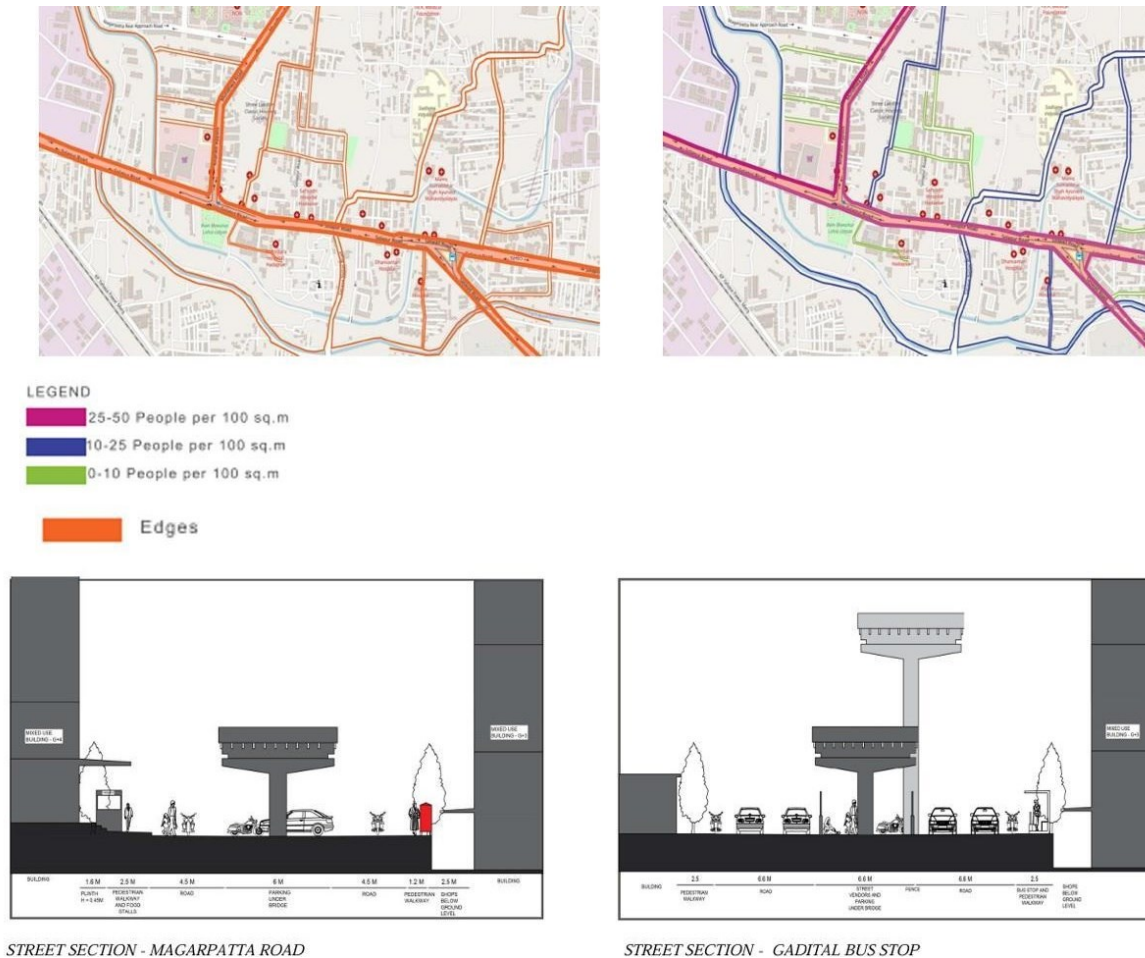


Figure 8. Distinction of Nodes.

2.2.4 Edge

In Hadapsar, the edge can be seen as the riverside and expressway which mark the urban boundary from a macro perspective. From a micro perspective, the edge space refers to the transition space between buildings, and between buildings and roads. Edge space is a crucial component of urban public space as it serves as an intermediate space for various social activities. Over time, the nature of the edges has gradually transitioned due to the upcoming developments and modifications. Magarpatta is a unique project in India, where farmers pooled their land to build a township instead of selling it to a developer. It is located in the eastern part of the city and is characterized by a prominent bus route.

The proximity to businesses in Magarpatta is the main factor driving the expansion of the residential sector. Magarpatta is well known for its IT park and connectivity to other major areas in Pune, such as Kharadi IT Park and Koregaon Park, within a radius of 2 km only. The edges in Magarpatta are characterized by buildings (shops) on the plinth level and a pedestrian walkway with trees, food stalls, and parking on the side. The area under the bridge is also used for parking. Due to the limited space of land and increasing land prices, there are also shops below ground level. Figure 9 denotes the condition of edges according to the number of people using it and in correlation their street sections.



STREET SECTION - MAGARPATTA ROAD

STREET SECTION - GADITAL BUS STOP

Figure 9. Edge Condition Mapping on GIS and Corresponding Street Sections.

2.2.5 Landmarks

Over the past few decades, the area of Hadapsar has undergone significant developments. Before 1985, there were only a few main landmarks in Hadapsar, such as Hadapsar Gaon Tal, Hadapsar Post Office, and Hadapsar Vegetable Market. During this time, religious structures, including Dutta Mandir and Vittal Mandir, were also built. Between 1985 and 2002, new landmarks emerged in the area, such as hospitals, shopping centres, and schools. These landmarks played a vital role in the development of the region and made it more attractive for residents and visitors. This period marked a significant shift in the urbanization of Hadapsar. Between 2002 and 2012, several other significant landmarks were established in Hadapsar, including hospitals, institutes, malls, and the Magarpatta chowk.

The Magarpatta chowk is a bustling area in the locality that is home to several commercial establishments, such as shops and restaurants. In the past ten years, i.e., between 2012 and 2022, there have been further developments in Hadapsar, with the establishment of more hospitals, institutes, and amenity places. These developments have made Hadapsar an attractive destination for both residents and visitors. Overall, the development of Hadapsar has been significant over the past few decades. The area has transformed from a quiet, residential locality to a bustling commercial centre. The establishment of new landmarks has contributed to the growth of the area and has attracted more people to the locality. The timeline of landmark development in Hadapsar reflects the changes and development of the locality over the years. Figure 10 highlights different landmarks which are segregated by the typology of the buildings.

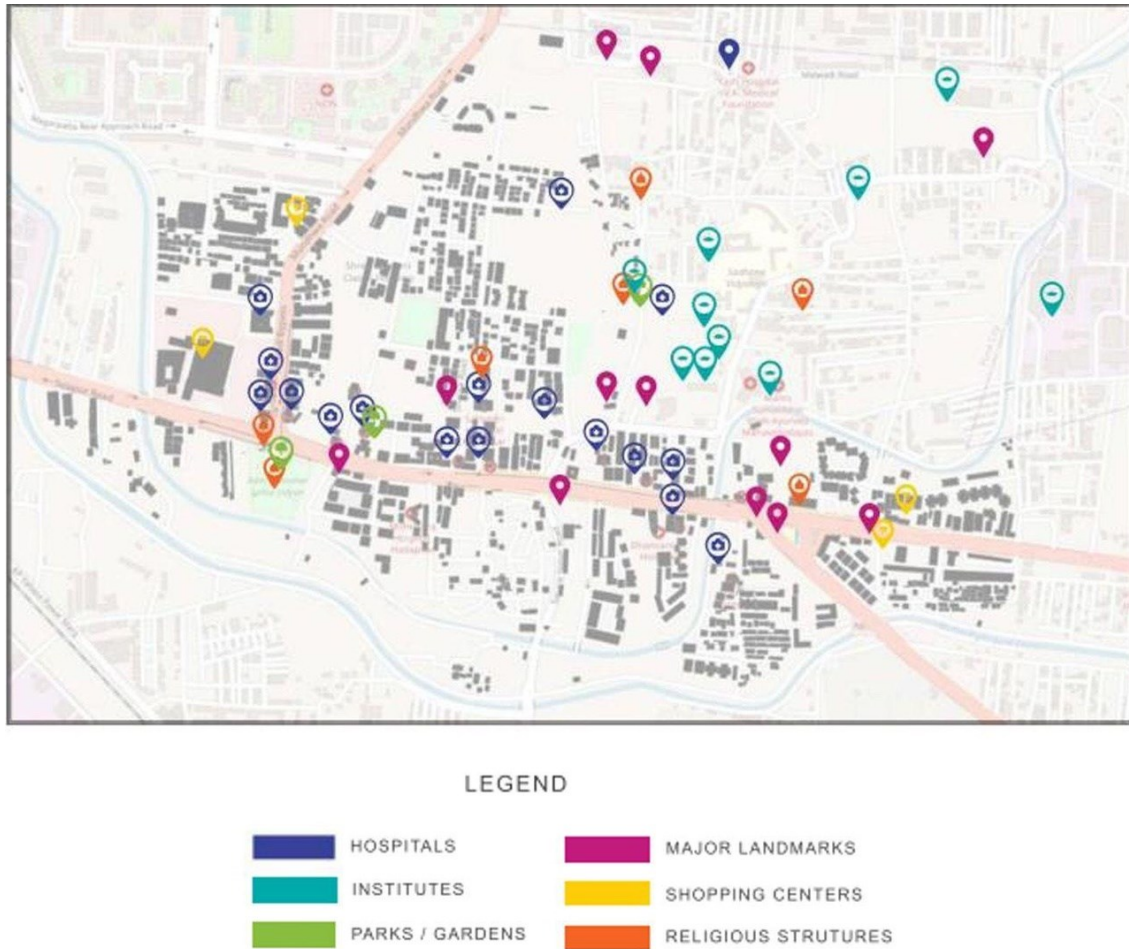


Figure 10. Landmarks Identification and Segregation.

3. Results

3.1 Districts

The Pune-Solapur Road region has undergone significant architectural development over the past few decades. In the 1980s, there was limited development on the outskirts of the road and a surplus of agricultural land away from it. However, since the arrival of IT industries in 2002, there has been intensified settlement on both sides of the road. The construction of Magarpatta city in 2003 acted as a catalyst for the growth of Hadapsar, leading to the emergence of many townships, IT industries, and commercial spaces. This trend has continued, with several proposed residential and commercial developments planned for the future.

The architectural development of the region emphasises sustainability and eco-friendliness, with many new developments incorporating green spaces, solar panels, and other environmentally friendly features. The focus is also on creating vibrant and liveable communities, with new townships featuring parks, recreational facilities, and shopping centres. This creates a sense of community and enhances the quality of life for residents.

The building use plan of the Pune-Solapur Road region includes a mix of residential and commercial structures. Commercial buildings along the main road are designed to be functional and efficient, with multi-story structures, modern facades, and ample parking facilities. They house a range of businesses, from small shops to large corporate offices. Residential buildings are designed to provide comfortable and safe living spaces, ranging from high-rise apartments to spacious bungalows. Landscaped gardens, parks, and other amenities are designed to enhance the quality of life for residents.

The region also includes several amenities, such as educational institutions, hospitals, and health centres. Educational institutions are located among residential settlements, while hospitals and health centres are situated near commercial and residential zones to provide easy access to medical care when needed. The architectural language of the buildings in the region reflects a blend of modernity and functionality, with a focus on creating efficient and comfortable living and working spaces. The buildings along the main road feature sleek, modern facades, while the residential buildings in the interior are designed to be more traditional and comfortable, with spacious balconies and open living spaces. Figure 11 highlights the two different districts identified according to its image.



Figure 11. Difference in development pattern within the identified district.

3.2. Paths

An activity mapping exercise was conducted in Hadapsar to better understand the behaviour patterns of migrants. This exercise involved tracking and locating frequently visited buildings and spaces such as commercial spaces, eateries, and hospitals, which were mainly concentrated along the primary routes. Consequently, these areas experienced heavy traffic and high pedestrian footprints. On the other hand, the secondary and tertiary routes were mostly residential spaces interconnected in smaller groups and accessed through smaller roads and pathways. By understanding the migration pattern of residents and visitors, architects and urban planners can design and plan the city better to accommodate their needs. The heavy influx of migrants in Hadapsar has led to the development of a dense road network, including flyovers and the widening of roads to reduce the increasing vehicular density. However, the lack of a distinguishable road hierarchy and pedestrian paths has created heavy traffic and high pedestrian footprints.

During peak hours, the central road experiences significant traffic congestion, while the flyovers provide parking spaces near commercial spaces, reducing traffic congestion. The higher frequency of permanent and temporary migrants settled nearby has reduced travel distances, resulting in higher use of the main road and causing traffic congestion at the Hadapsar Saswad junction. The visible traffic and pedestrian congestion on the main road is due to the segregation of residential and commercial spaces, leaving emptier branched paths. Figure 12 highlights major and minor paths within the district.

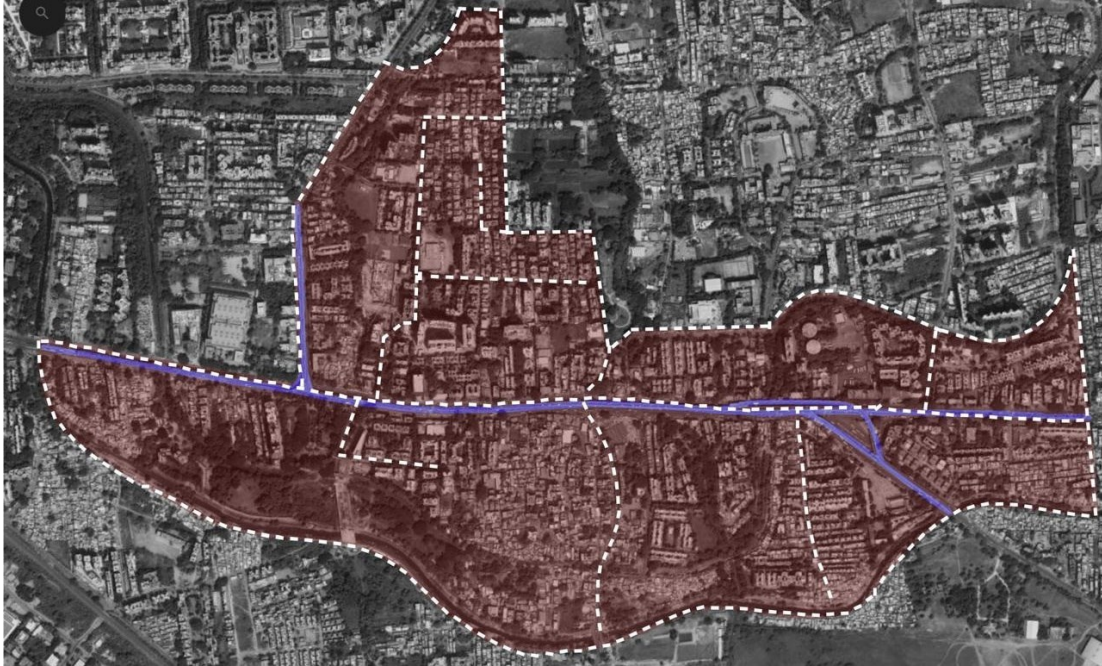


Figure 12. Major and minor paths affecting the district.

3.3. Nodes

During the mapping and analysis of the nodes in the study area, several types of nodal activities were observed. Small public squares and community facilities were identified as vital nodes for pedestrian movement and social interaction. These places provide opportunities for people to meet and interact, contributing to the social fabric of the community. Bus transit junctions and depots were also identified as significant nodes for pedestrian and transit-oriented communities. These nodes allow for easy movement between different parts of the city and provide access to public transportation. As a result, they are essential for improving the overall mobility of the area. Another important nodal activity observed was the Mantri Market, which is a hub for commercial and retail activity. This node attracts people from all over the area and offers a diverse range of goods and services, contributing to the local economy. The combination of community facilities and local vendors is another important nodal activity observed in the study area. These nodes offer a mix of community services and local vendors, including small shops and food stalls. Figure 13 highlights the nodes identified within the studied district.



Figure 13. Nodes identified according to QGIS mapping.

The road hierarchy was observed as a nodal activity for reducing vehicle-pedestrian conflicts. This nodal activity is essential for ensuring the safety of pedestrians and cyclists and improving the overall quality of life in the area. The road hierarchy includes measures such as traffic calming, pedestrian crossings, and bike lanes to encourage non-motorized forms of transportation. The observations made during the mapping of nodes revealed several inferences about the surrounding areas. The streets were found to be dominated by vehicles, indicating that the pedestrian infrastructure is inadequate. The neighboring areas are a mix of commercial, residential, and mainly transit activity, highlighting the need for transit-oriented communities. The population has increased, and as a result, the neighborhood has evolved. This can be seen in the diverse range of activities and facilities available at the nodes. The study also revealed that there has been migration to the area due to inadequate or limited urban services and infrastructure such as healthcare, education, utilities, and transport.

This has resulted in an increase in the population and the need for better facilities and services. The streets were widened to accommodate vehicles, which has negatively impacted the pedestrian movement. The study highlighted the need to reduce vehicle-pedestrian conflicts by redesigning the road hierarchy. Overall, the inferences suggest that the area is in need of better pedestrian infrastructure and transit-oriented communities. The study recommends that urban services and infrastructure be improved to meet the needs of the growing population, and the road hierarchy be redesigned to prioritize pedestrian movement. After studying the nodes in detail, their types were further analyzed, including cross T-junctions, Y-junctions, L-junctions, and four-way junctions. Among these, T-junctions were found to be the most common type on internal roads and near the main road, while L-junctions were the least common. Four-way junctions were identified as playing a crucial role in the minor node category. This information can aid architects and urban planners in understanding the spatial configuration of the area and its potential for future development.

3.4. Edges

Figure 14 highlights the edges developed in the study area according to the landmarks identified.

The population density of edges in this area has been categorized. The edges located along the primary road, from Noble Hospital in the north to Magarpatta Chowk in the south, and from Hadapsar Gadital in the east to Karnabadhvir Vidyalaya in the west, have the highest population density. This is because they have easy access to transportation, major landmarks, infrastructure, and amenities such as bus and rickshaw stands, food stalls, temples, and streetlights. Due to the increased density caused by migration, street vendors can be observed sitting along the edges and under the Inder bridge. As the width and length of roads decrease towards the interior, the density also decreases. The edges along the canal are unoccupied due to the unhygienic environment caused by the disposal of waste by pedestrians.



Figure 14. Edges developed according to the Landmarks identified.

3.5. Landmarks

A study was conducted on the site to classify landmarks based on their function. The major landmarks such as the gadital, vegetable market, post office, and cremation ground create nodes in the area and are considered important landmarks. These landmarks were present in the area before 1985 and have become essential for people to navigate and conduct daily activities. Hospitals and clinics are mostly located on the main roadside, indicating that the area is well-equipped with medical facilities for the residents. Educational institutions, on the other hand, are primarily located along the inner roads, indicating that the area has a good education system in place for the locals. This suggests that the area has a robust educational infrastructure. There are only a few parks located on the main road and one on the internal road, indicating that the area has limited open spaces for recreational activities. This can affect the well-being of the locals. Shopping centers are mostly located on the main road and have developed in the area in the past few years, indicating that the area has experienced commercial development, and the residents have access to shopping centers for their daily needs. Religious buildings such as temples are old structures located in the area before 1985.

These religious buildings serve as important landmarks in the area and contribute to the cultural and religious practices of the locals. In conclusion, the study conducted on the site revealed that the landmarks in the area are primarily focused on meeting the basic needs of the residents, such as medical facilities, educational institutes, and shopping centers. The lack of open spaces for recreational activities and the presence of religious buildings contribute to the cultural and social practices of the locals.



4. Discussion

4.1 Interpretation of Key Findings

Addressing rural infrastructure bottlenecks from the standpoint of migration directs attention to the process by which households move, where they are trying to go and what resources and expectations they have to work with. Migration flows respond rapidly to incentives. Extreme unemployment rates are creating a context of migration to second-best or default incentives where jobs are not available and infrastructure access is pivotal to household migration decisions. At the same time, migration also flows to areas with higher cash incomes and more economic options. Infrastructure delivery promotes the informal sector, carrying potential multiplier effects. Households dismissed or expelled from farms or elsewhere are often forced into the migration stream with only the default option of the nearest farm town. This concentrates on poverty and need around failing small towns. Urban and rural income sources can probably no longer be brought into balance for most of the rural poor: it appears that urban planners can no longer rely on the rural sector to absorb urban unemployment, as rural communities can no longer count on wage work in the urban areas to support families unable to live off the land economy. Migration to advantaged areas or at a minimum to centres that offer access to services and mass transport may not provide an optimum income, but it allows the household to cut its transport costs and its labour time loss so as to put more resources into cash earning.

Planning for spatial development in a context of high migration levels and an unstable population needs to build livelihood priorities actively into delivery, and cannot concentrate narrowly on housing and infrastructure. Migration findings suggest that the infrastructure delivery problematic has two axes: first, how to formulate spatial policy and structure delivery of infrastructure in relation to rural-to-rural migration, and particularly for the dense destination areas; and second, how to look at re-establishing rural/urban linkages through policies that will minimise rural exclusion if not immediately increase access to jobs. An ancillary question is how to increase developmental response from the grass roots, by enlisting the individual mobile household's capacity to invest and to generate income for its own members. Rural exclusion exacerbates both poverty and out-migration. Migration characteristically flows along transport corridors connecting source areas as catchments to destinations, and can be expected to orient quickly toward any areas that begin to receive infrastructure on scale. This approach to spatial policy would move infrastructure delivery out of the reactive category as far as possible. Better rural/urban linkages could reduce the exclusion effect of high urban unemployment on rural migration patterns, by encouraging rural households to maintain urban access and information flows. The social capital needed to overcome rural exclusion is maintained by people travelling back and forth regularly.

The Pune-Solapur Road region has gone through significant architectural development over the past few decades. In 1985, there was limited and scattered development on the outskirts of the road, with agricultural land located away from it. However, the region underwent a transformation in 2002 with the emergence of IT industries, which led to intensified settlements on both sides of the road. The construction of Magarpatta city in 2003 acted as a catalyst for the general growth of Hadapsar, leading to the emergence of a large number of townships, IT industries, and other commercial spaces in the area. The building use plan of the Pune-Solapur Road region reflects a mix of residential and commercial structures, with a focus on creating liveable and vibrant communities. Commercial buildings along the main road are multi-story structures with sleek, modern facades and ample parking facilities. They house a wide range of businesses, from small shops and cafes to large corporate offices and commercial centers. Residential buildings in the area range from high-rise apartments to spacious bungalows, each designed to meet the unique needs and preferences of different residents.

The interior residential settlements are designed to create a sense of community, with landscaped gardens, parks, and other amenities designed to enhance the quality of life for residents. Educational institutions, hospitals, and health centers are also situated in the area, providing easy access to amenities such as education, healthcare, and recreational facilities. The architectural language of the buildings in the area reflects a blend of modernity and functionality, with a focus on creating efficient and comfortable living and working spaces. Buildings along the main road feature sleek, modern facades with ample glass and



metal detailing, while the residential buildings in the interior are designed to be more traditional and comfortable, with spacious balconies and open living spaces.

Due to the heavy influx of migrants, the area has developed a dense road network, with the construction of flyovers and the widening of roads to reduce the increasing vehicular density. The lack of a distinguishable road hierarchy and pedestrian paths has created heavy traffic and high pedestrian footprints, with the central road experiencing significant traffic congestion at peak hours. However, the flyovers provide parking spaces underneath and near commercial spaces, reducing traffic congestion. Understanding the activity patterns of migrants in the area can help architects and urban planners better design and plan the city to accommodate the needs of its residents and visitors.

5. Conclusion

Hadapsar, a suburb in Pune, has undergone significant transformation over the years. In 2003, the settlements primarily ran along the periphery of the Pune-Solapur Road, with very little development of Magarpatta city. The major and a few minor connecting roads were visible throughout the area, with little to no riverside construction. In 2010, the scenario started to change as settlements began to run along and beyond the periphery of the Pune-Solapur Road. Magarpatta city's development progressed to about 60%, and there was a noticeable improvement in connectivity. There was also an increase in built spaces along both sides of the river. However, the area was still predominantly residential, with limited commercial development. In 2022 Hadapsar transformed into a bustling commercial and residential hub, with settlements and commercial spaces consuming most of the available land. The construction of Magarpatta city is now fully proposed with expansion and redevelopment plans. The riverside, which was once devoid of any construction, is now flooded with settlements and commercial development with structured landscaping, and limited agricultural land.

The development of an urban road network is a complex process that is heavily influenced by socio-economic and environmental factors. These factors have varying degrees of impact on different districts, which should be considered during the planning and implementation stages to create a sustainable and equitable urban environment. The development of roads and urban areas are crucial elements in the process of urbanization, as they influence the patterns of growth and level of economic activity. The creation of accessible transportation systems allows for the mobility of people and goods, which in turn encourages development and settlement patterns. In Hadapsar, the presence of major townships like Magarpatta city, with their IT and banking firms, has contributed to the development of the area. These findings of this paper exemplify the excess pressure exerted on urbanised cities due to migration from neighbouring peri-urban areas as a result of contemporary urbanisation.

As Hadapsar developed over the years, urban planners and architects played a crucial role in shaping the area's growth. They designed and implemented plans that focused on improving connectivity, increasing green spaces, and creating better infrastructure to support the growing population. The transformation from a predominantly residential area to a commercial and residential hub was due to the efforts of these planners and architects. The architectural style in Hadapsar has also undergone significant changes over the years. In 2003, the buildings were relatively simple and functional, with little emphasis on aesthetics. However, currently, the area boasts modern, state-of-the-art buildings that feature innovative designs, materials, and technology. The buildings are not just functional but are also visually appealing and sustainable. In conclusion, Hadapsar's transformation over the years is an example of the impact of urbanization on an area's development. With the right vision, planning, and execution, architects and planners can create vibrant, sustainable communities that meet the needs of the growing population while preserving the area's natural resources.

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The author(s) declare(s) no conflicts of interest.

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Original scientific paper

Exploring Commercial Development in Delhi's Mixed-Use Neighbourhoods: An Empirical Study

¹ Puneet Mishra , ² Prof. Dr. Uttam Kumar Roy 

¹ & ² Department of Architecture & Planning, Indian Institute of Technology, Roorkee, India

¹ E-mail: pmishra@ar.iitr.ac.in, ² E-mail: ukroyfap@ar.iitr.ac.in

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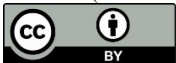
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ABSTRACT



In rapidly urbanizing regions like Delhi, India, mixed-use developments have emerged as vital urban forms, driven by the organic conversion of residential spaces into commercial hubs. This study investigates the dynamics influencing commercial performance in both planned and unplanned mixed-use neighborhoods in North-West Delhi. Employing multiple linear regression analysis on data collected from 213 commercial establishments, the research identifies key factors such as commercial area characteristics, road accessibility, and the proximity of storeowners to their businesses as significant drivers of commercial growth. However, the study reveals that local customer bases are insufficient for sustaining high commercial performance, emphasizing the need for broader catchment areas. The findings contribute to urban planning discourse by providing empirical insights into the economic sustainability of self-organized mixed-use neighbourhoods. The study highlights the complex interplay between commercial development, spatial accessibility, and urban form, offering guidance for future urban planning strategies aimed at enhancing neighbourhood-level commercial performance. These results underline the importance of considering mixed-use dynamics in urban planning to support sustainable commercial growth and community vitality in rapidly evolving urban landscapes.

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Highlights:

- The Study helps in determining critical elements influencing commercial performance in mixed-use neighbourhoods.
- Provides empirical evidence supporting the positive correlation between increased area, job-housing balance, accessibility and increased sales.
- Demonstrates the impact of store owner residency on commercial success and highlights its importance in self-organized mixed-use development.
- It recommends areas where urban planners can focus like optimizing plot size, floor area, and transportation infrastructure for sustainable mixed-use development.

Contribution to the field statement:

This study advances understanding of factors influencing commercial performance of mixed-use neighbourhood by identifying key factors influencing sales, such as store size, employment density, and accessibility. It provides empirical evidence to link economic activity performance with mixed-use characteristics and offers insights for urban planners to understand what drives self-organized mixed-use commercialization in large Indian cities.

*Corresponding Author:

Department of Architecture & Planning, Indian Institute of Technology, Roorkee, India

Email address: ukroyfap@ar.iitr.ac.in

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1. Introduction

Mixed land-use development allows for the coexistence of several land-use uses, including residential, commercial, recreational, and educational uses, and is characterized by enhanced land-use intensity and a variety of functions (Bahadure & Kotharkar, 2015). Over time, it has evolved into a crucial component of many planning and development initiatives, including smart growth, new urbanism, livable communities, conventional neighbourhood development, and transit-oriented development (Kafrawy et al., 2021). As defined in the "The Congress of New Urbanism" charter, compact, pedestrian-friendly, mixed-use neighborhoods have become essential to contemporary urban planning (Song et al., 2013; Zheng et al., 2021). Jane Jacobs (1961) highlighted the importance of mixed neighborhoods as a well-balanced combination of living, working, and service for a vibrant, safe, and secure public space in the city and promoted fine-grain mixing of diverse activities to create livable and vibrant communities (Stiftel, 2004; Jacobs, 1961). The benefits of the urban land-use mix have been studied in several fields, particularly in transportation, public health, and urban economy (Ho et al., 2023; Iannillo & Fasolino, 2021; Mavoia et al., 2018; Song et al., 2013). From a transportation point of view, combining usage near the place of employment lowers the need for travel, and introducing mixed-use development stimulates the rise in walking and cycling and promotes the decrease in the usage of personal automobiles (Bahadure & Kotharkar, 2015; Litman, 2024). In general, mixed-use zones provide a range of services and amenities (jobs, retail, and business opportunities) to the public, resulting in a livelier urban environment with higher density, which in turn forms a larger catchment population to maintain public transportation (Guzman & Gomez Cardona, 2021). From the standpoint of public health, bringing varied locations closer to residential areas promotes active travel modes (Gehrke & Clifton, 2017; Im & Choi, 2019). Lastly, from the perspective of the urban economy, a suitable mix of complementary urban land uses can stimulate higher-density development by supplying urban services and increasing property values (Kang, 2017; Kim & Jin, 2019).

In developing countries like India, urban development has undergone significant transformations, especially in mixed-use development, and has evolved dynamically and intricately in response to local demands and socioeconomic conditions. Thus, distinct from planned, controlled, and zoning-based mixed-use mainly highlighted in international planning paradigms, Indian cities typically show the characteristics of evolved mixed-use patterns resulting from pre-independence and present urban and socio-economic factors. This phenomenon has particularly evolved in response to the inadequacies of early urban planning efforts and the organic growth driven by economic demands. At present, the masterplan approach delineates mixed-use zones under zonal plans and along transit-oriented development corridors, while a distinct variant emerges in residential areas, where businesses are gradually added to the residential property over time (Raman & Roy, 2019). This organic mixed-use development frequently occurs around streets or traffic corridors, driven by the need for local businesses and improved connectivity. This development approach presents issues like increased parking demand, traffic management, and regulation of informal activities, even though it fosters local economic growth and liveliness and requires more exploration.

Going through the previous research, most mixed-use-based studies have broadly focused on two main areas first: measuring the benefits of mixed-use based development and its contribution, especially in the field of transportation, health (increased walkability), and economic benefits like enhanced property or rent value, and secondly: in measuring the spatial mixedness to derive advanced measurement techniques to overcome the limitations presented by different mixed-use measurement indices (Song et al., 2013; Zheng et al., 2021; Zhuo et al., 2019). Carefully going through the available body of research, we have found that there is a lack of empirical research in studying the evolved pattern of mixed-use development resulting from the commercialization of residential areas in developing cities and its contributing factors. Also, while focusing too much on developing spatial techniques and mathematical mixed-use measurement indices, researchers focused on mixed-use development at larger scales, ignoring its complex presence at the neighbourhood level, especially on residential streets, and the factors influencing this commercialization and formation of these self-organized mixed-use streets. "Self-organization" in the

context of urban development refers to a process in which systems independently arrange themselves into structured patterns or behaviors, with less need for outside control. This process involves communities and residents coming together to design and modify their living environments through bottom-up initiatives (Suhartini, 2023).

Therefore, this study tries to focus on two important areas, commercialization and self-organizing patterns in mixed-use neighbourhoods, while first emphasising the reason for their formation, and second presenting the nature of mixed-use neighbourhoods. Advancing this approach we have tried to model commercial performance as the primary driver of expanding commercialization of such streets, given that economic and business interests are the driving forces behind this organic development. While commercial performance and related variables have been studied extensively concerning socioeconomic indicators, retail locations, and transportation factors (Sung, 2022), this study contributes to the existing body of research by exploring how these variables interact in the context of self-organized mixed-use development. We have selected the northwest zone of Delhi due to its high heterogeneity in different types of residential areas with mixed characteristics. We have also used store owner survey data to develop a multiple regression-based model to predict commercial performance and its influencing factors. The novelty of this study can be presented in the following points:

- Presenting a unique approach by measuring economic output at the store level, based on a survey focusing directly on the store owners and/or residents in mixed-use neighbourhoods.
- Following an empirical model development approach to measure commercial performance on mixed-use streets.
- Assessing the effect of different commercial area-based characteristics and network accessibility on it.
- Exploring the interlinkage between perceived and actual benefits of mixedness in terms of neighbourhood-level commercial performance.

The findings from this study provide valuable insights into how commercial performance is influenced by factors such as commercial characteristics, the variety of commercial activities, customer footfall, and the origins of customers within mixed-use neighborhood settings. We discovered that elements like store size, the number of employees, retail activity type, and improved network accessibility have a positive impact on commercial performance. Additionally, our model shows that more mixed-use neighborhoods tend to yield greater economic benefits. However, the study also reveals that well-established mixed-use streets draw customers from beyond the local neighborhood. Overall, these results offer crucial insights for testing mixed-use theories and exploring their connections with concepts like urban containment, job-housing balance, and other perceived economic advantages, as well as for understanding customer footfall patterns to anticipate infrastructure needs in mixed-use neighborhoods.

2. Literature Review

This section is divided into two parts. The first section gives an overview of the relationship between commercialization and urban planning, and the second section discusses the evolution and current state of commercialization of residential areas and the formation of mixed-use neighbourhoods in Delhi.

2.1. Commercialization and Urban Planning

Urban planning and commercial performance are intricately connected, as commercial spaces play a crucial role in shaping urban economies and landscapes. Urban development and planning decisions are significantly influenced by retail businesses' location, the tenants' diversity, and the overall commercial environment. Numerous studies have demonstrated the impact of changes in commercial performance on urban mobility, spatial land-use patterns, and local economic well-being (Glaeser et al., 2001). For instance, Han et al., (2019) emphasize the importance of identifying patterns in the spatial organization of retail outlets within road networks, essential for optimizing store placements and enhancing both commercial performance and urban planning.

The relationship between retail urbanism and urban planning is further elucidated by Barata-Salgueiro & Guimarães (2020), who explain that public policies aimed at sustainability and retail resilience in urban



centres are crucial for strengthening this link. Lowe (2005) underscores the critical connection between commercial growth and urban revitalization initiatives, delving into how shopping activities can drive urban regeneration, thus supporting the argument for mixed-use development. Research by Teller & Elms (2012) highlights the role of commercial clusters in the urban fabric by differentiating between created and evolved commercial agglomerations. Recognizing this distinction is important in the context of self-organized mixed-use streets that have evolved over time. Therefore, this study focuses on exploring various factors that contribute to enhanced commercial performance in residential neighbourhoods.

As this commercialization is oriented along the streets in residential areas rather than being part of an established commercial centre, factors involved in improved commercial performance should also be selected from this perspective. Erkip & Ozuduru, (2015), in examining the evolution of commercial spaces over two decades in Turkey, identified key characteristics of evolved street retailers. These retailers tend to offer more specialized goods and services than shopping malls and provide a variety of other shopping malls and various related products. They also demonstrate adaptability to the diverse needs of consumers by offering personalized services and products, adding diversity through food and restaurants, fostering relationships with residents, and enhancing community engagement. Thus, this study focuses on finding the relationship between the measure of commercial performance and its influencing factors like commercial characteristics, mixedness-based indicators, and spatial accessibility indices.

2.2. Commercialization of Residential Areas in Delhi

The initial master plans, such as the first Delhi Master Plan of 1962, intended to create designated commercial zones like Rajendra Place and Nehru Place. However, these planned commercial centres did not develop as anticipated due to slow economic growth and the lack of localized planning efforts. Consequently, commercial activities organically expanded in areas such as Lajpat Nagar and South Extension, driven by the proximity to residential areas and the local demand for retail and services.

This organic development led to mixed-use areas, which integrated residential, commercial, and transport-based activities, deviating significantly from the master plan's directives. Subsequent master plans in 1990 and 2007 failed to adequately address the evolving urban landscape, resulting in unregulated commercialization within residential zones. The unchecked proliferation of commercial activities prompted concerns from resident welfare associations about parking issues, security threats, and the loss of residential character. With rising conflicts, authorities responded by initiating a sealing campaign in 2006, even though later under the pressure of rising litigations and traders' discontent, the number of such mixed-use streets was regularized. Delhi Master Plan 2021 highlighted the challenges in managing such mixed-use developments. These efforts often prioritized traders' concerns over comprehensive planning strategies, leading to continued conflicts among civic agencies, residents, and traders.

More recently, Raman and Roy's categorization of mixed-use areas based on origin and character provided a framework for understanding these developments. Their classification distinguishes between planned and unplanned, lawful and unlawful origins, and various scales of development, such as plot level and neighbourhood level (Raman & Roy, 2019). Expanding on their work, this study focuses on 'Tonal Mixed Land Use,' where commercialization occurs by adding commercial functions in a residential property which increases plot density and variety, often starting as unlawful but later regularized, significantly impacting the neighbourhood character.



Figure 1. Typical Mixed-use Commercial Street in Delhi's Residential Neighbourhood (Source: the authors).

3. Materials & Methods

This section explains the main research gaps, site selection and data collection techniques, description of different variables and statistical modelling approach used for this study in detail.

3.1. Research Gaps and Research Strategy

By reviewing the available literature and studying the evolution of mixed-use commercial streets in Delhi, we find that this self-organized commercial development and the reasons behind it from an urban planning perspective have largely remained unexplored. Therefore, we hypothesize that the tendency to receive economic gains leads to such commercialization of residential neighbourhoods, converting them into mixed-use neighbourhoods. It is essential to measure the commercial performance of stores located in such areas and to explain different factors and their effect size on these stores' commercial performance. For this study, based on available literature (Kang, 2022; C. D. Kang, 2016; Reigadinha et al., 2017; Sung, 2022), we have decided to study commercial performance based on three main factors: indicators defining commercial characteristics, mixedness based indicators, and transport network accessibility-based measures. The background and relevance of these factors are discussed further in the variable description section. Finally, to study this relationship, we have tried to test three main hypotheses in this study.

- HP-1: Commercial characteristics of these stores have a significant relationship with commercial performance.
- HP-2: Mixedness-based indicators have a significant relationship with commercial performance.
- HP-3: Network accessibility-based indicators have a significant relationship with commercial performance.

This research aims to test these hypotheses and understand the dynamics between commercial performance and the type of commercial development taking place at the neighbourhood level based on specific attributes like the area of the shop, number of people employed, number of customers buying, and types of businesses. Secondly, to understand the formation of self-organized mixed-use street patterns and the knowledge gap between actual performance and perceived benefits derived via theories regarding urban containment and addressing the local commercial demand in the context of mixed-use

neighbourhoods. Third, establishing the impact of road accessibility in the context of vehicular and pedestrian friendliness on commercial performance. In general, the answers to these queries will aid in comprehending how organically evolved mixed-use development interacts with the commercial environment in terms of its performance. Planners can reduce future stakeholder conflicts and successfully manage these areas by using insights about different variables and their level of influence on commercial performance. Key steps and approaches adopted for this study are presented in *Figure 2*.

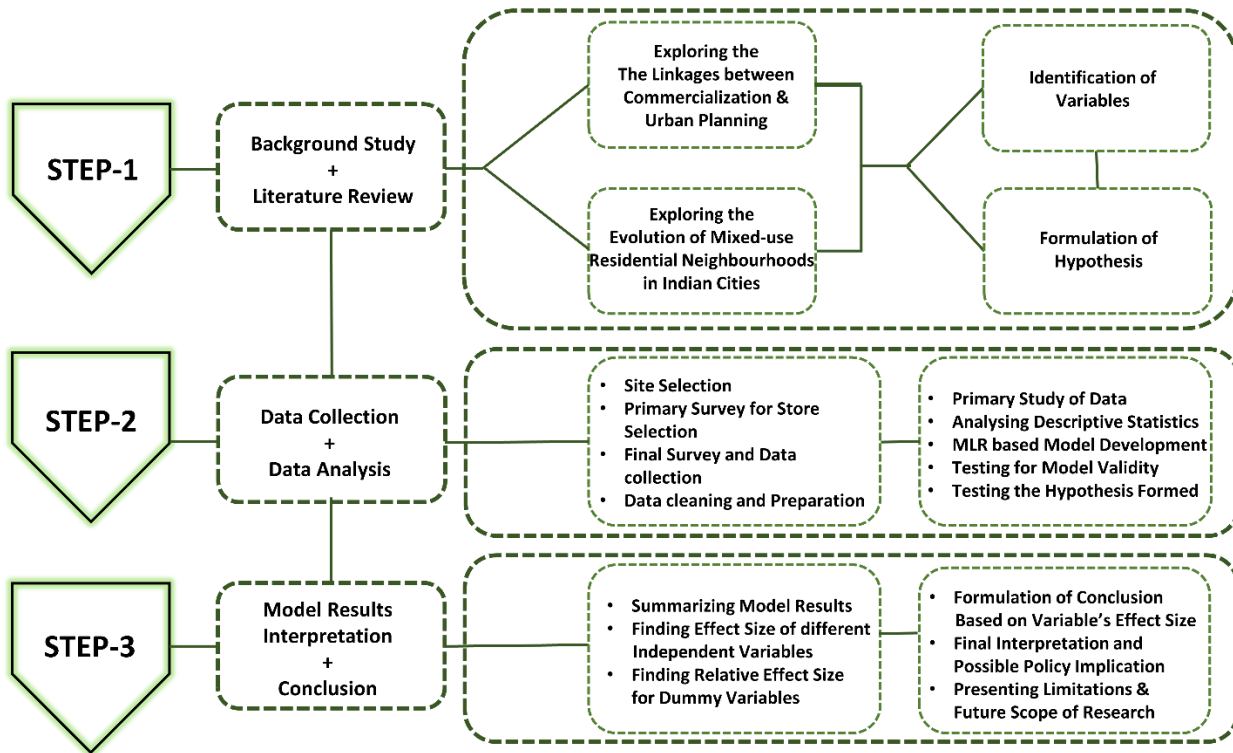


Figure 2. Key Steps for Data Collection, Analysis, and Model Development (Source: The authors).

3.2. Site Selection and Data Collection

Within the national capital region of Delhi, there are fifteen planning zones as per the master plan for Delhi-2021. Zone ‘H, also referred to as Northwest Delhi-I, spans 5677 hectares of land and is primarily characterized by a combination of commercial, institutional, planned industrial, and recreational land uses organized into various hierarchies (Delhi Development Authority, 2007). The neighborhoods are effectively connected to all other major city attractions through an effective road network and Delhi metro service (red line). It comprised urbanized villages, pre-1962 residential and rehabilitation colonies, cooperative housing, resettlement colonies, unlawful regularized colonies, and planned residential (plotted and group housing). This zone was chosen for the study's mixed-use street survey because of its diversity of settlements. Conducting a mixed-use street survey involved first choosing the streets from the list of declared mixed-use streets in zone H's zonal development plan.

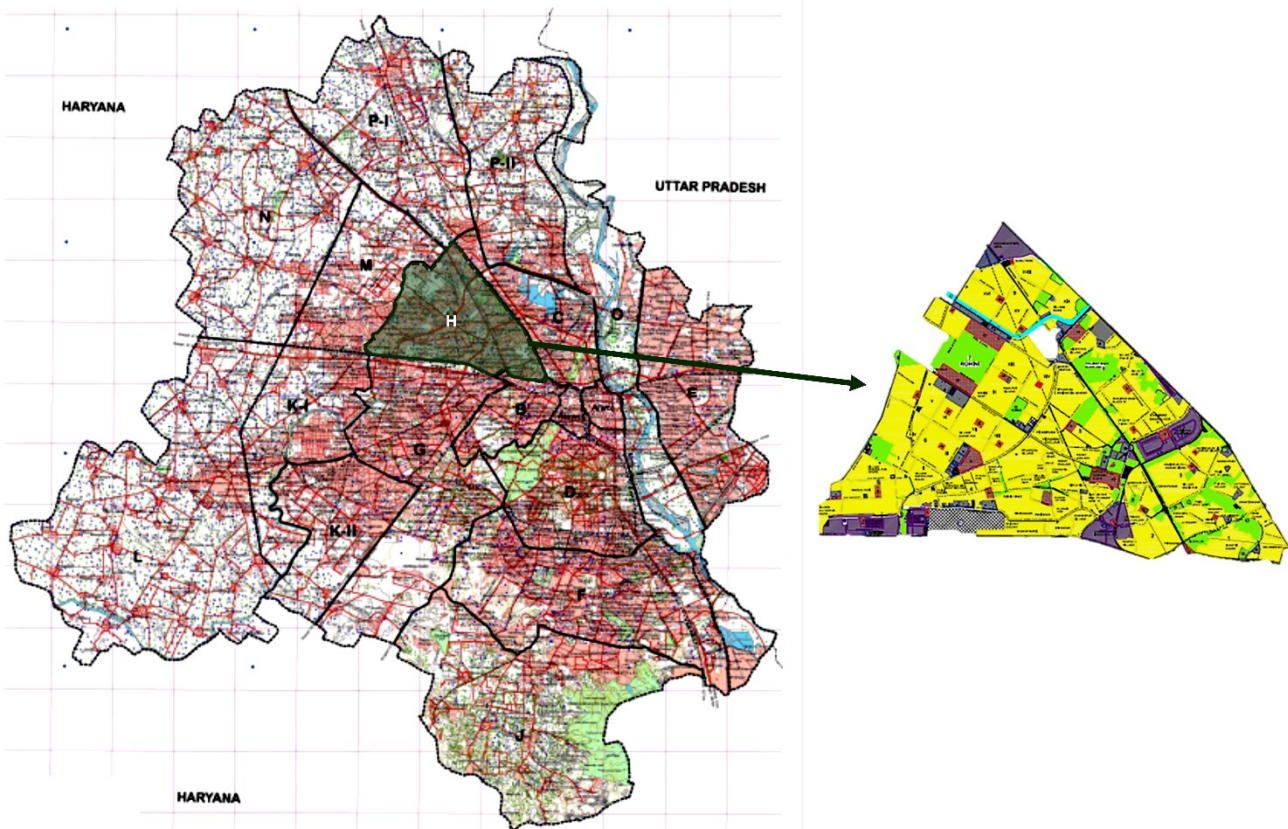


Figure 3. Survey Location Zone-H, Delhi and its Land use with Residential Areas (in Yellow) (Source: Delhi Development Authority).

These streets were carefully chosen to include both planned and unplanned areas to better represent the residential areas' heterogeneity. The zonal development plan categorizes these streets based on the right of way (ROW). Thus, streets representing different road widths were selected, ranging in 9-meter, 13.5-meter, and 18-meter widths. After completing a site assessment, it was discovered that many of the streets regularized by the local authorities are just short stretches or small clusters of commercial stores. As a result, only those streets with a total length of at least 500 meters were chosen for this study. The commercial activities occurring on these streets were analysed using a video recording before the questionnaire survey. This allowed for a better representation of a wider variety of activities, including informal ones, on the finally selected eight streets. Subsequently, a systematic sampling technique was used where the survey started from the street's midpoint. Every 5th store was selected for survey extending in both opposite directions and repeated on both sides of the street. Data was collected in between 25-28 stores from each surveyed street, and 213 samples were gathered using questionnaire surveys, which were further used for statistical analysis.

3.3. Description of Variables

a) Average Sale of a store on a weekday: Several studies have used the sale values of stores to study the relationship between different urban planning and socioeconomic factors with commercialization, customer attraction, and commercial performance (Kang, 2022; C. D. Kang, 2016; Lewison & Hawes, 2015; Perdikaki et al., 2012; Yoshimura et al., 2020). To model commercial performance, average sales on an average weekday are taken as a dependent variable for this study, and several independent predictor variables are employed and explained here. The unit for this variable was set as a sale figure in multiple of 1000 rupees.

3.3.1. Commercial Characteristics-Based Indicators

Several studies have demonstrated how commercial activity characteristics and composition affect local economies, urban mobility, and land-use patterns (C. D. Kang, 2016). Multiple variables are selected to investigate their possible influence on commercial performance and are presented here.

a) *Store Size*: The number of floors designated for commercial activities and the total area determines the size of the store. The extent to which it affects commercial performance might guide the planning decisions such as floor area ratio and built-up area concerns. The unit for this variable was set as the area in square feet.

b) *Number of People Employed*: Studies suggest customer satisfaction and loyalty are directly correlated with the quality of the salesperson-customer contact. Customers' preference for small stores on shopping streets is attributed to the individualized attention they receive from personnel (Medrano et al., 2016). Therefore, the relationship between average sales and the number of store employees is selected for this study. It is also an important variable in assessing the effect of the size of the job-housing balance on the productivity of mixed-use neighbourhoods.

c) *Number of Customers Visiting*: Past research has established that the number of customers visiting shops is a crucial indicator of commercial performance affecting increased sales value. It represents areas like economic vitality, customer engagement, attractiveness & appeal of the product, and social interaction (Philp et al., 2021; Torrens, 2022). Therefore, the number of individuals that visit a store on an average weekday (Categories; 0–25, 26–50, 51–75, 76–100, Above 100) is used as an independent measurable variable for this study.

d) *Product/Service Type*: An important factor in determining the average sales of a specific establishment is the kind of products or services it offers. A site survey was conducted to identify a broad typology of commercial activity along with previous research (Saraiva & Pinho, 2015; Sarma, 2006) and contextualized according to the local conditions. As a result, five main typologies of commercial activities were included.

- Retail (various products and brands offered by the stores)
- Services (medical, personal care, professional services, repair, maintenance etc.)
- Multipurpose (general store/groceries and all-purpose stores etc.)
- Food (restaurants/ eateries and takeaways)
- Others (additional undefined categories)

e) *Informal Activity Linked*: These mixed-use streets are integral to the informal activities that take place there. Demand-driven informal commercial activity aggregation has been seen to occur as sidewalk vendors, transient kiosks, and frequently as an outgrowth of long-term businesses (Roni et al., 2022). The government has recommended a separate vending regulation to properly administer this unstructured but essential industry. Due to their importance, a binary variable is created to study the informal activity taking place. A specific store's average sale relates to the informal activity in front of that store. Data was collected by asking simple Yes/No questions about the existence of informal activity.

3.3.2. Mixedness Based Indicators

Two key metrics are devised and tested to validate the widely accepted advantages of mixed-use areas in theoretical discussions to determine whether a higher degree of shopkeeper association with the business location correlates with increased commercial performance. Additionally, the location-based composition of the visiting customers and its relationship with commercial performance within a specific radius of the neighbourhood are considered. Determining the correlation between the variables can help in offering further insights into the impact of store owners' and customers' location on neighbourhood economics and urban confinement.

a) *Distance to Shop Owner's Residence*: A polychotomous variable is created regarding the distance between the store and the business owner's home. The question of whether they lived within 500 meters, 1000 meters, or further away from the store was posed to the store owners.

b) *Number of Local Customers Based on Distance*: Data is gathered to determine the proportion of customers originating from different areas. The criterion for establishing whether a consumer is local was set at 2000 meters (2 km) based on primary interviews with experts and shop owners. Responses on the

proportion of visitors who are local customers were categorized into five groups: 0–20%, 21–40%, 41–60%, 61–80%, and over 80%. This variable was created to test the assumption that mixed-use zones satisfy local demand and to determine whether stores with higher average sales also attract more local customers.

3.3.3. Network Accessibility Based Indicator

a) *Right-of-way (ROW)*: As a critical measure of accessibility, the right-of-way can impact accessibility by determining the amount of space available for pedestrians, cyclists, and vehicles to move through the area (Dawson, 2004). Measuring its relationship with commercial performance is also important because the basic categorization of regularized mixed-used streets is based on ROW. Therefore, the measurement of surveyed roads right of way in meters is taken as a variable for network accessibility measure.

3.4. Sample Size Calculation and Statistical Model Development

a) *Sample Size*: This study calculated sample size using G*Power software (version 3.1.9.7). An a priori power analysis was performed to ascertain the necessary sample size for the multiple linear regression analysis. The power analysis aimed to establish adequate power for determining a significant effect, with specified significance level, effect size, and number of predictors. A power ($1-\beta$) of .80, a medium effect size ($f^2 = 0.15$), and an alpha level (α) of .05 were the parameters used for the power analysis (Faul et al., 2009). Furthermore, the number of independent variables used as predictors was taken to be 22, including all continuous and categorical variables. These criteria led the G*Power analysis to conclude that 163 would be the minimum sample size needed to detect a medium effect size with adequate power. Thus, to ensure the validity of the statistical analysis, sufficiently more than the minimum requirement, 213 samples were utilized for this study.

b) *Statistical Model Development*: Multiple Linear Regression with a dummy coding-based model is developed. It's a powerful statistical tool to analyse the relationship between a continuous dependent variable and multiple independent variables, including categorical variables (Schinka et al., 2003). Dummy variables are employed to convert categorical data into numerical values that may be utilized in the regression analysis. In this study, 'average sale' is chosen as a dependent variable and a continuous variable, along with many other independent variables that are categorical. The generalized equation for multiple linear regression with dummy variables is presented as:

$$y = b_0 + b_1x_1 + b_2x_2 + \dots + b_nx_n + \varepsilon$$

Where y is the dependent variable (continuous), b_0 is the intercept or constant term, b_1, b_2, \dots, b_n are the regression coefficients for each independent variable, and x_1, x_2, \dots, x_n are the independent variables (including dummy variables), with ε representing error term. Here, each dummy variable is a binary variable with a value of 0 otherwise and 1 if the observation falls into a particular category. The category that a dummy variable does not specifically represent is the reference category. Regression coefficients are used to interpret the results, which show the variation in the dependent variable, after adjusting for all other independent factors, between the reference category and the category represented by the dummy variable. The results-based discussion and implications of the model results are presented in the next sections.

4. Results & Discussion

Data obtained from a survey of 213 businesses was tested by running multiple linear regression analyses in the SPSS statistical package. Descriptive statistics of important categorical variables are presented in *Figure 4 and Figure 5*.

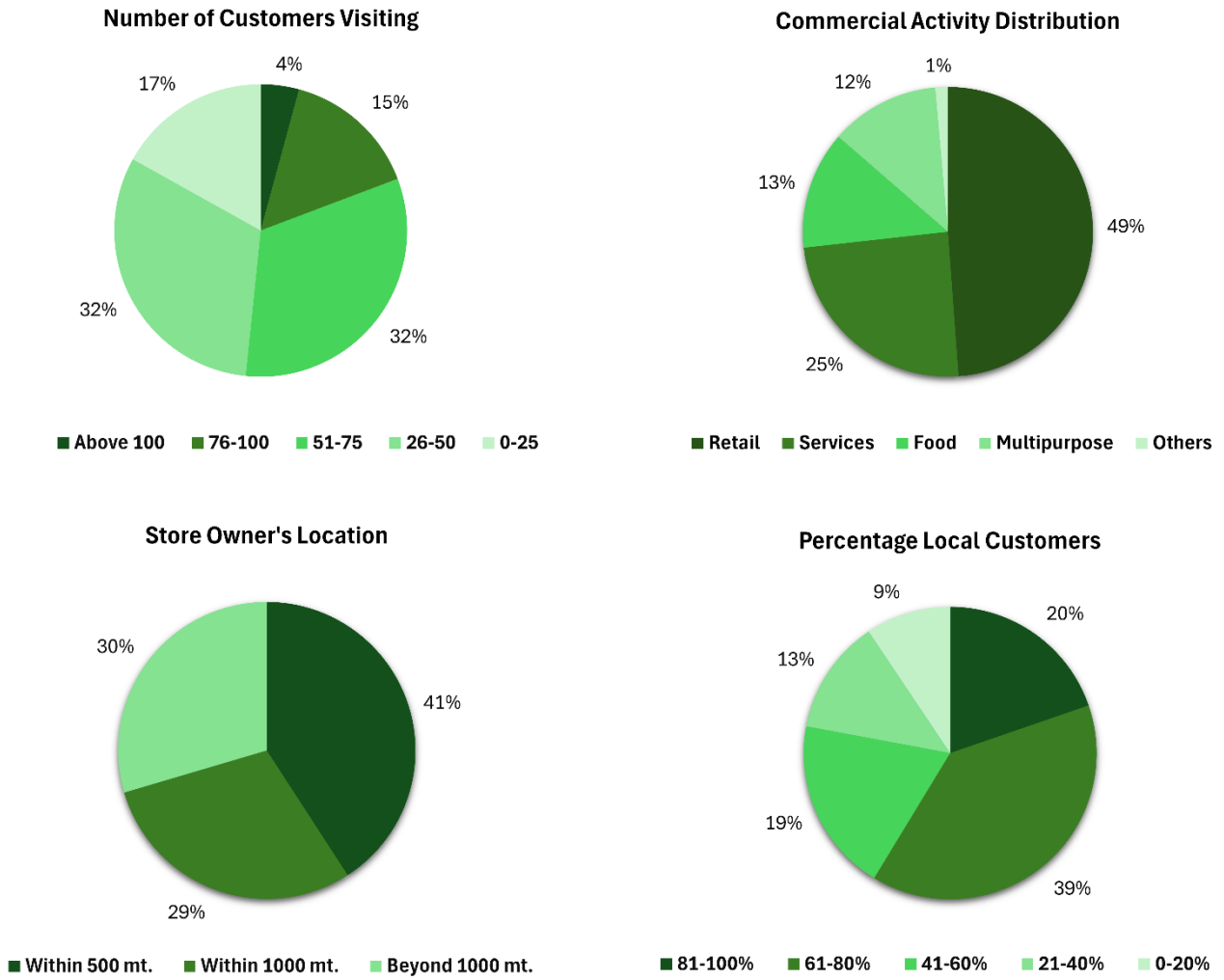


Figure 4. Survey Results for Different Stores (Developed by the authors).

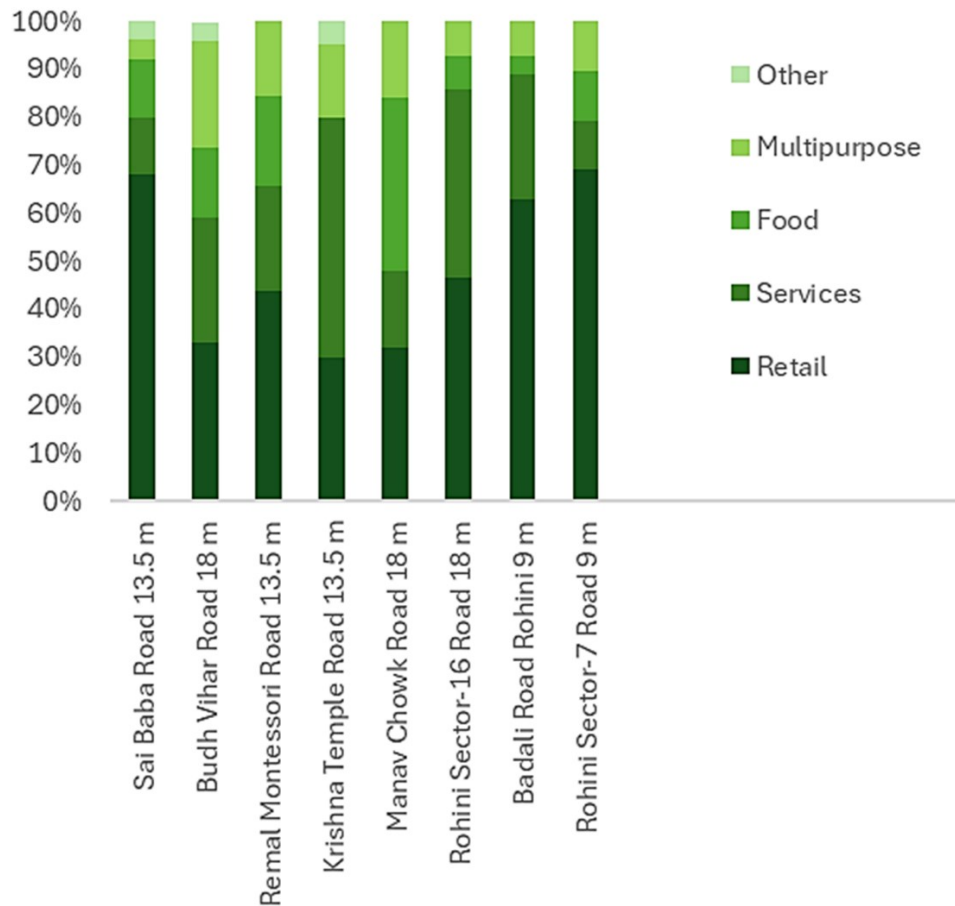


Figure 5. Distribution of Commercial Activity Type on Eight Surveyed Streets (Developed by the authors).

Analysis results are based on the relationship of the dependent variable (average sale of a store on a typical weekday) with several predictor variables, and results based on parameter estimates are explained further.

The analysis incorporates log-transformed values for different continuous variables. Assessing the validity of the model, we found the overall model was statistically significant, $F(19, 190) = 18.046, p < .001$, indicating that the set of independent variables explained a significant portion of the variance in average sales. The model accounted for 64.3% ($R^2 = .643$) of the variance in average sales. After adjusting for the number of predictors in the model, the adjusted R^2 remained substantial at 60.8%, suggesting good explanatory power. In general, VIF values below 5 are considered acceptable; in this analysis, all VIF values are below 3.74, suggesting that the issue of multicollinearity is not present. The model's intercept is significant ($\beta = 1.417, t = 2.298, p = .023$), representing the average sale when all other independent variables are set to zero. Based on these parameters, the internal validity of the model is confirmed before studying the effect size and significance of various predictor variables, which are discussed in detail here.

Table 1: Model Summary.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.802 ^a	0.643	0.608	0.18214

Table 2: Model Coefficients

	Unstandardized Beta	Standard Error	Coefficient Beta	t	Sig.	VIF
(Constant)	1.417	0.617		2.298	0.023*	
Commercial Characteristics Variables						
Log Store Size	0.294	0.063	0.274	4.648	<.001**	1.854
Log Employee	0.589	0.098	0.390	6.004	<.001**	2.246
Customer Visiting= 0-25(Ref.)						
Customer Visiting=26-50	0.056	0.041	0.090	1.391	0.166	2.250
Customer Visiting=51-75	0.144	0.043	0.232	3.318	0.001*	2.613
Customer Visiting=76-100	0.293	0.057	0.363	5.184	<.001**	2.614
Customer Visiting=Above 100	0.340	0.083	0.238	4.124	<.001**	1.768
Activity Type-Others	0.145	0.115	0.059	1.269	0.206	1.171
Activity Type-Multipurpose	-0.138	0.048	-0.156	-2.847	0.005*	1.610
Activity Type- Food	-0.153	0.052	-0.180	-2.948	0.004*	1.982
Activity Type- Services	-0.076	0.037	-0.114	-2.092	0.038*	1.577
Activity Type- Retail (Ref.)						
Informal Activity Linked (Yes)	0.025	0.032	0.041	0.805	0.422	1.403
Mixedness Based Variables						
Shop Owner Living= Beyond 1000mtr. (Ref.)						
Shop Owner Living=500-1000mtr.	0.069	0.036	0.102	1.949	0.053	1.469
Shop Owner Living=Within 500mtr.	0.090	0.034	0.151	2.666	0.008*	1.708
Local Customer=0-20% (Ref.)						
Local Customer=21-40%	-0.081	0.058	-0.091	-1.407	0.161	2.223
Local Customer=41-60%	-0.091	0.053	-0.125	-1.71	0.089	2.827
Local Customer=61-80%	-0.133	0.050	-0.225	-2.68	0.008*	3.739
Local Customer=81-100%	-0.078	0.054	-0.107	-1.431	0.154	2.979
Network Accessibility						
Log ROW	0.511	0.165	0.204	3.102	0.002*	2.31

Dependent Variable= Log Average Sale, (Ref. = Reference category); *Significant at 95% confidence interval, ** Significant at 99% confidence interval

4.1. Effect of Commercial Characteristics-Based Variables

- Store size is an important indicator tested to predict average sales, and the parameter estimate value of ($\beta = .294$, $t = 4.648$, $p < .001$) suggests a positive relationship between the two. This suggests that stores with larger floor areas tend to generate higher average sales as one unit increase in the value of store area is associated with a 0.294 unit increase in the average sale value of the store. These results provide clear evidence that dedicating a larger area to commercial purposes brings more revenue in the form of increased average sales. Thus, these results can be further interpreted in defining the inclination of neighbourhood residents to a covert sizable part of their residential property into a commercial one.
- Several employees also demonstrate a significant positive relationship with the average sale ($\beta = .589$, $t = 6.004$, $p < .001$), indicating that stores with more employees tend to achieve higher average sales and the addition of one worker increases the average sale by 0.589 times. These results are significant in the context of previous studies where better job housing balance in an

area indicates more mix (Litman, 2024). Thereby approving the perceived benefit of mixed-use neighbourhoods that increased job-housing balance relates positively with economic performance and supports the ability of mixed-use in creating self-contained neighbourhoods.

- The Total number of customers visiting a store has shown a generally positive relationship with increased average sales. The reference category with (0-25 visitors) accounts for 17% of total stores. Compared to reference category stores receiving (25-50 visitors) are 32% in number but show a non-significant relationship. However, categories with higher customer footfall, like (51-75 visitors) with 32% share and ($\beta = 0.144$, $t = 3.318$, $p < .05$), (76-100 visitors) with 15% share and ($\beta = 0.293$, $t = 5.184$, $p < .001$) and (above 100 visitors) with 4% share and ($\beta = 0.340$, $t = -2.847$, $p < .05$) show significant and positive association with higher average sales. These results suggest a gradual increase in average sales value with a gradual increase in average sales value with increased customer footfall to these stores. These results confirm the association between sales value and customer footfall, as highlighted by Sung (2022). They can be further utilized to predict the floating population by using customer footfall in these stores. The results hold significance in guiding future policies regarding parking and pedestrian infrastructure demands in these neighbourhoods.
- The effects of various commercial activities on average sales vary category-wise. The reference category used is 'retail' 49.0% of the total surveyed stores, and it has a higher association with average sales among all other categories. Services (25.0%) is the second most common commercial activity taking place on these streets with results ($\beta = -0.076$, $t = -2.092$, $p < .05$), similarly food joints representing 13.0% of total stores, with ($\beta = -0.153$, $t = -2.948$, $p < .05$) and multipurpose stores with total 12% representation of all stores and ($\beta = -0.138$, $t = -2.847$, $p < .05$) show significantly lower association with a high average sale than the reference category 'retail'. These results indicate retail activities are dominant in the composition of commercial activities and are associated with higher commercial performance. Also, studies like C. D. Kang (2016) highlight the tendency of retail, food, and services to align along the streets, attracting higher pedestrian volume to receive higher sales. Thus, our results confirm that major business categories incentivize greater heterogeneity and higher accessibility along the mixed-use streets.
- The model suggests a nominal increase in commercial performance if a particular store indicates that informal activity is taking place in front of that store; however, the results are not statistically significant and need further investigation. However, two-thirds of the stores have registered some kind of informal activities attached in front of their location, contributing to the overall mixedness of the area and increasing pedestrian volume. This spillover effect of informal activities in the context of pedestrian volume, floating population, and overall environment of commercial agglomeration needs to be studied in the future, especially in the context of studies like Kang, (2022), which suggest their positive influence on retail sales.

Overall, these results pertaining to retail characteristics variables confirm the significant relationship between store size, number of employees, and number of visiting customers, store type- retail is an important predictor of average sales of a store. This supports our hypothesis HP-1 and provides a better understanding of the dynamics between commercial performance and type of commercial development at the mixed-use neighbourhood level. However, specific attributes, such as informal activities, must be tested further with larger data sets.

4.2. Effect of Mixedness-Based Variables

- Shop owner residence in locations with categories (Within 1000 meters) and (Within 500 meters) has significant positive associations with average sales ($\beta = .069$, $t = 1.949$, $p = .053$; $\beta = .090$, $t = 2.666$, $p = .008$, respectively) compared to reference category representing stores beyond 1000 meters from storekeepers residence, indicating that stores with shop owners living nearby tend to generate higher average sales compared to the reference category. These results show a strong association between shop-owner's residences and high commercial performance. These results are significant in testing the perceived benefits of mixed-use neighbourhoods (Kang, 2022; Litman,

2024) regarding self-containment and in controlling urban sprawl. It also shows that better job housing balance in a limited area (within 500 meters buffer area) results in higher commercial performance. These results provide strong evidence to support our hypothesis HP-2 and suggest that with the reduction of distance between residential and business places, commercial performance experiences a significant increase.

- The local customers category (0-20%) is the reference category, and 9% of the stores fall in this category. Compared to this, stores receiving 21-40%, 41-60%, 61-80%, and 81-100% local customers show a negative association with average sales. With a statistically significant relationship for category (61-80%) with ($\beta = -.133$, $t = -2.680$, $p < .05$). These results indicate that higher average sale is not positively associated with an increased percentage of local customers. Thus, better sales are associated with receiving a larger customer base from regions well beyond 2000 meters from the store location. These results don't support our hypothesis HP-2 and provide contrary evidence regarding the positive relationship between a higher number of local customers and higher average sales. In light of studies like Kang (2017) and Sung (2022), which highlight the role of the floating population in receiving higher sales, these results need to be explored further to differentiate the impact of local versus distant visitors to these stores' sales.

4.3. Effect of Network Accessibility-Based Variables

- Road width (ROW) based indicator presents a significant positive relationship with the average sale ($\beta = .511$, $t = 3.102$, $p < .05$). These results suggest that a unit increase in the width of the road increases the value of the average sale of a store by 0.51 units. In conformation with past studies like Yoshimura et al.,(2020), and Kang (2022), which highlighted the role of transport accessibility and commercial performance, this study presents strong empirical evidence to confirm our hypothesis HP-3. Residential areas with greater street accessibility are better equipped to receive higher sales in store locations.

These results provide a better understanding of the commercialization of mixed-use neighbourhoods and their influencing factors. Overall, we have found evidence-based findings via empirical modelling to highlight specific attributes which support the hypothesis initially formed for this study. With these results, one can assess the effect size and relative importance of different indicators and carry out further research into specific areas to gain further insights.

5. Conclusion

This study proposes a framework to assess commercial performance in mixed-use neighbourhoods, considering three main factors: retail characteristics, mixedness, and network accessibility. This study focuses on the evolved pattern of mixed-use development and tries to find the contributing factors that result in commercializing residential areas in developing cities. The model provides clear evidence in terms of the positive relation between store size and increased sales, which justifies people's motivation to make incremental changes towards more commercialization of residential units. Similarly, the model shows that the effect of additional employment marks a positive relationship with commercial performance, thus, as highlighted in other studies, the perceived benefit of mixedness in terms of better job-housing balance can be confirmed. The association between customer footfall and its positive relation with sales value can be utilized further to predict the floating population in these neighbourhoods to meet parking pedestrian infrastructure demands and resolve stakeholder conflicts among residents, customers, and traders. Survey results confirm there is strong diversity in terms of the type of commercial activity taking place, retail businesses being the dominant one. It will be interesting to study the role of these specific business activities in attracting pedestrian and customer traffic to these areas in the future to develop planning policies. To understand the tendency of self-organization and incremental increase in commercialization, this study provides clear evidence that storeowners' residential proximity increases the commercial performance of the store, which justifies more residents choosing to commercialize their own property for economic benefits. However, the model result shows significant dependence on customers from distant locations to receive increased sales. Therefore, further studies are required to study



the effect of store types and other factors on customer distribution in these stores to define optimum catchment areas for future mix-use neighbourhood planning. Finally, road network accessibility has proved to be one of the crucial factors in our model. Higher average sale is expected with stores on streets with increased right of way. These results indicate that increased plot size, which is also associated with higher road accessibility, is positively related to commercial performance, and therefore, from a spatial planning point of view, plot size and prescribed floor area guidelines must consider their role in neighbourhood economic sustainability in advance. Future studies about the interrelationship of such developments with associated transit stations must be conducted to further help in planning for TOD-based developments, with mixed-use as one of their policy objectives.

While this study employs a data-driven, statistical modelling-based approach to explore the commercial performance of existing self-organized mixed-use streets, there are certain limitations of our study, like direct survey-based responses might be underreported or overreported by the store owners thus, to ensure the reliability of average sale data other methods like trade-based tax and revenue records and other secondary sources can be adopted. Also, this study was conducted in October, which is considered less harsh and more pleasant from consumers' point of view. However, studies like Badorf & Hoberg, (2020) suggest weather conditions affect daily sales. As accounting for weather conditions was out of scope for this study, we suggest further research in this area to address this limitation. Furthermore, as this model is exploratory, it would be advised to use a larger dataset before making more generalized predictions about commercial performance. Finally, areas like the effect of agglomeration and competitive clustering on commercial performance and other spatio-temporal variables related to mixed-use urban areas must be considered for future studies apart from addressing the limitations mentioned in this study.

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The author(s) declare(s) no conflicts of interest.

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