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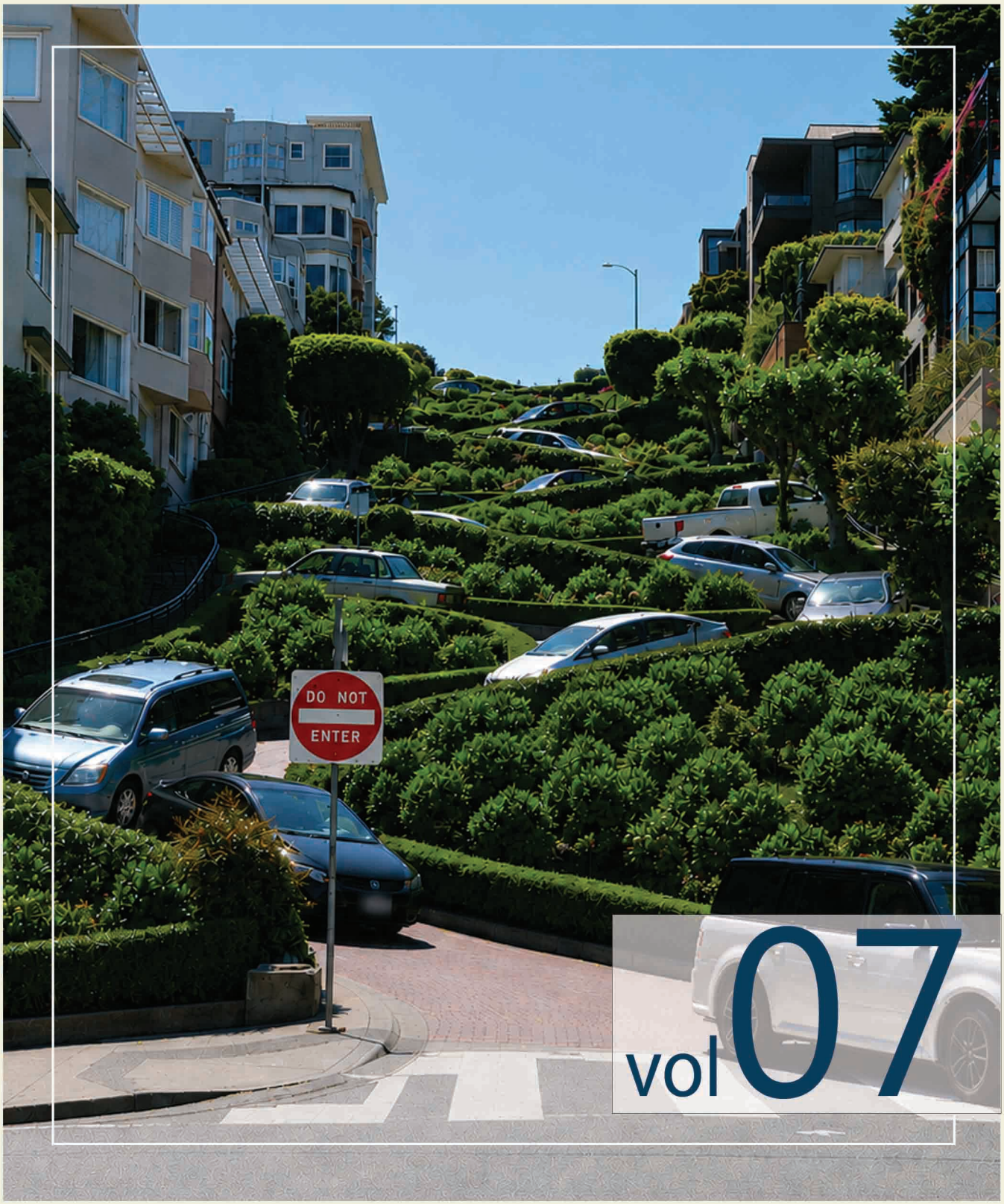

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Editorial

Mehmet Topçu (Editor in Chief)

The Journal of Design for Resilience in Architecture & Planning (DRArch) is pleased to present Volume 7, Issue 2. At a moment when resilience is increasingly invoked across architecture and planning, the contributions gathered here insist on a more exacting question: resilience of what, for whom, at which scale, and through which forms of evidence? Across metropolitan food systems, post-industrial landscapes, coastal settlements, conflict zones, temporary housing, green building certification, heritage sites, public housing, photographic counter-memory, coastal infrastructure, domestic workplaces, building form, and design education, this issue approaches resilience not as a fixed attribute or a simple return to equilibrium, but as the situated capacity to recognize vulnerability, coordinate action, preserve meaning, and revise spatial practices.

The issue opens with “Designing metropolitan food reserve portfolios for urban food resilience: A policy-design case from Surabaya, Indonesia” by Medea Ramadhani Utomo and Yayuk Yuliati. Moving beyond the conventional equation of food reserves with agricultural production or stockholding, the authors reconstruct urban food security as a multi-scalar governance architecture. Their portfolio model connects household provisioning, neighborhood retail, civic redistribution, municipal logistics, market information, and inter-regional procurement, offering a pilotable framework for translating fragmented instruments into coordinated resilience functions.

Questions of urban transformation and the evidence used to evaluate it are then developed in two complementary studies. In “From SEKA to Sekapark: An analysis of post-industrial transformation through measurable spatial indicators,” Aslıhan Uygun and Elif Sağlık combine field observation, archival interpretation, remote sensing, and GIS-based analyses to assess the conversion of the SEKA Paper Factory in İzmit into a cultural, recreational, ecological, and publicly accessible waterfront landscape. The study makes visible both the consolidation of transformation along the waterfront and the unresolved conditions of the former production core.

“A morphological framework for delineating character areas in a coastal town: The case of Görele, Türkiye,” by Beyza Karadeniz and Yelda Aydın Türk, similarly turns spatial differentiation into a basis for planning action. By integrating historical development, environmental structure, built form, land use, and a rural-to-urban transect, the authors show why density measures alone cannot adequately guide context-sensitive development in topographically constrained coastal towns.

The social and political stakes of spatial resilience become particularly urgent in “Reading spatial inequality in Gaza through UNRWA reports: Displacement and urban fragmentation” by Areen Soboh and Bengi Su Ertürkmen. Drawing on situation reports from October 2023 to December 2025, the study translates textual and numerical records into a temporal-spatial reading of displacement, shelter overcrowding, infrastructural damage, service access, and uneven humanitarian assistance. Importantly, it also examines the representational limits of institutional reporting. Resilience here cannot be reduced to recovery language: the article demonstrates how repeated displacement and disrupted services continually reproduce vulnerability and spatial inequality.

The lived consequences of emergency shelter are examined at the scale of the interior in “Interior comfort performance and improvement approaches of temporary housing units in disaster zones” by Esra Avlanmaz Bilecen and Buse Büyükkömürcü. Based on field observations and a survey of 90 residents in the Osmangazi Neighborhood container settlement in İslahiye, Gaziantep, established after the February 6, 2023 earthquakes, the study identifies noise, odor, inadequate air conditioning, spatial restriction, and household size as significant factors shaping comfort. Its human-centered improvement framework reminds us that temporary housing frequently becomes prolonged habitation; speed and quantity therefore cannot substitute for environmental quality, privacy, ergonomics, and everyday dignity.

In “Green building certification systems: An assessment of the city of Izmir,” Duygu Gökce, Onur Tos, and Harika Tos examine LEED- and BREEAM-certified projects across different building functions. For LEED-certified buildings, the findings identify strong performance in energy, water, indoor environmental quality, location, and site-related categories, together with weaker attention to materials and resources. BREEAM records, by contrast, are characterized more by the operational performance of existing buildings, environmental management, energy and water conservation, waste control, and user comfort. The study also points to the limits of publicly available records for assessing the wider spatial and socio-economic distribution of certified development.

Heritage resilience is approached not as the preservation of isolated objects, but as the management of layered relationships. In “Contemporary practices and policies for the conservation and presentation of antique ruins in multi-layered cities: Insights from İzmir,” Beylem Doğa Tabur and Mine Hamamcıoğlu Turan examine the Kadifekale city walls through historical research, fieldwork, comparative cases, and policy analysis. Their proposed framework emphasizes integrated, participatory, and sustainable management capable of making obscured historical layers physically, socially, and intellectually accessible within a changing urban fabric.

The institutional production of urban space is addressed in “Spatial and economic effects of TOKI practices in the context of public housing investments: The Erzincan example” by Banu Tantan and Şevkiye Şence Türk. Examining public housing investments in a non-metropolitan city center through seven spatial and economic variables, the study finds no discernible direct economic impact: in Erzincan, TOKI appears primarily as earthquake, disaster, or social housing practice rather than as a local economic catalyst. Spatially, the picture is mixed. Cooperation with local administrations on inner-city transformation is associated with more planned settlement, while projects outside the center, particularly along the west–northwest development axis, raise concerns about urban integrity, architectural character, and rising infrastructure costs. The article therefore invites a more differentiated evaluation of centralized housing policy, one attentive not only to housing provision but also to location, urban integration, and the restructuring of land and development dynamics.

This concern with visibility and erasure takes a critical visual turn in “Photographic counter-memory as urban resilience: Evaluating Murat Germen’s photographic practice in Istanbul’s urban transformation since 2000” by Sena Özfiliz and İpek Akpınar. Through the cases of Fikirtepe and Bağdat Avenue, the article distinguishes aggressive erasure from aesthetic recoding and interprets photographic practice as a counter-archive. Its contribution lies in clarifying two functions of counter-memory: preserving testimony for future contestation and, where loss remains publicly legible, mobilizing collective recognition. Photography cannot reverse material transformation, but it can sustain the capacity to remember, interpret, and challenge it.

At the infrastructural scale, “Climate-induced flooding and coastal transportation vulnerability: Implications for urban resilience in Izmir, Türkiye,” by Çağla Ercanlı and Ahmet Karakurt, links long-term relative sea-level observations with high-frequency traffic data. The analysis demonstrates that even modest, statistically significant reductions in traffic flow can reveal localized vulnerabilities that broader regional assessments may obscure. The study strengthens the case for corridor-scale evidence in climate adaptation, infrastructure management, and emergency mobility planning.

“Impact of form factor variability on building energy assessment: A computational and empirical analysis for early-stage design” by Mark Alegbe, Hammed Nasiru, John Lekwauwa Kalu, Laurence Chukwuemeka, and Nnamdi Diribe challenges the assumption that compactness automatically improves energy performance. Through parametric form transformation, EnergyPlus simulation, and statistical analysis, the authors show that energy demand in tropical residential contexts emerges from the interaction of morphology, volume, façade exposure, orientation, and climatic response. The article therefore argues for context-sensitive early-stage assessment rather than reliance on a single geometric metric.

Everyday environments provide another important register of resilience. “User satisfaction in home office environments: A comparative analysis of environmental factors by gender and age” by Kemal Yıldırım, Kübra Müezzinoğlu Başpınar, and Pınar Arı demonstrates that satisfaction with remote-working spaces is not homogeneous. Ergonomics, spatial organization, technical equipment, concentration, and perceived flexibility vary across demographic groups, with age emerging as a particularly influential factor. The findings support more inclusive interior design strategies and ergonomic policies for home-based and hybrid work.

The issue concludes with “Sustainability theory and practice in industrial design education: A comparative case study” by Elif Küçüksayraç. Comparing two consecutive semesters of an undergraduate course, the study shows how changes in the time plan and assessment criteria shift student work from ideation toward design development. It also considers the role of international design competitions in strengthening motivation, project quality, and external validation. The article positions sustainability education as an iterative pedagogical design problem in its own right, requiring alignment among theory, process, evaluation, and demonstrable outcomes.

Taken together, the articles in this issue resist a narrow understanding of resilience as durability or recovery. They show that resilient environments depend on measurable performance, but also on governance, accessibility, memory, representation, user experience, and pedagogical capacity. They move across scales without treating them as separate domains: household practices connect to metropolitan systems; interiors

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connect to post-disaster recovery; building form connects to climatic performance; heritage connects to public memory; and data connect to the political question of what becomes visible in planning and design.

As DRArch continues to provide a platform for interdisciplinary and critically engaged research, we invite readers to consider resilience not as a self-evident label, but as a proposition that must be specified, tested, and situated. We extend our sincere gratitude to the authors, reviewers, and all contributors whose careful work made this issue possible. We hope that the studies presented here will support further research, collaboration, and action toward built environments that are not only adaptive and sustainable, but also equitable, meaningful, and accountable.

Best regards...

Following names that provided valuable contribution as referees of articles in this issue are:

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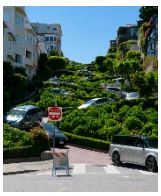

Cover photo: Image copyright ©Mehmet Topçu, (2014). The image on the left is detail "Lombard Street, San Francisco, 2014. A distinctive street characterized by its winding layout adapted to the steep slope, dense landscaping, and surrounding residences."

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DRArch's objectives are:

- to question how future building technologies are revolutionizing architectural design, city planning, urban design, landscape design, industrial design, interior design and education,

- to catalyze the processes that lean on interdisciplinary and collaborative design thinking, creating a resilient thinking culture,

- to improve the quality of built environment through encouraging greater sharing of academicians, analysts and specialists to share their experience and answer for issues in various areas, which distributes top-level work,

- to discover role of the designers and design disciplines -architecture, city planning, urban design, landscape design, industrial design, interior design, education and art in creating building and urban resilience,

- to retrofit the existing urban fabric to produce resilience appears and to support making and using technology within the building arts,

- to discuss academic issue about the digital life and its built-up environments, internet of space, digital in architecture, digital data in design, digital fabrication, software development in architecture, photogrammetry software, information technology in architecture, Archi-Walks, virtual design, cyber space, experiences through simulations, 3D technology in design, robotic construction, digital fabrication, parametric design and architecture, Building Information Management (BIM), extraterrestrial architecture, , artificial intelligence (AI) systems, Energy efficiency in buildings, digitization of human, the digitization of the construction, manufacturing, collaborative design, design integration, the accessibility of mobile devices and sensors, augmented reality apps, and GPS, emerging materials, new constructions techniques,

-to express new technology in architecture and planning for parametric urban design, real estate development and design, parametric smart planning (PSP), more human-centered products, sustainable development, sustainable cities, smart cities, vertical cities, urban morphology, urban aesthetics and townscape, urban structure and form, urban transformation, local and regional identity, design control and guidance, property development, practice and implementation.

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Research Article
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Designing metropolitan food reserve portfolios for urban food resilience: A policy-design case from Surabaya, Indonesia

Medea Ramadhani Utomo*
Yayuk Yuliati**

Abstract

Urban food resilience is often treated as a question of agricultural production, staple stock availability, or emergency food aid. Such interpretations are useful but incomplete for dense metropolitan regions whose food security depends on household coping capacities, neighborhood retail systems, civic redistribution networks, market information, municipal logistics, and inter-regional procurement. This article develops a qualitative policy-design case study of Surabaya, Indonesia, to examine how metropolitan food reserves can be planned beyond conventional stockholding. Using a documentary archive consisting of a 2022 food-reserve focus group discussion report, presentation materials, coordination notes, food-station and food-bank models, local food-security mapping, and urban baseline records, the study codes stakeholder inputs by problem domain, actor mandate, reserve function, spatial scale, and implementation risk. The analysis shows that Surabaya's favorable food-security classification coexists with structural dependence on external supply, limited urban agricultural land, long market chains, food-quality concerns, storage and budget risks, and fragmented reserve governance. Rather than treating sustainable home-food garden areas, women's farmer groups, family welfare and empowerment groups, city food units, food banks, food stations/municipally owned food enterprises, and inter-regional procurement as separate alternatives, the article reconstructs them as a collaborative food reserve portfolio. The contribution is conceptual and policy-design oriented: it reframes urban food reserves as a multi-scalar governance architecture composed of material stocks, social provisioning, surplus redistribution, city-region logistics, rules, data, and emergency capacities. The model is best read as a pilotable planning framework, not as evidence of program impact, and is intended to help planners translate fragmented food-security instruments into coordinated, monitorable resilience functions.

Keywords: city-region food systems, collaborative governance, food reserves, metropolitan planning, urban food resilience

1. Introduction

Food has become a central urban planning question. The issue is not new: planning scholars have long argued that food systems shape land use, distribution infrastructure, public markets, neighbourhood access, waste flows and public health while remaining peripheral to the formal planning field (Pothukuchi & Kaufman, 2000; Satterthwaite et al., 2010; Battersby, 2013; Morgan, 2015). What has changed is the intensity with which food access is now exposed to climate disturbance, price volatility, logistical disruption, public-health emergencies, uneven purchasing power and metropolitan demand growth. Cities concentrate food demand and vulnerability, but they also concentrate institutions, retail networks, waste streams, social assistance mechanisms and public decision-making capacities. Urban food resilience therefore depends not only on food availability, but on how cities organise the conditions under which food remains accessible, affordable, safe and socially legitimate during disturbance (Ericksen, 2008).

In many metropolitan regions, food security is still interpreted through aggregate availability or the existence of public staple stocks. This interpretation is necessary but insufficient. A city may

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appear secure in a composite food-security map while still depending on external supply territories, long distribution chains, weak household purchasing power, poorly coordinated relief systems and avoidable food loss or waste. A sectoral view also produces a false choice among agricultural production, public procurement, food donation, urban farming, retail support and market monitoring. These instruments do not perform the same function. They operate at different spatial scales, involve different institutional carriers and address different kinds of vulnerability. The planning problem is therefore not simply how much food is stored, but how reserve capacity is distributed, activated and governed across households, neighbourhoods, markets, civic organisations and city-regional logistics.

This gap has two consequences for urban planning. First, food reserves are often treated as an emergency-management problem rather than as a spatial-institutional planning issue. Second, aggregate food-security indicators can conceal the uneven ways in which households experience food insecurity. A municipal stock may exist while some groups face weak access, poor information, low trust in distributed food, limited purchasing power or distance from reliable retail channels. Planning must therefore connect reserve capacity with the spatial organisation of markets, communities, storage, transport, digital information and public assistance (Cohen & Garrett, 2010).

The challenge is particularly visible in metropolitan cities of the Global South. These cities are neither self-sufficient food territories nor passive endpoints of national food chains. They are organised through wholesale markets, warehouses, informal retail, digital platforms, public agencies, social assistance, household coping practices and inter-regional procurement. Their food resilience depends on the ability of public, private and civic actors to absorb disturbance, adapt routines and preserve food entitlements under uncertainty (Béné, 2020; Tendall et al., 2015). Recent urban food governance scholarship has moved beyond food as a private consumption matter and has emphasised place, time, relations, diversity and power in the governance of urban food systems (Moragues-Faus et al., 2024).

Surabaya, Indonesia, offers an instrumental case for developing this argument. The documentary archive used in this study records that the city's 2024 food-security mapping classified all 154 urban villages, or kelurahan, as Priority 6, the most favourable local category (Dinas Ketahanan Pangan dan Pertanian Kota Surabaya, 2024). This indicates strong aggregate food-security performance. Yet the same archive describes a metropolitan dilemma: Surabaya is primarily a consuming city, its agricultural land is limited, and much of its food availability depends on producing regions outside the municipal boundary. This is not a contradiction. It is the precise urban planning paradox that aggregate indicators can hide: a city may be food secure in static classification while still requiring a reserve system capable of governing flows, access, price risk and emergency capacities across scales.

The Surabaya archive contains a 2022 focus group discussion (FGD) report, presentation and discussion materials, coordination notes, a food-station note, a food-bank-and-investment-system model, a document on community empowerment for food-reserve strengthening and local food-security mapping records. These materials document stakeholder problem statements from public procurement, market management, economic, cooperative, community and food-rescue actors. They also document proposed instruments such as urban farming, Sustainable Home-Food Garden Areas (KRPL), One Area One Product, household diversification, Women's Farmer Groups (KWT), Family Welfare and Empowerment groups (PKK), City Food Units (UPK), a food bank and a Food Station or municipally owned food enterprise (BUMD Pangan).

This article reconstructs that agenda as a collaborative food reserve portfolio. The term portfolio is used as an analytical concept, not merely as a metaphor. It refers to a multi-layered governance architecture that distributes reserve functions across different spatial scales, institutional carriers, temporalities and risk domains. Unlike conventional reserve models centred on commodity stockholding, the portfolio approach treats reserve capacity as a combination of material buffers, household provisioning, community retail mechanisms, surplus redistribution, market intelligence,

legal rules, financing mechanisms and emergency activation protocols. The research question is: how can a metropolitan food-reserve model be designed as an urban-regional planning portfolio rather than as a single stockholding programme?

The article contributes to urbanism and territorial planning in three ways. First, it reframes food reserves as a planning object composed of stocks, flows, rules, data and socio-institutional capacities. Second, it shows why urban farming, food donation, neighbourhood retail and Food Station mechanisms should be treated as differentiated resilience layers rather than as substitutes for city-region logistics. Third, it translates stakeholder-defined instruments into a pilotable planning architecture with implementation requirements and monitoring indicators. The contribution is analytical rather than impact-evaluative: the article does not claim that the proposed portfolio has already improved food security, but explains how a city can convert fragmented reserve ideas into a coherent, testable urban-regional strategy.

2. From Stockholding to Collaborative Reserve Portfolios

2.1. Urban Food Reserves as Spatial-Institutional Infrastructure

Urban food systems are infrastructures of everyday life, even when they are not formally recognised as infrastructure in statutory planning. Roads, wholesale markets, wet markets, warehouses, retailers, informal vendors, school food systems, social-assistance channels, kitchens, household storage, food banks and waste-recovery networks all mediate food access. Urban planning often regulates some of these spaces indirectly, while food as a system remains fragmented across agencies responsible for agriculture, trade, public works, health, social affairs, cooperatives, emergency response and environmental management. This fragmentation weakens the capacity of cities to anticipate food-related shocks and to link long-term planning with emergency response (Haysom, 2015; Moragues-Faus & Battersby, 2021; Candel, 2014; Sonnino, 2016).

Food-system resilience literature provides a broad but useful vocabulary for this problem. Resilience is not simply the ability to return to a pre-shock condition. In food systems, it refers to the capacity of actors, infrastructures and institutions to maintain sufficient, appropriate and accessible food over time while adapting to disturbance (Tendall et al., 2015). In metropolitan contexts, this capacity is multi-scalar: it includes household coping, neighbourhood access points, city-level price and stock monitoring, and regional supply-chain reliability. Urban planning matters because these capacities have spatial locations, institutional boundaries and resource requirements.

A resilience perspective also changes the meaning of reserve capacity. A reserve is not only a physical stock that waits for a crisis; it is a set of options that can be activated under different conditions. Some options are material, such as stored rice, alternative suppliers, household gardens or refrigerated redistribution. Others are institutional, such as procurement rules, donor agreements, budget procedures, monitoring dashboards and quality standards. Others are social, such as the capacity of women's groups, neighbourhood shops, NGOs and youth organisations to mobilise and coordinate. Urban planning can connect these options because it works at the intersection of space, institutions, infrastructure and public purpose.

2.2. City-Region Food Systems and the Limits of Municipal Self-Sufficiency

The city-region food system approach reinforces this view by treating the city and its surrounding production, distribution and ecological territories as one functional food system (FAO, 2023; Krähmer et al., 2024). From this perspective, the question is not whether a dense metropolitan city can become food self-sufficient within its administrative boundary. The more defensible question is how the city can build redundancy, diversity, equity and adaptability into flows that connect households, neighbourhood institutions, retailers, civic redistribution networks, municipal agencies and inter-regional suppliers.

This territorial interpretation is especially important when food planning is discussed in relation to reserves. A city-region reserve system cannot be reduced to whatever is located inside the city. It depends on procurement routes, supplier diversity, wholesale and retail nodes, market information, storage rotation and the ability to prioritise vulnerable residents when normal market access weakens. The portfolio model developed here therefore treats the administrative boundary as a governance boundary rather than as the boundary of the food system itself (Sonnino et al., 2019).

Urban agriculture must be positioned carefully within this architecture. It can improve food literacy, household coping, community participation and access to some fresh foods, especially when it uses home yards, hydroponics, aquaponics, verticulture and wall gardening. However, systematic reviews caution against overstating urban agriculture as a city-scale supply solution in low-income and land-constrained settings (Poulsen et al., 2015; Zezza & Tasciotti, 2010). Within a metropolitan reserve portfolio, urban farming is therefore best interpreted as a household and neighbourhood resilience layer, not as a substitute for logistics, procurement, warehousing or regional supply coordination.

2.3. Collaborative Governance and Portfolio Thinking

Food surplus redistribution raises a different planning issue. Food banks, food-rescue organizations and near-expiry food redistribution can reduce avoidable food waste while increasing emergency access, but they also require strict attention to safety, traceability, dignity and targeting (Lambie-Mumford, 2013; Papargyropoulou et al., 2014; Schneider, 2013; Tarasuk & Eakin, 2005). In planning terms, surplus redistribution is not merely charity. It is a governed flow of edible resources through donor agreements, sorting spaces, cold-chain decisions, transport routes, beneficiary identification and accountability rules (Mourad, 2016; United Nations Environment Programme, 2024).

Collaborative governance provides the institutional lens. Food resilience cannot be produced by a single agency because food systems connect procurement, markets, social welfare, small enterprises, women's groups, NGOs, hotels, restaurants, street vendors, supermarkets and regional suppliers (Horst, 2017; Vara-Sánchez et al., 2021). Collaborative governance theory emphasizes joint problem definition, shared rules, facilitative leadership, trust-building and iterative monitoring (Ansell & Gash, 2008; Emerson et al., 2012). The Surabaya case extends this logic to food-reserve strategy by asking how different reserve functions can be distributed across actors without pretending that mandate automatically equals capacity.

Portfolio thinking adds a stricter analytical layer to collaborative governance. Collaboration often becomes a general normative term, implying that actors should cooperate because cooperation is desirable. The portfolio approach asks a more demanding set of questions: which actor contributes which function, at which scale, under which rule, with which risk and which indicator? It prevents collaboration from becoming a loose list of stakeholders and prevents a single instrument from being overburdened with expectations (Luger et al., 2025; Manderbach et al., 2025). Refer to Table 1, four principles guide the reconstruction in this article: functional differentiation, scalar distribution, temporal layering and governance accountability.

Table 1 Analytical Principles of a Collaborative Food Reserve Portfolio

Principle	Analytical meaning	Implication for Surabaya
Functional differentiation	Reserve capacity is produced by different functions: provisioning, retail access, redistribution, logistics, information and rule-setting.	KRPL, UPK, food banks and Food Station/BUMD Pangan should not be ranked as substitutes; they should be assigned distinct reserve functions.
Scalar distribution	Reserve functions operate across household, neighbourhood, civic, market, municipal and city-regional scales.	Household gardens and women's groups support coping capacity, while Food Station and procurement mechanisms address city-region flows.

Principle	Analytical meaning	Implication for Surabaya
Temporal layering	Some capacities are routine, some are standby, and some are activated during disruption.	Food literacy and retail bookkeeping are continuous; donor networks and emergency distribution require activation protocols; warehousing and supplier contracts require long-term investment.
Governance accountability	Reserve capacity depends on rules, data, budgets, quality standards, monitoring and responsibility.	The portfolio requires legal clarity, food-safety SOPs, stock-rotation rules, beneficiary targeting and a monitoring dashboard.

Source: Authors' conceptual synthesis based on the documentary archive and urban food governance literature.

3. Methodology

3.1. Research Design and Case Logic

This study uses a qualitative policy-design case approach. It does not claim to be a transcript-based ethnography, survey or quantitative impact evaluation. Instead, it treats FGD reports, coordination notes and technical materials as a documentary archive that records how local actors understood the food-reserve problem and assembled candidate instruments. The analytical task is to reconstruct the implicit planning logic, make the evidence boundary transparent and convert the policy materials into a conceptually coherent urban-regional model (Chambers, 1994).

Surabaya is used as an instrumental case rather than as a statistically representative case. The city combines three features that matter for metropolitan food governance: favourable aggregate food-security classification, limited local production capacity and dependence on regional supply chains. These conditions are common in large cities whose food security depends on city-region flows. The case is valuable not because it proves that one model will work everywhere, but because it clarifies how reserve functions can be distributed across household, community, market, civic and municipal layers. The article therefore offers analytical generalisation rather than statistical generalization.

3.2. Documentary Sources and Evidence Boundary

The analysis draws on an expanded documentary archive supplied by the authors. The archive includes the main FGD report, presentation materials, meeting notes, written suggestions from the facilitation team, a food-station note, a food-bank-and-investment-system model, a document on empowerment for food-reserve strengthening and the local 2024 food-security mapping record. These materials are treated as empirical data rather than as bibliographic literature. Unpublished local institutional documents are therefore described as documentary sources but are not listed in the reference list. The scholarly framing is built from peer-reviewed journal articles and policy-planning literature on urban food governance, food-system resilience, participatory policy design, urban agriculture and food surplus redistribution (Table 2 details the documentary sources and their analytical use).

The study applies a conservative evidentiary strategy. It uses only information present in the supplied documents or in official secondary sources. It does not invent FGD participant numbers, verbatim quotations, survey results, production volumes, food-waste quantities, warehouse capacity, GIS measurements or financial estimates. Where the documents identify a need for such information, the article treats it as a baseline data requirement rather than as an existing finding. This protects the validity of the paper and prevents the policy model from being overstated.

To support international readability, Indonesian acronyms are retained only after functional translation. KRPL refers to Kawasan Rumah Pangan Lestari, rendered as Sustainable Home-Food Garden Areas; KWT refers to *Kelompok Wanita Tani*, rendered as Women's Farmer Groups; PKK

refers to *Pemberdayaan dan Kesejahteraan Keluarga*, rendered as Family Welfare and Empowerment groups; BUMD refers to Badan Usaha Milik Daerah, rendered as a municipally owned or regional-owned enterprise; UPK refers to Unit Pangan Kota, rendered as City Food Unit; PSPK refers to *Pusat Stabilisasi Pangan Kota*, rendered as Urban Food Stabilization Centre. Other local terms are translated by function: RT/RW as neighbourhood associations, PKL as informal street-food vendors, *toko kelontong* as neighbourhood grocery stores, *tabungan pangan* as food-savings accounts and *lumbung pangan* as community food barns or local food granaries.

Table 2 Documentary Sources and Analytical Use

Documentary source	Key information extracted	Analytical use
Main FGD report, 2022	Stakeholder list, proposed models, integrated collaborative food-reserve model and recommended pilot at urban-village scale.	Primary evidence for the original policy design and stakeholder-defined agenda.
FGD presentation and discussion materials, 2022	Reserve functions, strategic steps, participatory appraisal logic, stakeholder analysis, beneficiary assessment and model options.	Reconstruction of method logic and reserve-function categories.
Meeting suggestions, 21 September 2022	Empowerment of PKK/KWT; Food Station as BUMD Pangan; food bank sources from hotels, restaurants, informal vendors, events and near-expiry food.	Strengthening of implementation chronology and institutional design.
Food Station note, 2022	Distribution, sales, warehousing, warehouse receipt, retail services, transport, buffer stock, electronic trade and market information.	Clarification of city logistics and price-stabilisation functions.
Food Bank and Investment System model, 2022	PSPK, Garda Pangan, Bulog, unused food sources, neighbourhood grocery stores, food-savings accounts, processing and emergency distribution.	Clarification of surplus redistribution and community-retail layers.
Coordination notes, 2022	Limited public stock, risk of stored-rice deterioration, budget absorption issues, lack of warehouse, need for baseline data and vulnerability maps.	Identification of implementation risks and baseline data requirements.
Local food-security mapping and urban baseline records	Urban-village-level food-security classification, metropolitan food-system profile and contextual baseline.	Contextual updating and external validation of the case setting.

Source: Authors' reconstruction based on the documentary archive.

3.3. Coding Procedure and Analytical Reconstruction

The analysis proceeded through five steps. First, stakeholder statements and documentary entries were coded by actor and problem domain. Second, each proposed model was reclassified by its primary reserve function: production, diversification, retail saving, surplus redistribution, logistics, market information or governance. Third, the intervention scale of each model was identified as household, neighbourhood, market, civic, municipal or city-regional. Fourth, implementation risks were extracted from the coordination notes and written suggestions. Fifth, the resulting model was interpreted against the literature on food-system resilience, collaborative governance, urban food planning and participatory appraisal.

The coding was deductive-inductive. Deductive categories were derived from food-system resilience and collaborative governance literature, especially the distinction among stocks, flows, institutions, information and adaptive capacities. Inductive codes were generated from the documentary archive, including land limitation, rice dependence, surplus food, food-quality perception, retail saving, stock deterioration, warehouse absence, budget uncertainty and baseline-

data needs. According to Table 3, the final codebook was organized around five dimensions: problem domain, actor mandate, reserve function, spatial scale and implementation risk.

Because the archive does not contain full transcripts, the article does not report individual quotations or attribute personal views. Instead, it reconstructs institutional problem framings and planning functions. This evidence boundary is central to the validity of the article: the findings show how the documentary archive can be organized into a coherent policy-design model, not how individual participants experienced the FGD process.

Table 3 Coding Framework and Evidence-Trace Examples

Coding dimension	Guiding question	Example documentary signal	Analytical output
Problem domain	What vulnerability or constraint is identified?	Limited agricultural land; long market chains; stored-rice deterioration; weak baseline data.	Map of land, access, price, storage, budget, quality, waste and coordination concerns.
Actor mandate	Which institution or community actor is positioned to respond?	Bulog, market agency, economic affairs office, PKK/KWT, Garda Pangan, food-security authority and university facilitators.	Stakeholder-function matrix that distinguishes mandate from capacity.
Reserve function	What kind of reserve capacity does the instrument create?	KRPL as household provisioning; UPK as retail saving; food bank as surplus redistribution; Food Station as logistics and market information.	Classification into provisioning, diversification, retail access, redistribution, logistics and governance.
Spatial scale	Where does the mechanism operate?	Home yards and neighbourhood associations; local shops; city logistics; inter-regional suppliers.	Household, neighbourhood, market, civic, municipal and city-regional layers.
Implementation risk	What could prevent operationalisation?	Food-safety risk, unclear budget rules, warehouse absence, weak bookkeeping, unpaid women's labour, absence of vulnerability map.	Design requirements rather than solved problems.

Source: Authors' reconstruction based on the documentary archive.

3.4. Trustworthiness, Ethics and Permissions

Credibility was strengthened through triangulation across multiple internal documents, official municipal data and peer-reviewed literature. Dependability was addressed by using explicit coding dimensions rather than a loose narrative summary. Confirmability was addressed by distinguishing among documented stakeholder inputs, interpretive reconstruction and policy-design recommendations. Transferability was addressed by presenting Surabaya as a metropolitan case whose relevance lies in external supply dependence and multi-actor governance rather than in a unique local feature.

The documentary archive used in this study does not contain participant-level personal data and the article does not report identifiable individual statements. The analysis reports institutional roles and policy ideas rather than personal views. Because the archive includes unpublished institutional materials, the authors should retain written permission or institutional authorization for the use of these materials in scholarly publication and provide the relevant approval statement according to the target journal's requirements. If full transcripts, interviews or identifiable stakeholder data are added in later revisions, institutional ethics clearance, informed consent, anonymization and data-retention protocols should be reported explicitly.

The GIS component was used as spatial evidence rather than as decorative mapping. The FSVA composite map and the food-provisioning infrastructure map were read together to identify a planning paradox: all urban villages are classified as food secure at the composite level, but several neighbourhoods show weaker ratios of food-provisioning facilities relative to households. This spatial divergence supports the article's argument that reserve planning should move beyond aggregate food-security status and target differentiated household, neighbourhood, market and logistics functions.

Three rules governed this integration. First, quantitative indicators were used only where the source, unit and year were clear. Second, derived indicators, such as estimated rice demand, were explicitly labelled as estimates rather than official food-balance figures. Third, unavailable or incomplete variables, especially city-level warehouse capacity and farmer profit-loss accounts, were treated as data gaps and converted into monitoring requirements for the proposed reserve portfolio.

To address the risk that the documentary reconstruction could appear empirically thin, the revised analysis incorporated official secondary statistics as contextual triangulation. The additional data were used to strengthen the case logic, not to claim program impact. The sources included BPS agricultural statistics, Surabaya Food Security and Vulnerability Atlas (FSVA) maps, Satu Data Surabaya sectoral statistics, municipal price and cheap-market reports, Bulog/SPHP distribution information, and publicly available information on food-related enterprises.

3.5. Secondary Statistical and GIS Evidence

Where official city-level balances were unavailable, the article reports bounded proxy calculations rather than unsupported claims. The rice-demand and local rice-equivalent estimates are therefore presented as NBM-style approximations, while farmer profit-loss accounts, actor-level marketing margins, official commodity balances and facility-level warehouse registers are treated as baseline data requirements for future pilot implementation. This evidentiary boundary is retained throughout the results and discussion sections.

Secondary statistical and GIS-ready evidence was used to strengthen the case logic without changing the study into a quantitative impact evaluation. The analysis incorporated official data on population, rice consumption, paddy harvested area, productivity, paddy production, warehouse capacity, public stock, stabilization program, retail-price observations and sectoral food-system records. These sources were used to contextualize the documentary findings and to test whether the proposed reserve portfolio was consistent with Surabaya's status as a large consuming metropolis.

4. Results

4.1. A Favourable Food-Security Classification with Hidden Systemic Exposure

The first result is a food-security paradox. Surabaya's 2024 food-security mapping classified all 154 urban villages as Priority 6, the most favourable category in the local classification. This suggests strong aggregate performance. However, the FGD materials repeatedly describe Surabaya as a consuming city whose food availability is still obtained from food-producing regions. Resilience therefore cannot be inferred from aggregate classification alone. A city can be food secure in a composite mapping exercise while remaining exposed to inter-regional supply disruption, price volatility, retail bottlenecks and uneven household access.

The archive sharpens this paradox by documenting vulnerabilities that are not captured by a favourable aggregate category. Stakeholders identified shrinking agricultural land, long market chains, underused home yards, low diversification of local food products, limited public understanding of food quality and persistent dependence on rice. Coordination notes further identified limited public stock, possible deterioration of stored rice, weak budget absorption, lack

of warehouse capacity and the need for better baseline data. These points shift the analytical focus from how much food is stored to how reserve capacity is governed through planning institutions.

The distinction is important. The archive does not support an alarmist claim that Surabaya is generally food insecure. It does support a more precise claim: the city's reserve strategy must address vulnerabilities that are not visible in aggregate classification. The question is not whether Surabaya currently lacks food, but whether its reserve governance is robust enough to manage future disruption, price movement, quality concerns and unequal access (As outlined in Table 4).

Table 4 Documented Vulnerabilities and Reserve-Design İmplications

Documented issue	Evidence from the archive	Design implication
Limited local production base	Urban land is increasingly narrow and Surabaya depends on food-producing areas outside the city.	Urban agriculture should be treated as a household-resilience layer, not as a claim of city self-sufficiency.
Long market chain and price risk	Stakeholders noted potential price increases due to excessive market-chain length.	Food Station/BUMD Pangan should coordinate suppliers, market data, distribution and price responsiveness.
Food-quality and targeting concerns	Market actors noted public perceptions of poor-quality distributed rice and the need for better targeting.	Reserve governance needs quality assurance, communication and beneficiary targeting.
Storage and budget risk	Coordination notes mention limited stock, deteriorating stored rice, contingency-budget logic and lack of warehouse.	The reserve strategy needs stock rotation, procurement rules, legal clarity and financing design.
Avoidable surplus food	Food-bank materials identify hotels, restaurants, informal vendors, community events, supermarkets and near-expiry food as potential sources.	Surplus redistribution should be incorporated with food-safety SOPs, traceability and dignity-based targeting.
Missing baseline data	Coordination notes list needs for data on business actors, production capacity, land, enterprise types and vulnerability maps.	Pilot implementation must begin with baseline mapping before scaling.

Source: Authors' reconstruction based on the documentary archive.

4.2. Stakeholder Problem Framings and Governance Functions

The stakeholder materials show that the food-reserve issue was understood differently by different actor groups. Bulog, Indonesia's public logistics agency, emphasized shrinking agricultural land, coverage of vulnerable areas, non-rice alternatives, subsidised access and the risk of staple-stock deterioration. Market-management actors focused on public perceptions of rice quality, education about food suitability and accurate targeting. Economic and cooperative actors emphasized household production, diversification, price monitoring, warehousing, supply-chain shortening and local retail. Garda Pangan and related civic actors highlighted edible surplus, near-expiry food, platform-based redistribution, frozen-food potential and collaboration with youth organizations, small shops and community groups.

This diversity of problem framing is analytically valuable. Actors were not merely proposing separate projects; they were diagnosing different parts of the metropolitan food system. Procurement actors saw the risk of staple availability and subsidy. Market actors saw problems of trust, quality and targeting. Community actors saw household capacity and diversification. Civic food-rescue actors saw surplus and redistribution. Economic and cooperative actors saw retail, warehousing and local enterprise. A planning portfolio becomes necessary precisely because these diagnoses cannot be merged into one instrument without losing their functional specificity.

Written suggestions from the facilitation team added two institutional directions. First, PKK, KWT and households should be empowered to manage home yards and available agricultural land through KRPL, hydroponics, aquaponics, verticulture and wall gardening. Second, a Food Station should be developed as a municipally owned food enterprise to accommodate multiple food

sources, prioritize residents with access difficulties and function as a city food stabilizer. These suggestions do not provide a finished policy design; they identify complementary governance layers (Table 5).

Table 5 Stakeholder Framing, Portfolio Function and Risk if Isolated

Actor or actor group	Problem signal	Function in the portfolio	Risk if isolated
Bulog	Limited urban production, vulnerable residents, non-rice alternatives, subsidised food and staple-stock deterioration.	Buffer-stock interface, public procurement support and staple-price stabilisation.	System remains staple-centred and may neglect fresh food, household behaviour and stock-rotation risk.
Market-management actors	Perceived low quality of distributed rice, need for education and accurate targeting.	Quality communication, market monitoring and retail-channel coordination.	Assistance may fail if households do not trust product quality or targeting.
Municipal economic affairs actors	Household reserve through home yards or hydroponics, diversification, price and distribution monitoring, cooperation with producing areas.	City-region supply coordination and household provisioning agenda.	Household initiatives may be disconnected from market and logistics systems.
Cooperative and MSME actors	Price and stock monitoring, warehouse monitoring, local granaries and difficult agreements between shops and farmers.	Community enterprise, retail saving, processing and market-linkage support.	Local initiatives may fail without bookkeeping, contracts and accountability.
PKK, KWT and households	Home-yard food gardens, KRPL, local processing, food literacy and women's roles in household food management.	Micro-production, diversification, processing and household resilience.	Risk of romanticising unpaid domestic and women's labour.
Garda Pangan and civic actors	Edible surplus from cafés, restaurants, hotels, informal vendors, community events, supermarkets and near-expiry products.	Food bank, surplus rescue, emergency redistribution and platform coordination.	Food-safety and dignity risks if redistribution is not governed.
University facilitators and municipal food-security authority	Technical design, facilitation, pilot strategy and updated potential mapping.	Knowledge brokerage, evaluation and governance facilitation.	Model may remain a report unless converted into a pilot with measurable indicators.

Source: Authors' reconstruction based on the documentary archive.

4.3. Alternative Instruments as Differentiated Reserve Functions

Based on Table 6, the original materials presented several models: urban farming through KRPL, One Area One Product, household diversification, KWT-led strengthening, UPK, food bank and Food Station. A weak interpretation would ask which model is best. The stronger interpretation is functional. Each instrument creates a different type of reserve capacity and operates at a different scale. The strategic task is therefore not model selection in isolation, but portfolio assembly.

The archive provides several important details. The City Food Unit (UPK) is not simply a shop; it is a neighbourhood retail-saving mechanism in which small shops record food savings associated with transactions. The food bank model is not only charity; it links unused food sources, near-expiry products, processing, rapid distribution, neighbourhood grocery stores and the Urban Food Stabilization Centre. The Food Station is not merely a warehouse; the food-station note describes distribution, sales, warehousing, warehouse receipts, retail services, transportation, buffer stock, electronic food trade, quality standardization and market information.

These details show why a standard food-security program would be too narrow. UPK introduces a micro-financial and retail dimension. Food bank arrangements introduce circularity and

emergency redistribution. Food Station/BUMD Pangan introduces logistics, market intelligence and procurement. KRPL and women- and family-welfare group activities introduce household production, literacy and social organization. The policy challenge is therefore not a shortage of ideas, but the absence of an organizing framework that clarifies complementarities, responsibilities and thresholds for implementation.

Table 6 Functional Appraisal of Food-Reserve Instruments

Instrument	Primary reserve function	Main strength	Main limitation or risk
Urban farming / KRPL	Household micro-production and food literacy.	Builds coping capacity, fresh-food access and participation through home yards, hydroponics, aquaponics, verticulture and wall gardening.	Scale is limited; it cannot replace regional supply.
One Area One Product at neighbourhood scale	Neighbourhood commodity organisation and local diversity.	Can organise diverse commodities across neighbourhoods if adapted from rural OAOP logic.	Weak if treated as a city reserve strategy by itself.
Food diversification	Reduced dependence on rice and broader consumption practices.	Supports stability when rice prices rise and links food security with behaviour change.	Requires sustained education, acceptance and household-level adoption.
KWT/PKK processing and local food store	Women's group-led processing, seedling support and value addition.	Converts home-yard output and local potential into household income and processed products.	May burden women unless incentives, market links and labour recognition are provided.
City Food Unit (UPK)	Community retail saving and affordability support.	Connects local shops, bookkeeping and food saving for periods of scarcity or price increase.	Requires transparent accounting, trust and oversight.
Food bank / PSPK	Emergency redistribution of edible surplus and near-expiry food.	Reduces avoidable food waste while reaching access-constrained households rapidly.	Requires food-safety SOPs, traceability, dignity and targeting protocols.
Food Station / BUMD Pangan	City logistics, procurement, storage, market information and price stabilisation.	Can coordinate inter-regional suppliers, online food markets, quality standards and buffer-stock functions.	Capital-intensive and legally complex; needs procurement, warehousing and governance clarity.

Source: Authors' reconstruction based on the documentary archive.

4.4. Reconstructed Collaborative Food Reserve Portfolio

The reconstructed model is the collaborative food reserve portfolio. It has four operational layers and one governance core. The household reserve layer includes KRPL, KWT/PKK action, hydroponics, aquaponics, verticulture and wall gardening. The community and retail layer includes food diversification, KWT/PKK processing, local food shops and UPK saving. The surplus redistribution layer includes food-bank-style collection from hotels, restaurants, informal vendors, supermarkets, minimarkets and community events, supported by Garda Pangan, youth groups, PKK, KWT and other civic actors. The city logistics layer includes Food Station/BUMD Pangan, inter-regional supply coordination, warehousing, procurement, online markets and price information. The governance core links these layers through baseline mapping, rules, budgets, monitoring and evaluation.

The model's central insight is that resilience requires alignment across layers. Household gardens may increase coping capacity, but they need seedling support, knowledge, group organization and links to food literacy. KWT/PKK processing can add value, but products require

quality standards, packaging, retail access and MSME support. Food banks can redistribute edible surplus, but they need safety protocols, donor agreements and beneficiary targeting rules. Food Station/BUMD Pangan can stabilize flows, but it needs supplier contracts, warehouse strategy, data and financing. The portfolio therefore treats collaboration not as a slogan but as an operational strategic architecture (Table 7).

This architecture also clarifies the temporal dimension of resilience. Some functions are continuous, such as household food literacy, garden maintenance, retail bookkeeping and price monitoring. Others are episodic, such as emergency distribution or rapid activation of donor networks. Others require long-term investment, such as warehousing, supplier contracts, information platforms and institutional mandates. Planning failure occurs when these temporalities are confused: for example, when a training activity is treated as a permanent reserve, or when a warehouse is created without stock-rotation rules and demand information (Figure 1).

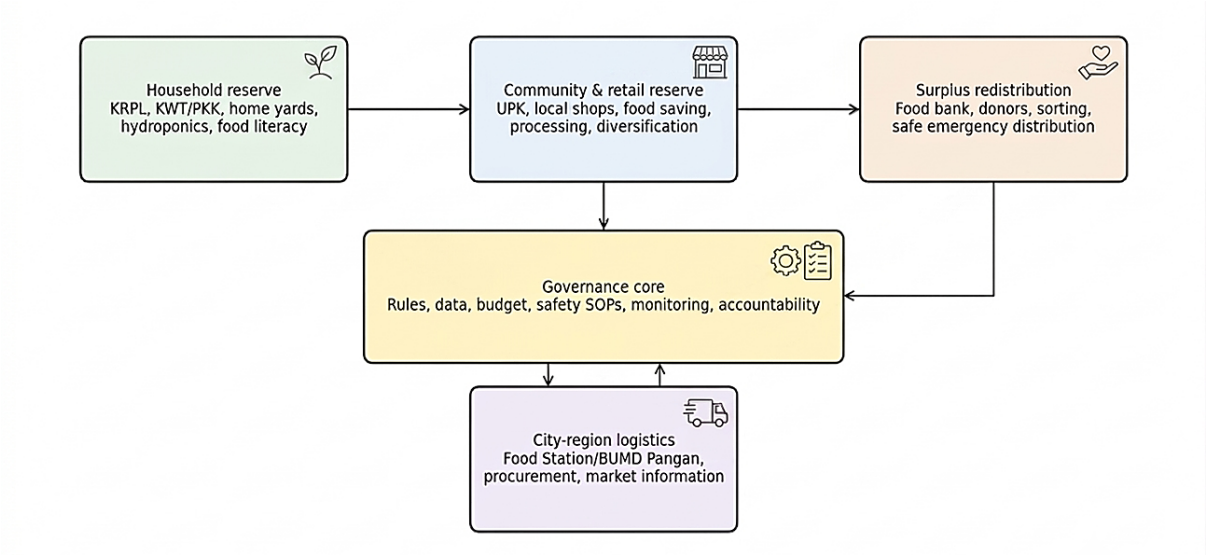

Figure 1 Collaborative food reserve portfolio for metropolitan food resilience

Source: Authors' elaboration based on the documentary archive.

Table 7 Architecture of the Collaborative Food Reserve Portfolio

Layer	Main actors	Core mechanisms	Indicators for pilot monitoring
Household reserve	KWT, PKK, households, extension officers and municipal facilitators.	KRPL, seed support, hydroponics, aquaponics, verticulture, wall gardening and food-literacy training.	Active households; garden continuity; small-produce volume; household dietary diversity.
Community and retail reserve	PKK, KWT, MSME/UMKM agency, neighbourhood grocery stores and local enterprises.	Food diversification, KRPL processing, local product development, UPK food-saving and local shop bookkeeping.	Number of products; food-saving accounts; sales value; transparent bookkeeping; non-rice consumption.
Surplus redistribution	Garda Pangan, hotels, restaurants, informal vendors, supermarkets, minimarkets, youth groups, PKK/KWT and social agencies.	Collection of edible surplus and near-expiry food, sorting, processing, rapid distribution and beneficiary targeting.	Safe food volume; donors registered; beneficiaries reached; compliance with food-safety SOPs.
City logistics and market information	Municipal food authority, Food Station/BUMD Pangan, procurement actor, market agency, cooperative/MSME agency, regional suppliers and retailers.	Procurement, warehousing, stock rotation, supplier coordination, online market, price information and quality standards.	Stock days; supplier diversity; price responsiveness; warehouse use; procurement transparency.

Layer	Main actors	Core mechanisms	Indicators for pilot monitoring
Governance core	Municipal task force, university facilitation team, relevant agencies and community representatives.	Baseline mapping, legal rules, budget design, data dashboard, participatory monitoring and periodic evaluation.	Updated food-provider database; vulnerability map; meeting frequency; decision log; budget realisation.

Source: Authors' reconstruction based on the documentary archive.

4.5. Quantitative Food-Balance, Stock, Market and GIS Evidence

The strengthened secondary evidence turns the Surabaya case from a purely documentary policy-design reconstruction into a data-anchored reserve-planning case. BPS recorded Surabaya's 2024 paddy harvested area at 1,321.75 ha, productivity at 55.54 quintals/ha and paddy production at 7,340.42 ton of dry unhusked paddy (GKG) (Badan Pusat Statistik Provinsi Jawa Timur, 2025). Using the BPS 2024 rice-consumption entry for Kota Surabaya of approximately 1.413 kg/capita/week (Badan Pusat Statistik, 2026) and the 2024 registered population of 3,018,022 people (Badan Pusat Statistik Kota Surabaya, 2025), annual household rice demand can be approximated at 221,752 ton. Applying a conservative NBM-style conversion to local paddy output--deducting 7.3% for seed, feed, non-food use and loss and then applying a 64.02% GKG-to-rice conversion--local rice-equivalent output is only about 4,356 ton. This proxy balance suggests that local rice production covers roughly 2.0% of estimated household rice consumption, leaving an indicative supply gap of about 217,396 ton that must be met through inter-regional flows.

The stock and warehouse evidence reinforces the same argument. The National Food Agency reported that *Perum Bulog* Surabaya had warehouse capacity of 200,000 ton, with 25,582 ton of rice in stock for Cadangan Beras Pemerintah (CBP), SPHP and food assistance as of 15 October 2024 (Badan Pangan Nasional, 2024a, 2024b, 2024c). SPHP realization through Bulog Kanca Surabaya reached 15,853 ton, including 6,460 ton for Kota Surabaya. By May 2026, the Ministry of Agriculture reported that Bulog had rented two additional warehouses at Romokalisari II with combined capacity of 8,000 ton (Kementerian Pertanian Republik Indonesia, 2026), already filled with 7,610 ton of rice; the same report stated that the earlier 200,000-tonne Surabaya capacity had been reported full. These figures show why reserve planning cannot treat warehouse capacity as a static number. Capacity, utilization, stock age, ownership status and location must be recorded as time-stamped GIS attributes.

The farmer-profit and market-margin evidence must be handled more cautiously. No official open Surabaya dataset was found that reports per-hectare profit-loss accounts for paddy farmers or actor-disaggregated marketing margins from farmer, collector, miller, wholesaler and retailer. The manuscript therefore uses only bounded proxy calculations. With 2024 productivity of 5,554 kg GKG/ha and the 2024 HPP for GKG at the milling level of Rp7,300/kg (Badan Pangan Nasional, 2024d; Badan Pemeriksa Keuangan Republik Indonesia, 2024), the gross paddy value is approximately Rp40.54 million/ha before production costs. This is not farmer profit. Net profit-loss can only be calculated after observing seed, fertilizer, pesticide, labor, machinery, irrigation, land rent, post-harvest, transport, credit and marketing costs. Similarly, the policy price spread between the HPP rice price at Bulog warehouse and retail/HET prices can show the stabilization corridor, but it cannot replace a complete margin study. The 2024 HET for medium rice in Java was Rp12,500/kg, while NFA observations at Pasar Nambangan Surabaya recorded medium rice around Rp12,100-Rp12,200/kg and premium rice below Rp15,000/kg. Against the HPP rice-at-Bulog-warehouse benchmark of Rp11,000/kg, this indicates a rough warehouse-to-retail policy spread of Rp1,100-Rp1,500/kg for medium rice, not a decomposed marketing margin.

The NBM and GIS evidence also need explicit boundary control. Public sources confirm that NBM is the appropriate framework for measuring food availability, utilization and per-capita availability, and that regional NBM can use national conversion coefficients when local coefficients are

unavailable. However, an official, complete Surabaya NBM table with commodity-by-commodity supply, use and per-capita availability was not publicly accessible during this revision. The article therefore reports a rice-only NBM-style proxy while identifying the official Surabaya NBM as a necessary data input before pilot implementation. Satu Data Surabaya and sectoral statistical reports already provide GIS-ready production, harvested-area, irrigation and food-system datasets, including 2023 paddy harvested area of 1,090.74 ha and paddy production of 7,150.76 ton in the municipal sectoral statistics (Satu Data Surabaya, 2024a, 2024b, 2026). These datasets should be geocoded by *kecamatan*/urban-village and linked with warehouse, market, food-bank, donor and vulnerable-household layers (Table 8).

Table 8 Quantitative Evidence Matrix for Strengthening the Surabaya Reserve-Portfolio Case

Indicator domain	Evidence added to case	Implication for reserve-portfolio design	Source basis
Population and rice demand	Registered population in 2024: 3,018,022 people. BPS rice-consumption entry for Kota Surabaya: approximately 1.413 kg/capita/week. Estimated annual household rice demand: about 221,752 tonnes.	The reserve system must be designed for a large consuming metropolis, not for a self-sufficient production territory.	BPS Kota Surabaya; BPS consumption table; authors' calculation
Local paddy supply and rice equivalent	2024 paddy harvested area: 1,321.75 ha; productivity: 55.54 quintals/ha; production: 7,340.42 tonnes GKG. NBM-style rice-equivalent output after deductions and conversion: about 4,356 tonnes.	Local paddy production can support only a small share of rice consumption; urban agriculture cannot substitute for inter-regional supply coordination.	BPS Jawa Timur; NBM conversion guidance; authors' calculation
Rice demand-supply proxy	Estimated household rice demand: 221,752 tonnes/year; local rice-equivalent output: 4,356 tonnes/year; indicative gap: 217,396 tonnes/year; local cover ratio: about 2.0%.	Food Station/BUMD Pangan, supplier contracts, market intelligence and emergency procurement are central rather than optional.	Authors' NBM-style proxy calculation
Warehouse capacity and public stock	Bulog Surabaya warehouse capacity was reported at 200,000 tonnes; stock on 15 Oct 2024 was 25,582 tonnes of rice. SPHP realisation by Bulog Kanca Surabaya was 15,853 tonnes, including 6,460 tonnes for Kota Surabaya.	The city already uses stabilisation channels, but these need to be linked with stock-age, capacity and location monitoring.	National Food Agency/Bulog, 2024
Location-specific warehouse evidence	In May 2026, two rented Romokalisari II warehouses had combined capacity of 8,000 tonnes and were filled with 7,610 tonnes; each rented warehouse was reported at 4,000 tonnes. A complete public, location-by-location Bulog warehouse register for Surabaya was not found.	The pilot should request official facility-level data: warehouse name, address/coordinates, ownership/rental status, capacity, utilisation, commodity, stock age and quality status.	Ministry of Agriculture, 2026; data-gap control
Farmer gross value and profit-loss boundary	Using productivity of 5,554 kg GKG/ha and HPP GKG at mill of Rp7,300/kg, gross paddy value is approximately Rp40.54 million/ha before costs. No official Surabaya farm profit-loss account was found.	The paper should not claim farmer profit or loss. A farm-enterprise baseline survey is required before evaluating welfare effects.	BPS Jawa Timur; Perbadan 4/2024; authors' calculation

Indicator domain	Evidence added to case	Implication for reserve-portfolio design	Source basis
Market-margin proxy	HPP rice at Bulog warehouse: Rp11,000/kg. 2024 HET medium rice for Java: Rp12,500/kg. NFA observed medium rice at Pasar Nambangan Surabaya at about Rp12,100-Rp12,200/kg. Proxy warehouse-to-retail policy spread: roughly Rp1,100-Rp1,500/kg.	The spread indicates the policy stabilisation corridor but not a complete margin by actor. A market-chain survey is still required.	Perbadan 4/2024; NFA HET and market observation
GIS-ready production and land data	Satu Data Surabaya and sectoral reports provide paddy harvested area, production, irrigation and food-system datasets, including 2023 paddy harvested area of 1,090.74 ha and paddy production of 7,150.76 tonnes.	A GIS reserve dashboard should overlay production nodes, market nodes, warehouses, donor sources, vulnerable households and distribution routes.	Satu Data Surabaya; DKPP sectoral statistics
Official NBM demand-supply gap	Official Surabaya NBM tables were not publicly accessible during revision, although NBM is the proper framework for commodity availability, use and per-capita availability.	The manuscript uses a rice-only NBM-style proxy and identifies the official NBM as a mandatory pre-pilot dataset.	NBM guidance; DKPP data-function evidence; evidence-gap control

Source: Authors' synthesis from BPS, DKPP Kota Surabaya, Satu Data Surabaya, National Food Agency/Bulog, Ministry of Agriculture, BPK/JDIH regulatory records and authors' calculations. Demand, local rice-equivalent output, gross paddy value and price-spread values are transparent proxies; they should be replaced by official Surabaya NBM, farm enterprise budgets and actor-level market-margin data when those datasets are obtained.

For future implementation, the Food Station/BUMD Pangan layer should therefore maintain a GIS-linked dashboard with at least twelve fields: commodity stock by warehouse and date, warehouse capacity and utilization, stock age and quality status, supplier origin, procurement price, wholesale price, retail price, household vulnerability, food-retail density, donor and food-bank sources, local production nodes and emergency distribution routes. The dashboard should distinguish verified administrative data from proxy estimates so that reserve decisions remain auditable.

This evidence matrix strengthens the article but also clarifies the remaining evidence boundary. The data now substantiate Surabaya's local-production deficit, external-supply dependence, stock-distribution scale and warehouse-capacity dynamics. At the same time, the requested variables that remain incomplete in public sources--farm profit-loss, complete actor-level marketing margins, location-by-location official warehouse capacity and complete Surabaya NBM demand-supply balances--are converted into a mandatory baseline package for the pilot, rather than being hidden or replaced by unsupported claims.

5. Discussion

5.1. Theoretical Contribution: Reserves as Urban-Regional Governance Architecture

The Surabaya case supports a shift from reserve stock to reserve strategy. In conventional policy language, reserves are often associated with stored staple commodities. This remains important, especially for rice. However, the Surabaya archive shows that the practical vulnerabilities of a metropolitan food system are wider: limited land, price instability, long supply chains, household access, weak diversification, quality perception, surplus food, budget rules, warehousing and data gaps. A reserve system that responds only by holding staple stock would address only part of the problem. Urban food reserves should therefore be understood as an institutional-spatial system linking emergency readiness with everyday access.

This argument adds to urban food governance literature by making reserve capacity operational. Much resilience literature remains conceptual, while much urban food policy literature focuses on councils, networks or strategies. The Surabaya case sits between these discussions. It asks how a city can translate broad resilience principles into a sequence of instruments that can be piloted at urban-village scale. The result is not a universal recipe but an operational grammar: identify the vulnerability, locate the spatial scale, assign a reserve function, define the actor configuration, specify the operational risk and select a monitoring indicator.

The portfolio concept is the main theoretical contribution. Its value lies in four moves. First, it differentiates reserve functions instead of treating all food-security instruments as equivalent. Second, it distributes these functions across household, neighbourhood, civic, municipal and city-region scales. Third, it recognizes that routine, standby and emergency capacities require different rules and investments. Fourth, it makes accountability central through data, safety protocols, budgets, legal mandates and monitoring. These moves transform food reserves from a commodity-stock question into a governance architecture.

5.2. Urban Agriculture, Food Banks and Food Station as Complementary Layers

A key implication is the careful positioning of urban agriculture. The archive rightly places KRPL, KWT, PKK and home-yard food production at the centre of household resilience. These activities can increase food literacy, fresh-food access, social participation and productive use of limited household space. However, a strong urban-planning argument must avoid the self-sufficiency illusion. Urban agriculture in a dense, externally dependent city cannot secure metropolitan food availability by itself. Its value lies in household-level and neighbourhood-level resilience, not in replacing city-regional supply chains.

A second implication is the differentiation among Food Station, food bank and UPK. These three instruments are often discussed separately or rhetorically merged under food-security programming. In the Surabaya portfolio, they perform different forms of access governance. The food bank responds to avoidable surplus and immediate access constraints. The Food Station responds to city logistics, market information, procurement and price stabilisation. UPK responds to household affordability and community retail through food-saving mechanisms. Their complementarity clarifies why a portfolio is preferable to a single model.

The portfolio also exposes implementation risks that should not be hidden. Food banks can improve emergency redistribution, but they must not become unsafe or undignified charity. Food Stations can stabilize supply, but they may become capital-heavy institutions without clear procurement and stock-rotation rules. UPK can increase affordability, but it depends on trustworthy bookkeeping and shop-level accountability. Women's groups can strengthen household resilience, but they should not be treated as an invisible labor reserve. A serious planning model must therefore include protocols, incentives, data systems and monitoring indicators.

5.3. City-Region Planning and Policy Transfer

The city-region dimension is especially important. Surabaya's reserve problem cannot be solved within the administrative boundary of the city. Food Station/BUMD Pangan is strongest when interpreted as a mechanism for organising regional supply, supplier diversity, quality standards, price information and emergency procurement. This makes the model relevant to urban and regional planning: food resilience is produced through the link among household practices, neighbourhood institutions, city logistics and regional production networks. A Food Station without city-region supplier coordination is only a facility; a food bank without neighbourhood targeting and safety rules is only charity; KRPL without links to retail, processing and dietary change is only a garden programme.

For policy transfer, the portfolio should be read as a design logic rather than as a fixed institutional recipe. Other metropolitan cities may not have the same organisations, food-rescue networks or community structures, but they can still use the same diagnostic sequence: identify

the food-system vulnerability, locate the spatial scale, assign a reserve function, define the actor configuration, specify the operational risk and select a monitoring indicator. This is the broader planning value of the Surabaya case. It transforms a local FGD archive into a generalisable way of thinking about metropolitan food reserves without detaching the model from its empirical origin.

5.4. Implementation Roadmap Before Scaling

The coordination notes make clear that implementation should not begin with a city-wide launch. Several prerequisites are unresolved. The city needs data on agricultural, fisheries and livestock business actors, their production capacity, enterprise types, remaining agricultural land and food-vulnerability mapping. It also needs clarity on how contingency budgets can be translated into reserve operations, whether warehouses are required, how stored staples will be rotated before quality deteriorates and what legal relationships govern the use of municipal or former village land for community food programmes.

The Food Station/BUMD Pangan planning document also requires institutional realism. A municipal food enterprise may stabilise prices and organise suppliers, but only if its mandate is clear: whether it will buy, store, distribute, provide market information, run online retail, support MSME products, manage quality standards or coordinate emergency reserves. Without such clarity, the Food Station risks becoming an expensive warehouse or an underused online platform. Similarly, the food bank layer must be governed through food-safety SOPs, donor agreements, cold-chain considerations and dignity-based beneficiary targeting.

The recommended sequence begins with baseline and institutional design, moves to an urban-village pilot, then consolidates linkages with Food Station/BUMD Pangan and MSME support (Pemerintah Kota Surabaya, 2024a, 2024b, 2024c) before any city-wide scaling (Table 9). This staged approach is consistent with the article's conservative evidence boundary. The model is not yet an impact evaluation. It is a strategic proposition that should be tested through participation, safety, affordability, stock rotation, data updating and equitable access indicators.

Table 9 Pilot Roadmap and Monitoring Indicators

Phase	Priority action	Decision gate	Core indicators
0-6 months: baseline and institutional design	Create food-resilience task force; map KRPL/KWT/PKK, markets, retailers, donors, vulnerable households, business actors, land and production capacity.	Pilot urban village selected and institutional roles agreed.	Baseline food-diversity data; food-provider database; vulnerability map; donor list; legal and budget notes.
6-18 months: urban-village pilot	Implement KRPL support, diversification training, UPK bookkeeping, donor registration, food-safety SOPs and limited Food Station linkage.	Evidence of participation, safe handling, transparent accounting and data use.	Active households; food-saving accounts; safe food redistributed; beneficiaries reached; price-monitoring entries.
18-36 months: consolidation	Connect pilots to BUMD/Food Station functions, MSME support, supplier coordination, market information and periodic monitoring.	Functions continue beyond training events and are financially traceable.	Supplier diversity; stock rotation; enterprise sales; reduced avoidable food waste; budget realisation.
Beyond 36 months: scale-up	Institutionalise financing, dashboard reporting, legal agreements, inter-regional procurement and participatory evaluation.	Model embedded in municipal planning and budget cycles.	Stock days; affordability index; dashboard updating frequency; equity of access; audit results.

Source: Authors' reconstruction based on the documentary archive.

6. Limitations and Future Research

This study has five limitations. First, the documentary archive does not provide full FGD transcripts, participant-level data or verbatim quotations, so the analysis reconstructs institutional problem framings rather than individual narratives. Second, although the revision adds production, consumption, stock, warehouse and GIS-ready secondary data, several variables requested for a full economic reserve assessment remain unavailable in open public sources: official Surabaya NBM commodity balances, location-by-location warehouse capacity and utilisation, farmer profit-loss accounts and complete actor-level market margins. Third, the rice-balance, gross paddy value and price-spread figures are transparent proxies, not substitutes for official NBM, farm-enterprise budgets or marketing-margin surveys. Fourth, the spatial dimension is still partly conceptual because the manuscript does not yet include a geocoded GIS layer of markets, warehouses, donor sources, supplier corridors and vulnerable households. Fifth, the use of unpublished institutional materials requires careful documentation of institutional permission before journal submission.

Future research should therefore proceed in two stages. The first stage should compile a baseline dataset from DKPP, Bulog Kanca Surabaya, BPS, Satu Data Surabaya, market authorities and food-bank actors, covering commodity stock, warehouse coordinates and capacity, farm enterprise budgets, market-chain margins, official NBM tables, food-waste flows and vulnerable-household locations. The second stage should test the portfolio through mixed methods: spatial food-access mapping, Delphi or analytic hierarchy process prioritization, pilot evaluation of KRPL-UPK-food-bank-Food Station linkages, cost-benefit analysis under disruption scenarios and governance research on accountability when a Food Station/BUMD Pangan operates across procurement, market stabilization and commercial retail functions.

7. Conclusions

This article has reconstructed a Surabaya FGD-based planning archive into a collaborative food reserve portfolio for metropolitan food resilience. The central argument is that urban food reserves should not be reduced to stored staple commodities. In a dense and externally dependent city, reserve capacity also includes household provisioning, community diversification, local retail saving, surplus-food redistribution, city logistics, regional supplier coordination, food-safety protocols, data systems and financing rules. These capacities must be planned as complementary layers rather than as competing alternatives.

The documentary archive sharpens the model in three ways. First, it shows that the Food Station idea was intended not merely as a storehouse but as a possible municipally owned food enterprise and stabilisation instrument. Second, it shows that food-bank functions can draw on underused food sources from restaurants, hotels, small vendors, supermarkets, minimarkets and social events, provided safety and dignity are protected. Third, it shows that implementation requires a stronger baseline: data on business actors, production capacity, land, vulnerability, potential donors, legal arrangements and budget mechanisms.

The final model should therefore be piloted rather than immediately scaled city-wide. An urban-village pilot can test whether KRPL initiatives, KWT initiatives, UPK food-saving, food-bank redistribution and Food Station linkages can operate together under one monitoring framework. If the pilot demonstrates participation, safety, affordability, stock rotation, data updating and equitable access, Surabaya would have a stronger basis for institutionalizing metropolitan food-reserve governance. The broader lesson is that urban food resilience is best governed as a collaborative portfolio of complementary capacities, not as a single program, warehouse or charity mechanism.

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CRediT Authorship Contribution Statement

Medea Ramadhani Utomo: Conceptualization, methodology, investigation, data analysis, visualization, writing - original draft, and writing - review and editing. Yayuk Yuliati: Conceptualization, supervision, methodology, validation, and writing - review and editing. All authors approved the final version of the manuscript and agreed to be accountable for the integrity of the work.

Declaration of Competing Interest

The authors declared that this study has received no financial support. No conflict of interest was declared by the authors.

Data Availability

The documentary archive analyzed in this study consists of unpublished institutional materials and is not publicly deposited. Public secondary data used for contextual strengthening are available from BPS, Satu Data Surabaya, DKPP Kota Surabaya, Badan Pangan Nasional, Bulog-related official releases and the Ministry of Agriculture. Derived proxy calculations are reported transparently in the manuscript and should be replaced with official Surabaya NBM, farm profit-loss, market-margin and warehouse-register datasets when the relevant agencies provide them.

Ethics Committee Approval and Legal Public/Private Permissions

This article analyses a documentary policy-design archive and reports no identifiable participant-level personal data. Legal public/private permission for the use of unpublished institutional materials should be documented in the submission package and provided to the journal where required.

References

Ansell, C., & Gash, A. (2008). Collaborative governance in theory and practice. *Journal of Public Administration Research and Theory*, *18*(4), 543-571. https://doi.org/10.1093/jopart/mum032

Badan Pangan Nasional. (2024a). *NFA dorong peningkatan sinergi dan kolaborasi Perum Bulog untuk menjaga stabilitas pasokan dan harga beras*. Badan Pangan Nasional.

Badan Pangan Nasional. (2024b). *Perpanjangan relaksasi HET beras medium dan premium untuk menjaga stabilitas pasokan di pasar tradisional dan retail modern*. Badan Pangan Nasional.

Badan Pangan Nasional. (2024c). *Blusukan di Pasar Nambangan Surabaya, Kepala NFA dan Pj Gubernur Jatim pastikan kondisi pangan stabil dengan pasokan yang aman*. Badan Pangan Nasional.

Badan Pangan Nasional. (2024d). *Peraturan Badan Pangan Nasional Nomor 4 Tahun 2024 tentang Perubahan atas Peraturan Badan Pangan Nasional Nomor 6 Tahun 2023 tentang Harga Pembelian Pemerintah dan Rafaksi Harga Gabah dan Beras.* Badan Pangan Nasional.

Badan Pemeriksa Keuangan Republik Indonesia. (2024). *Peraturan Badan Pangan Nasional Nomor 4 Tahun 2024*. Database Peraturan BPK.

Badan Pusat Statistik. (2026). *Rata-rata konsumsi perkapita seminggu menurut kelompok padi-padian per kabupaten/kota*. Badan Pusat Statistik.

Badan Pusat Statistik Kota Surabaya. (2025). *Kota Surabaya dalam angka 2025*. BPS Kota Surabaya.

Badan Pusat Statistik Provinsi Jawa Timur. (2025). *Luas panen, produktivitas, dan produksi padi menurut kabupaten/kota di Provinsi Jawa Timur, 2024*. BPS Provinsi Jawa Timur.

Battersby, J. (2013). Hungry cities: A critical review of urban food security research in sub-Saharan African cities. *Geography Compass*, *7*(7), 452-463. https://doi.org/10.1111/gec3.12053

Béné, C. (2020). Resilience of local food systems and links to food security: A review of some important concepts in the context of COVID_19 and other shocks. *Food Security*, *12*, 805_822. https://doi.org/10.1007/s12571-020-01076-1

Candel, J. J. L. (2014). Food security governance: A systematic literature review. *Food Security*, *6*, 585-601. https://doi.org/10.1007/s12571-014-0364-2

Chambers, R. (1994). The origins and practice of participatory rural appraisal. *World Development*, *22*(7), 953-969. https://doi.org/10.1016/0305-750X(94)90141-4

Cohen, M. J., & Garrett, J. L. (2010). The food price crisis and urban food (in)security. *Environment and Urbanization*, *22*(2), 467-482. https://doi.org/10.1177/0956247810380375

Dinas Ketahanan Pangan dan Pertanian Kota Surabaya. (2024). *Laporan Peta Ketahanan dan Kerentanan Pangan (Food Security and Vulnerability Atlas - FSVA) Kota Surabaya Tahun 2024*. Pemerintah Kota Surabaya.

Emerson, K., Nabatchi, T., & Balogh, S. (2012). An integrative framework for collaborative governance. *Journal of Public Administration Research and Theory*, *22*(1), 1-29. https://doi.org/10.1093/jopart/mur011

Ericksen, P. J. (2008). Conceptualizing food systems for global environmental change research. *Global Environmental Change*, *18*(1), 234-245. https://doi.org/10.1016/j.gloenvcha.2007.09.002

Food and Agriculture Organization of the United Nations. (2023). *Building sustainable and resilient city region food systems: Assessment and planning handbook*. FAO. https://doi.org/10.4060/cc5184en

Haysom, G. (2015). Food and the city: Urban scale food system governance. *Urban Forum*, *26*(3), 263-281. https://doi.org/10.1007/s12132-015-9255-7

Horst, M. (2017). Food justice and municipal government in the USA. *Planning Theory & Practice*, *18*(1), 51-70. https://doi.org/10.1080/14649357.2016.1270351

Kementerian Pertanian Republik Indonesia. (2026). *Gudang sewa Bulog terisi penuh, Mentan Amran optimistis swasembada pangan menguat*. Kementerian Pertanian Republik Indonesia.

Krähmer, K., Dansero, E., & Pettenati, G. (2024). Towards sustainable and sufficient city region food systems: Reflections from the case study of Turin, Italy. *Sustainability*, *16*(19), 8569. https://doi.org/10.3390/su16198569

Lambie-Mumford, H. (2013). "Every town should have one": Emergency food banking in the UK. *Journal of Social Policy*, *42*(1), 73-89. https://doi.org/10.1017/S004727941200075X

Luger, J., Cohen, N., & Moragues-Faus, A. (2025). Transformative urban food governance: How municipal staff coordinate urban living labs for sustainable food systems. *Local Environment*. https://doi.org/10.1080/13549839.2025.2486297

Manderbach, J., Tanzer, M., Breitmeier, H., & Schwindenhammer, S. (2025). Sustainable urban food system policies as a new realm for transnational city networks. *International Journal of Urban Sustainable Development*, *17*(1), 120-135. https://doi.org/10.1080/19463138.2025.2495577

Moragues-Faus, A., & Battersby, J. (2021). Urban food policies for a sustainable and just future: Concepts and tools for a renewed agenda. *Food Policy*, *103*, 102124. https://doi.org/10.1016/j.foodpol.2021.102124

Moragues-Faus, A., Clark, J. K., Battersby, J., & Davies, A. R. (2024). The potential of urban food governance to transform lives, cities, and the planet. *Global Food Security*, *40*, 100751. https://doi.org/10.1016/j.gfs.2024.100751

Morgan, K. (2015). Nourishing the city: The rise of the urban food question in the Global North. *Urban Studies*, *52*(8), 1379-1394. https://doi.org/10.1177/0042098014534902

Mourad, M. (2016). Recycling, recovering and preventing food waste: Competing solutions for food systems sustainability in the United States and France. *Journal of Cleaner Production*, *126*, 461-477. https://doi.org/10.1016/j.jclepro.2016.03.084

Papargyropoulou, E., Lozano, R., Steinberger, J. K., Wright, N., & Ujang, Z. B. (2014). The food waste hierarchy as a framework for the management of food surplus and food waste. *Journal of Cleaner Production*, *76*, 106-115. https://doi.org/10.1016/j.jclepro.2014.04.020

Pemerintah Kota Surabaya. (2024a). *Pastikan ketersediaan stok bahan pokok jelang Ramadan, Pemkot Surabaya segera gelar Pasar Murah di 322 titik*. Pemerintah Kota Surabaya.

Pemerintah Kota Surabaya. (2024b). *Pemkot Surabaya optimalkan Gerakan Pasar Murah: Solusi jitu hadapi kenaikan harga bahan pokok*. Pemerintah Kota Surabaya.

Pemerintah Kota Surabaya. (2024c). *Pemkot Surabaya upayakan seluruh UMKM mamin memiliki sertifikasi halal*. Pemerintah Kota Surabaya.

Pothukuchi, K., & Kaufman, J. L. (2000). The food system: A stranger to the planning field. *Journal of the American Planning Association*, *66*(2), 113-124. https://doi.org/10.1080/01944360008976093

Poulsen, M. N., McNab, P. R., Clayton, M. L., & Neff, R. A. (2015). A systematic review of urban agriculture and food security impacts in low_income countries. *Food Policy*, *55*, 131_146. https://doi.org/10.1016/j.foodpol.2015.07.002

Satterthwaite, D., McGranahan, G., & Tacoli, C. (2010). Urbanization and its implications for food and farming. *Philosophical Transactions of the Royal Society B*, *365*(1554), 2809_2820. https://doi.org/10.1098/rstb.2010.0136

Satu Data Surabaya. (2024a). *Bab V: Pertanian, peternakan dan perikanan*. Pemerintah Kota Surabaya.

Satu Data Surabaya. (2024b). *Bab VI: Industri*. Pemerintah Kota Surabaya.

Satu Data Surabaya. (2026). *Luas lahan pertanian yang diusahakan menurut jenis pengairan per kecamatan; produksi dan luas panen tanaman pangan dan sayuran*. Pemerintah Kota Surabaya.

Schneider, F. (2013). The evolution of food donation with respect to waste prevention. *Waste Management*, *33*(3), 755-763. https://doi.org/10.1016/j.wasman.2012.10.025

Sonnino, R. (2016). The new geography of food security: Exploring the potential of urban food strategies. *The Geographical Journal*, *182*(2), 190-200. https://doi.org/10.1111/geoj.12129

Sonnino, R., Tegoni, C. L. S., & De Cunto, A. (2019). The challenge of systemic food change: Insights from cities. *Cities*, *85*, 110-116. https://doi.org/10.1016/j.cities.2018.08.008

Tarasuk, V., & Eakin, J. M. (2005). Food assistance through surplus food: Insights from an ethnographic study of food bank work. *Agriculture and Human Values*, *22*(2), 177-186. https://doi.org/10.1007/s10460-004-8277-x

Tendall, D. M., Joerin, J., Kopainsky, B., Edwards, P., Shreck, A., Le, Q. B., Krütli, P., Grant, M., & Six, J. (2015). Food system resilience: Defining the concept. *Global Food Security*, *6*, 17_23. https://doi.org/10.1016/j.gfs.2015.08.001

United Nations Environment Programme. (2024). *Food Waste Index Report 2024: Think eat save - Tracking progress to halve global food waste*. UNEP.

Vara-Sánchez, I., Gallar-Hernández, D., García-García, L., Morán Alonso, N., & Moragues-Faus, A. (2021). The co-production of urban food policies: Exploring the emergence of new governance spaces in three Spanish cities. *Food Policy*, *103*, 102120. https://doi.org/10.1016/j.foodpol.2021.102120

Zezza, A., & Tasciotti, L. (2010). Urban agriculture, poverty, and food security: Empirical evidence from a sample of developing countries. *Food Policy*, *35*(4), 265_273. https://doi.org/10.1016/j.foodpol.2010.04.007

Resume

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From SEKA to Sekapark: An analysis of post-industrial transformation through measurable spatial indicators

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Abstract

Post-industrial urban transformation is widely discussed through brownfield redevelopment, industrial heritage conservation, waterfront regeneration, ecological recovery, and culture-led reuse. However, site-scale studies that evaluate such transformations through measurable spatial indicators remain limited. This study examines the transformation of the SEKA Paper Factory in İzmit, Türkiye, into Sekapark as a case of transition from a Fordist industrial production landscape to a post-Fordist cultural, recreational, ecological, and publicly accessible coastal landscape. The research employs a mixed-method design combining field observation, GIS-based spatial analysis, remote sensing, OSM-based network analysis, DEM-based elevation assessment, and archival interpretation. A total of 280 building units were evaluated through physical-structural, ecological-environmental, transport-accessibility, and heritage-urban integration indicators. These include building typology, use status, building condition and intervention priority, NDVI-based vegetation change, elevation-based coastal vulnerability, public transport proximity, pedestrian connectivity, cultural heritage value, and city-center integration. The findings indicate that transformation has been most strongly consolidated along the waterfront through cultural and recreational functions, while parts of the former production core continue to display transitional use and intervention needs. NDVI analysis for 2000–2025 shows that mean NDVI increased from 0.068 to 0.250 and vegetated surface increased to 36.3% by 2025. Accessibility analyses show a strong pedestrian network and close public transport proximity, although the transport assessment is based on stop buffers rather than full route-based accessibility. The study develops and tests an adapted indicator-based spatial evaluation framework for assessing post-industrial transformation at the site scale.

Keywords: brownfield redevelopment, industrial heritage, measurable spatial indicators, post-fordist urbanism, seka–sekapark

1. Introduction

Post-industrial urban transformation refers not only to the cessation of production activities, but also to the spatial, economic, ecological, and cultural restructuring of former industrial areas (Harvey, 1989; CABERNET, 2006; Franz et al., 2008). These areas are often characterized by obsolete production buildings, fragmented urban connections, environmental degradation, limited public accessibility, and uncertain heritage value. Their transformation therefore involves more than functional reuse; it requires the reorganization of spatial continuity, ecological capacity, cultural memory, and urban integration.

The international literature has addressed post-industrial transformation through concepts such as brownfield redevelopment, adaptive reuse, waterfront regeneration, culture-led transformation, ecological restoration, and urban image-making (CABERNET, 2006; Plaza, 2000; Vanolo, 2008; Franz et al., 2008). Cases such as London Docklands, Ruhr IBA, HafenCity, Detroit,

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Bilbao, Katowice, Łódź, and Zorrotzaurre demonstrate different strategies for reactivating former industrial landscapes (Church, 1988; Detroit Future City, 2012; Jordan & von Daniels, 2019; Jacobs & Estensoro, 2020; Sobala-Gwosdz & Gwosdz, 2017; Masierek, 2021). However, many studies remain focused on strategic planning visions, symbolic architectural projects, governance models, or design narratives. Indicators such as building typology, current use, structural condition, vegetation capacity, coastal vulnerability, pedestrian accessibility, and public transport integration are often discussed separately rather than being combined into a unified field-based assessment model.

This limitation creates a methodological gap in the evaluation of post-industrial transformation areas. While existing studies explain why former industrial sites should be reused or regenerated, fewer studies demonstrate how the physical, ecological, and accessibility-related outcomes of such transformations can be measured at the site scale (Franz et al., 2008; Jordan & von Daniels, 2019). As a result, it becomes difficult to compare transformation processes across different periods, sites, and spatial conditions. This study addresses that gap by developing and testing an adapted indicator-based field assessment framework supported by GIS, remote sensing, OSM-based spatial data, and field interpretation.

In this study, urban resilience is understood as the capacity of a post-industrial area to adapt to changing environmental, spatial, social, and functional conditions while maintaining its physical, ecological, and cultural continuity. Within this framework, physical–structural indicators reveal the adaptive capacity of buildings and spaces to accommodate new functions, while ecological–environmental indicators assess vegetation capacity and the reduction of environmental vulnerability. Elevation-based coastal vulnerability indicators identify areas exposed to water-related and climate-related risks, whereas transport and accessibility indicators evaluate the integration of the site with the wider urban system and the accessibility of its public functions. Heritage value, adaptive reuse, and the visibility of industrial traces indicate the continuity of cultural memory and spatial identity. Taken together, these indicators provide a measurable basis for assessing adaptive capacity, vulnerability reduction, and the long-term sustainability of the SEKA–Sekapark transformation.

The SEKA Paper Factory–Sekapark site in İzmit provides a suitable case for testing this methodological framework. Established in 1936 in line with the state-led industrialization policies of the Early Republican period, SEKA represented a Fordist industrial complex composed of production halls, warehouses, technical facilities, administrative buildings, workers' housing, and social facilities (Oral Aydın & Çömlekçioğlu Kartal, 2010; Tunçelli et al., 2020). Following the cessation of production in 2005, the site experienced underuse, structural deterioration, and spatial disconnection. Its subsequent transformation into Sekapark introduced cultural, recreational, ecological, and public waterfront functions into the former industrial landscape (Oğuz et al., 2010).

The SEKA–Sekapark transformation provides an appropriate case for examining multiple spatial indicators, including building typology, use status, condition and intervention priority, NDVI-based vegetation change, elevation-based coastal vulnerability, pedestrian accessibility, public transport proximity, and morphological integration with the city center. These indicators also enable the SEKA case to be discussed in relation to international post-industrial transformation examples: Docklands in terms of accessibility, Ruhr IBA in terms of ecological restoration, HafenCity in terms of waterfront adaptation, Detroit in terms of condition-based spatial analysis, and Katowice–Łódź in terms of culture-led adaptive reuse (Church, 1988; Franz et al., 2008; Jordan & von Daniels, 2019; Detroit Future City, 2012; Sobala-Gwosdz & Gwosdz, 2017; Masierek, 2021).

The aim of this study is to analyze the transformation of SEKA–Sekapark through measurable spatial indicators and to test the applicability of an adapted evaluation framework for post-industrial areas. The study addresses three research questions: (1) How can the SEKA–Sekapark transformation be evaluated through measurable spatial indicators? (2) Which dimensions of the transformation are spatially consolidated, and which remain incomplete? (3) To what extent can an

adapted field-observation and GIS-based framework support site-scale assessment of post-industrial transformation areas?

The study focuses on four main dimensions: physical-structural transformation, ecological-environmental change, transport and pedestrian accessibility, and heritage-urban integration. By combining field observations with GIS-based, OSM-based, DEM-based, and remote sensing data, the research seeks to make the transformation process visible, comparable, and methodologically traceable. The contribution of the study is twofold. First, it provides a detailed spatial reading of the SEKA–Sekapark transformation beyond historical, architectural, or project-based interpretations. Second, it tests an adapted indicator-based framework that may support the assessment of similar post-industrial transformation sites in Türkiye and comparable international contexts.

2. Literature Background

2.1. Post-Industrial Urban Transformation Theories

Post-industrial urban transformation refers to the spatial, economic, ecological, and cultural restructuring processes that emerge following the decline of Fordist production regimes. The Fordist period was characterized by large-scale, vertically integrated, and predominantly single-function industrial areas supported by strong relationships among production, labor, logistics, housing, and social facilities (Harvey, 1989). By contrast, the post-Fordist period is associated with flexible production systems, service- and culture-based economies, mixed-use development, public-space provision, accessibility, and urban image-making (Harvey, 1989; Vanolo, 2008).

This transformation is particularly visible in former port areas, waterfronts, mining regions, and heavy industrial zones where production functions have become obsolete. In these areas, transformation involves more than a change in land use or building function. It also requires the reorganization of accessibility, ecological capacity, publicness, heritage value, spatial continuity, and functional integration. These components are directly related to urban resilience because they affect the capacity of former industrial areas to adapt to changing environmental, social, and functional conditions while maintaining their spatial and cultural continuity. However, these parameters are frequently addressed conceptually or individually rather than measured through an integrated site-scale framework. This limitation forms the theoretical basis of the measurability problem addressed in this study.

2.1.1. Fordist–Post-Fordist Spatial Transformation

Harvey (1989) emphasizes that capital produces “spatial fixes” through which idle or underused spaces are reorganized during periods of economic restructuring. From this perspective, Fordist spatial organization can be understood through integrated industrial settlements comprising production halls, logistics corridors, technical infrastructure, administrative units, workers’ housing, and social facilities. In the post-Fordist phase, these formerly single-function production areas are increasingly transformed into multifunctional environments in which cultural, recreational, residential, service, and public-space uses coexist.

London Docklands represents an investment- and infrastructure-oriented example of this transition. Following the decline of the port economy, the area was restructured through finance-oriented development, residential investment, transportation infrastructure, and urban image-making. Nevertheless, the transformation was also criticized for producing socially unequal and spatially fragmented outcomes (Church, 1988). HafenCity represents a different model in which mixed-use development, waterfront accessibility, elevated public spaces, and flood-sensitive planning were incorporated into post-industrial redevelopment (Jordan & von Daniels, 2019). Together, these examples demonstrate that physical transformation alone does not ensure spatial resilience; accessibility, social integration, environmental adaptation, and functional diversity are also essential.

The SEKA Paper Factory can be evaluated as a distinctive example of this theoretical transition in Türkiye. With its large production halls, logistics infrastructure, administrative units, workers' housing, and social facilities, SEKA embodied the Fordist spatial model of Early Republican industrialization (Oral Aydın & Çömlekçioğlu Kartal, 2010; Tunçelli et al., 2020). Following the cessation of production in 2005, the site became an underused industrial landscape. Through the Sekapark project, parts of the area were subsequently transformed into a recreational, cultural, ecological, and waterfront-oriented public space (Oğuz et al., 2010). SEKA–Sekapark therefore provides an appropriate case for examining the transition from a Fordist industrial settlement to a post-Fordist multifunctional landscape through measurable physical, ecological, accessibility-related, and heritage-based indicators.

2.1.2. Brownfield Concept

The concept of brownfield generally refers to previously developed urban areas affected by industrial decline, physical deterioration, environmental degradation, underuse, and loss of spatial integrity. CABERNET (2006) evaluates brownfield areas according to factors such as physical condition, environmental risk, redevelopment potential, and market conditions. Within this framework, brownfield transformation is not limited to the reuse of vacant land or obsolete buildings; it also involves ecological repair, spatial reconnection, functional adaptation, and social reintegration.

The Ruhr IBA process demonstrates how ecological corridors, regional park systems, industrial heritage conservation, and culture-oriented reuse can be combined within a post-industrial landscape strategy (Franz et al., 2008). Similarly, culture-led redevelopment in Katowice illustrates how former mining areas may be reactivated through cultural functions and urban image-making while retaining elements of industrial identity (Sobala-Gwosdz & Gwosdz, 2017). Detroit Future City (2012), by contrast, applies quantitative indicators such as building condition, vacancy, land-use intensity, and green infrastructure capacity to identify different intervention priorities.

These examples indicate that brownfield transformation involves three interrelated challenges: environmental vulnerability, spatial disconnection, and socio-economic or functional exclusion (CABERNET, 2006; Detroit Future City, 2012; Franz et al., 2008). Addressing these challenges can increase adaptive capacity by enabling former industrial areas to accommodate new functions, reduce environmental risks, and reconnect with surrounding urban systems. However, data-driven assessment models require adaptation when applied to industrial sites with strong cultural and historical significance. In the SEKA case, post-production underuse, varying building conditions, former accessibility limitations, and intervention needs resemble brownfield conditions, while the site's industrial heritage value necessitates the inclusion of cultural memory, adaptive reuse, and heritage visibility within the assessment framework.

2.2. International Transformation Cases and Methodological Discussions

International post-industrial transformation cases demonstrate that redevelopment strategies may prioritize different spatial, economic, ecological, and cultural dimensions. London Docklands, Bilbao, and Turin are primarily associated with investment-led redevelopment, symbolic architecture, tourism, creative economies, and urban image-making (Church, 1988; Plaza, 2000; Vanolo, 2008). Ruhr IBA, Katowice, and Łódź foreground ecological restoration, industrial heritage conservation, culture-led adaptive reuse, and the regeneration of deteriorated urban environments (Franz et al., 2008; Sobala-Gwosdz & Gwosdz, 2017; Masierek, 2021). HafenCity and Zorrotzaurre emphasize waterfront redevelopment, mixed-use planning, public accessibility, climate adaptation, and the integration of former industrial land with the wider urban structure (Jordan & von Daniels, 2019; Jacobs & Estensoro, 2020).

These cases reveal that no single strategy is sufficient for achieving comprehensive post-industrial transformation. Investment and urban image-making may improve economic visibility but can also produce spatial fragmentation or social exclusion. Culture-led adaptive reuse can strengthen identity and preserve industrial heritage, but its benefits may remain concentrated

around individual buildings or flagship projects. Ecological restoration and climate-sensitive design can reduce environmental vulnerability, while accessibility and mixed-use development can improve urban integration and long-term adaptability.

The international cases are therefore used in this study as conceptual and methodological references rather than as subjects of a full comparative analysis. Their main contribution is to identify recurring dimensions of post-industrial transformation, including building reuse, physical condition, ecological restoration, climate vulnerability, pedestrian accessibility, public transport integration, heritage continuity, and morphological connection. However, these dimensions are frequently assessed separately in the literature. The present study brings them together within a unified field- and GIS-based evaluation framework and tests their applicability in the SEKA–Sekapark transformation area.

2.3. Lack of Measurable Parameters in Transformation Areas

Many studies on post-industrial transformation areas focus on strategic planning visions, design decisions, architectural reuse, governance models, and cultural economy. However, the quantitative monitoring of the physical environment remains limited (Franz et al., 2008; Jordan & von Daniels, 2019). Building condition and deterioration are often addressed through descriptive narratives, while standardized scoring systems are used in relatively few cases. Similarly, ecological improvement and accessibility are frequently discussed separately rather than within an integrated analytical framework.

Although NDVI-based remote sensing indicators are widely used to assess vegetation density and ecological improvement, they are rarely combined with field observations, use status, building condition, and accessibility data in a holistic manner. Pedestrian and public transport accessibility analyses are also commonly discussed qualitatively, while OSM-based network analysis, buffer-based proximity assessment, and building-scale spatial evaluation remain limited in post-industrial transformation studies.

This methodological fragmentation makes it difficult to compare transformation processes across different sites and periods. It also limits the possibility of evaluating whether redevelopment produces measurable improvements in physical condition, ecological capacity, public accessibility, and urban integration. For the SEKA–Sekapark area, the observation form and GIS-based analyses developed in this study respond to this gap by operationalizing indicators such as building condition and intervention priority, use status, NDVI-based vegetation cover, elevation-based coastal vulnerability, pedestrian accessibility, public transport proximity, and cultural-urban integration.

2.4. Theoretical Basis of Observation Form Categories

The observation form is structured around four categories—physical–structural, ecological–environmental, transport–accessibility, and heritage–urban integration—which collectively assess adaptive capacity, environmental vulnerability, urban connectivity, and cultural continuity through measurable spatial indicators.

The physical–structural category includes building typology, current use, and building condition/intervention priority. Building typology helps identify the spatial characteristics and reuse potential of the industrial building stock, while use status indicates whether structures have been successfully reintegrated into contemporary urban life. Building condition and intervention priority reveal areas where deterioration may limit adaptive reuse and long-term functional continuity. These indicators are consistent with building-stock assessments used in post-industrial redevelopment studies and with condition-based approaches such as Detroit Future City (2012) and CABERNET (2006).

The ecological–environmental category includes NDVI-based vegetation cover and elevation-based coastal vulnerability. Vegetation cover provides measurable evidence of ecological capacity and green infrastructure development, while elevation-based coastal vulnerability identifies areas exposed to water-related environmental risks. These indicators are associated with ecological

restoration approaches applied in the Ruhr region and with climate-sensitive governance and adaptation strategies developed in waterfront cities such as Hamburg and Rotterdam (Franz et al., 2008; Mees et al., 2014). Together, they indicate whether the transformation contributes to ecological improvement, vulnerability reduction, and long-term environmental sustainability.

The transport–accessibility category includes pedestrian accessibility, public transport proximity, promenade continuity, entrance distribution, and the permeability of physical barriers. These indicators assess whether the transformed site is spatially connected to the city and whether its public functions can be reached through different modes of transportation. Accessibility and connectivity are central components of the Docklands, HafenCity, and Zorrotzaurre transformations, although the social and spatial outcomes of these projects vary (Church, 1988; Jordan & von Daniels, 2019; Jacobs & Estensoro, 2020). Within the SEKA–Sekapark area, these indicators help determine whether public access is distributed throughout the entire site or concentrated mainly along the waterfront.

The heritage-urban integration category includes industrial heritage value, adaptive reuse, visibility of industrial traces, urban image, and morphological–functional integration with the city center. Culture-led transformations in Bilbao, Turin, Katowice, and Łódź demonstrate that former industrial areas can be repositioned through cultural programming, tourism, adaptive reuse, and image-making strategies (Plaza, 2000; Vanolo, 2008; Sobala-Gwosdz & Gwosdz, 2017; Masierek, 2021). However, the preservation of individual buildings alone does not ensure heritage continuity. Industrial structures, routes, technical elements, and production-related spatial relationships must remain visible and legible within the transformed landscape.

In the SEKA case, this category is particularly important because the site represents both a former industrial production complex and a symbolic landscape of Republican-era industrialization. Assessing heritage value together with adaptive reuse and urban integration makes it possible to determine whether the transformation maintains cultural memory while enabling new uses. Accordingly, the four observation-form categories collectively measure the capacity of the SEKA–Sekapark area to adapt to new urban functions, reduce physical and environmental vulnerabilities, preserve industrial identity, and maintain long-term spatial continuity.

2.5. Research Gap in the Transformation of SEKA

Existing studies on SEKA mainly focus on the historical development of the factory, architectural characteristics, production processes, adaptive reuse, and museumization. Oral Aydın and Çömlekçioğlu Kartal (2010) examine the architectural analysis and reuse potential of SEKA Paper Factory I; Tunçelli et al. (2020) discuss cultural and industrial heritage project proposals for the Kocaeli region; and Oğuz et al. (2010) evaluate Sekapark as an example of industrial site transformation. These studies provide a strong background on SEKA's role in Republican-era industrialization and its value as industrial heritage, but they address the spatial analytical dimension of transformation in a limited way.

Figure 1 SEKA Paper Museum site photograph

As shown in Figure 1, the SEKA Paper Museum represents one of the most visible outcomes of adaptive reuse and museumization. However, the SEKA–Sekapark transformation cannot be evaluated only through museumization, architectural conservation, or project-based redevelopment narratives. A broader analytical framework is required to understand how the site has changed physically, ecologically, functionally, and spatially.

Studies that examine the SEKA–Sekapark area through comprehensive and quantitative field analysis based on indicators such as building condition/intervention priority, NDVI-based vegetation cover, elevation-based coastal vulnerability, pedestrian and public transport accessibility, and spatial integration with the city center remain limited. By addressing this gap through an observation form and GIS-based thematic mapping, this study introduces a spatial analytical dimension to the SEKA literature and positions SEKA as a local case that can be discussed on the same analytical ground as international post-industrial transformation examples.

3. Method

This study employs a mixed-method design combining field observation, GIS-based spatial analysis, remote sensing, OSM-based network/proximity analysis, DEM-based elevation assessment, and archival interpretation. The methodological framework was developed to evaluate the SEKA–Sekapark transformation through measurable physical, ecological, accessibility-based, and heritage-urban integration indicators.

3.1. Study Area

The study area includes the historical production site of the SEKA Paper Factory and the Sekapark coastal zone that emerged through its transformation. The boundaries were defined by considering former industrial parcels, preserved factory buildings, current cultural and recreational facilities, coastal public spaces, pedestrian connections, the tram line, and surrounding urban corridors. The multi-scale spatial structure of the study area is presented in Figure 2.

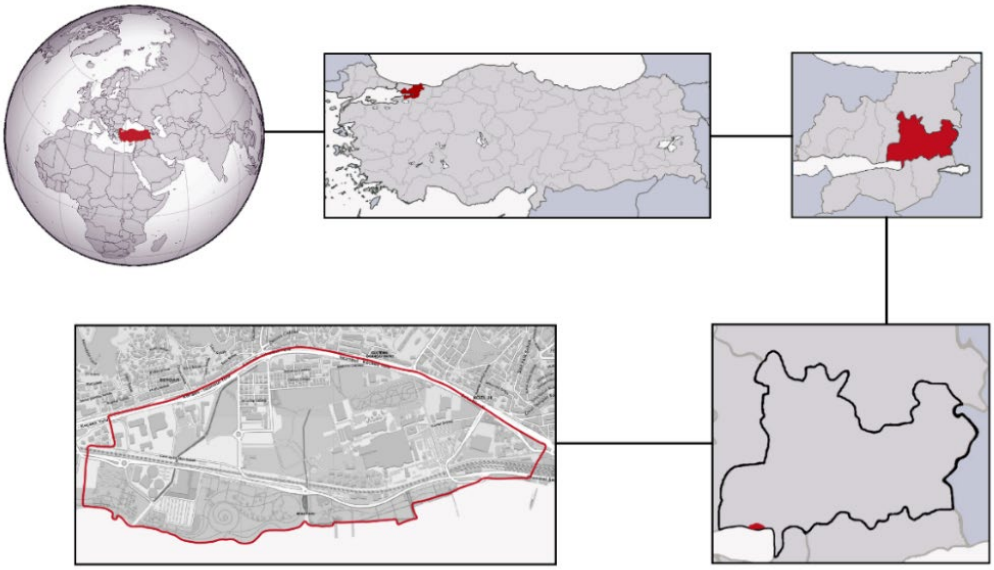

Figure 2 Multi-scale spatial representation of the SEKA–Sekapark area

SEKA was established in İzmit in 1936 as one of the most important industrial complexes of the Early Republican period. Its spatial structure included production halls, warehouses, energy facilities, administrative units, workers' housing, and social facilities (Oral Aydın & Çömlekçioğlu Kartal, 2010; Tunçelli et al., 2020). After production ceased in 2005, the site was transformed into a public coastal park, cultural destination, and recreational urban space within the Sekapark project (Oğuz et al., 2010). The coexistence of industrial heritage buildings, transformed cultural facilities, green public spaces, and accessibility infrastructure makes SEKA–Sekapark a suitable case for evaluating post-industrial transformation through multiple indicators.

3.2. Research Design

The research was structured in three phases. First, a standardized observation form was developed from indicators frequently discussed in post-industrial transformation literature, including building typology, use status, condition/intervention priority, ecological capacity, accessibility, cultural heritage, and urban integration (CABERNET, 2006; Detroit Future City, 2012; Franz et al., 2008; Jordan & von Daniels, 2019). Second, satellite images, OSM-based vector data, NASA SRTMGL1 DEM data, historical SEKA plans, Google Earth historical imagery, and field observation data were processed in a GIS environment. Third, the resulting layers were matched with building-level identifiers and transformed into thematic maps.

3.2.1. Observation Form Approach

The observation form used in this study was developed to integrate measurable physical, ecological, accessibility-based, and heritage-urban integration indicators into a single field-based evaluation tool. The indicators and classification scheme used in the observation form are summarized in Table 1. Fieldwork was conducted between September and October 2025. During this period, 280 building units within the SEKA–Sekapark study area were surveyed. Each building was treated as a separate observation unit. Since the evaluation was conducted through a single-observer approach, inter-observer reliability analysis was not included; however, field observations were cross-checked with photographic records, OSM data, Google Earth imagery, and historical plans where possible.

Table 1 Indicators, Measurement Methods, and Classification Schemes Used in the SEKA–Sekapark Study

Main Category	Sub-Indicator	What It Measures	Classification / Scale
Physical–Structural	Building typology	Original / adaptive function of the building	Production hall / warehouse / technical unit / administrative / residential / social facility / cultural / recreational
	Use status	Current functional activity	Active / Transitional / Idle
	Building condition and intervention priority	Physical condition and required intervention level	1 = urgent intervention / 2 = strengthening / 3 = maintenance / 4 = conservation / 5 = registration potential
Ecological–Environmental	NDVI	Vegetation density and vitality	Mean NDVI, NDVI > 0.30 vegetation mask, vegetation classes
	Coastal vulnerability	Low-elevation exposure within 0–3 m elevation zone	0–1 m high exposure / 1–2 m moderate exposure / 2–3 m low exposure
Transport–Accessibility	Public transport	Proximity to tram and bus stops	100 m and 200 m stop-proximity buffers
	Pedestrian accessibility	Pedestrian route continuity and barrier permeability	Pedestrian / Footway / Steps / Bridge / Underpass Categories
Macro-Scale	Cultural heritage & image	Historical and identity value	Heritage present/absent + cultural function
	Urban center relation	Urban connectivity and pedestrian continuity	Strong / Moderate / Weak

3.2.2. Data Sources

The spatial dataset consists of satellite imagery, DEM data, OSM-based vector data, historical SEKA plans, Google Earth historical imagery, and field observation data. The data sources, their content, purpose of use, and derived indicators are summarized in Table 2. Satellite images supported NDVI-based ecological analysis; DEM data supported elevation-based coastal vulnerability analysis; OSM data provided building footprints, road and pedestrian networks, transport stops, and route geometries; historical SEKA plans supported the interpretation of Fordist-era typologies and original spatial functions; Google Earth imagery supported spatial verification; and field observations validated current use, condition/intervention priority, and missing or inconsistent data points.

Table 2 Data Sources Used in the SEKA–Sekapark Study

Data Source	Content	Purpose of Use	Derived Indicators
Satellite Data	Landsat 7 ETM+ and Sentinel-2 MSI images	Monitoring vegetation change	NDVI, vegetation mask, vegetated area
DEM data	NASA SRTMGL1 DEM, 30 m resolution	Low-elevation coastal exposure assessment	0–3 m coastal vulnerability zones
OSM-Based Vector Data	Building footprints, road–pedestrian network, transport stops, route geometries, and building height tags	Morphological and accessibility analysis	Building geometry, current typology, pedestrian network, and public transport proximity
Historical SEKA plans	Period-based plans obtained from İzmitte SEKA digital archive	Verification of industrial-era typologies and functions	Historical building typology
Google Earth historical imagery	Historical and current image interpretation	Verification of building continuity and spatial configuration	Typological and functional validation
Field Observation Data	On-site building-level records and photographs	Validation of current spatial conditions	Use status, condition/intervention priority, boundary verification

3.2.3. Analytical Techniques

All datasets were processed in EPSG:32635 / UTM Zone 35N where metric calculations were required. The analyses were conducted through QGIS and Python-based tools, including rasterio, numpy, fiona, shapely, pyproj, geopandas, pandas, osmnx, and folium.

NDVI analysis was conducted using Landsat 7 ETM+ Collection 2 Level-2 Surface Reflectance products for 2000, 2005, and 2010, and Sentinel-2 images for 2015, 2020, and 2025. The satellite datasets, product types, spectral bands, spatial resolutions, and projection information used for

NDVI calculation are presented in Table 3. For Landsat 7, red and near-infrared bands correspond to SR_B3 and SR_B4; for Sentinel-2, they correspond to B04 and B08. Raster data were clipped to the SEKA–Sekapark boundary using a GeoJSON boundary file prepared for the SEKA–Sekapark study area, and NDVI was calculated using the standard formula: NDVI = (NIR − Red) / (NIR + Red) (Tucker, 1979). A binary vegetation mask was generated using NDVI > 0.30, and annual statistics including mean NDVI, vegetated surface percentage, and vegetated area were exported as CSV outputs. Because Landsat and Sentinel-2 have different spatial resolutions, and because a separate cloud-cover threshold was not applied, NDVI results were interpreted as broad temporal vegetation patterns rather than precise pixel-level change detection.

Table 3 Satellite Datasets and Bands Used for NDVI Analysis

Period	Satellite / Sensor	Product type	NIR band	Red band	Spatial resolution	Projection
2000–2010	Landsat 7 ETM+	Collection 2 Level-2 Surface Reflectance	SR_B4	SR_B3	30 m	EPSG:32635
2015–2025	Sentinel-2 MSI	Level-2A / available 10 m bands	B08	B04	10 m	EPSG:32635

Building typology was produced through the combined interpretation of OSM-based building geometries, period-based SEKA plans, Google Earth historical imagery, and field observations. Building geometries were obtained in QGIS using the QuickOSM “building” query. The period-based SEKA plans used for typological interpretation were obtained from the İzmitte SEKA digital archive (İzmitte SEKA, n.d.). The detailed typology used in Figure 3 consists of twelve categories representing the historical and contemporary functional diversity of SEKA–Sekapark; for Table 1, these detailed typologies were grouped under broader analytical categories.

Use status was analyzed through a Python–QGIS workflow based on OSM building attributes, road proximity, building size, and field interpretation. Buildings with tags indicating abandonment were classified as idle; buildings with current-use tags such as office, school, museum, or industrial were classified as active; large buildings over 1,500 m² without direct road proximity were identified as potential adaptive reuse candidates; and buildings smaller than 80 m² or with missing attributes were marked as unknown. These initial classes were harmonized into active, transitional, and idle categories. Transitional buildings include adaptive reuse candidates, buildings with uncertain or limited current use, and structures requiring further field interpretation.

Building condition was evaluated through a five-level condition and intervention-priority score informed by the CABERNET (2006) brownfield framework. The scoring process combined field observation with a Python-based rule classification using building area, number of floors, use status, and proximity to roads. The score is not an engineering-level structural safety assessment, but an indicator-based tool for identifying priority intervention zones. The score values and their planning/conservation meanings are explained in Table 4.

Table 4 Building Condition and Intervention-Priority Score

Score	Interpretation	Planning / conservation meaning
1	Urgent intervention	Demolition-level assessment or urgent intervention
2	Strengthening	Building requires strengthening
3	Maintenance	Building requires maintenance and repair
4	Conservation	Building should be considered within conservation strategies
5	Registration potential	Building has strong heritage value and may be proposed for registration or advanced conservation

Elevation-based coastal vulnerability was assessed using the NASA SRTMGL1 Digital Elevation Model with 30 m spatial resolution. DEM-derived elevation values were classified according to a 0–3 m low-elevation coastal exposure framework: 0–1 m as high exposure, 1–2 m as moderate exposure, and 2–3 m as low exposure. Areas above 3 m were considered outside the low-elevation coastal exposure zone. Sea-level rise scenarios, storm surge, wave dynamics, drainage capacity, and hydraulic flood modeling were not included.

Public transport proximity was analyzed through a stop-based buffer approach using OSM-based transport data. Tram, bus, and train stops were obtained through OSM-based spatial queries, duplicate records were removed, and tram/bus stops were used to generate 100 m and 200 m buffers. These buffers were interpreted as stop-proximity indicators rather than full network-based accessibility areas.

Pedestrian accessibility was analyzed using OSM-based walk-network data within the study boundary. The pedestrian network was extracted using the walking-network option in OSMnx and classified according to pedestrian-related OSM tags, including highway=pedestrian, highway=footway, highway=steps, bridge=yes, and tunnel=yes. These categories were used to evaluate pedestrian continuity, barrier permeability, and the relationship between the coastal promenade and inner urban connections. The OSM tags used in the analysis and the spatial indicators derived from them are summarized in Table 5.

Table 5 OSM Tags and Derived Spatial Indicators

Analysis	OSM data used	Derived Indicator
Building Typology	building=*, building:use=*	Building geometry and typological classification
Use status	building attributes, road proximity, building size	Active / transitional / idle use-status categories
Public transport proximity	tram stops, bus stops, railway/tram/bus route geometries	100 m and 200 m stop-proximity buffers
Pedestrian Accessibility	highway=pedestrian, highway=footway, highway=steps, bridge=yes, tunnel=yes	Pedestrian continuity and barrier permeability

4. Findings

The findings are presented under four dimensions corresponding to the indicator structure defined in the methodology: physical-structural characteristics, ecological-environmental characteristics, transport and accessibility, and heritage-urban integration criteria. The analysis shows that the SEKA–Sekapark transformation did not occur uniformly across the site. Cultural, recreational, and public functions are concentrated along the waterfront, while parts of the former production core continue to display transitional use patterns and intervention needs.

4.1. Physical and Structural Characteristics

The physical and structural analysis explains the transformation of SEKA from a Fordist production complex into a post-Fordist urban landscape oriented toward culture, recreation, and public use. This section evaluates building typology, current use status, and building condition/intervention priority through archival plans, field observations, OSM-based vector data, and thematic mapping.

4.1.1. Temporal Evolution of Building Typology

The temporal evolution of building typology reveals the layered spatial development of the SEKA Paper Factory from its establishment in 1936 to the contemporary Sekapark transformation. As shown in Figure 3, the site includes early production structures, later social and administrative facilities, and post-2005 cultural and recreational reuse areas.

The early industrial phase was characterized by large-span production halls, warehouses, technical units, boiler houses, and pulp preparation areas. These structures reflected the rational and production-oriented spatial logic of Fordist industrial organization. During the expansion period, especially from the 1950s to the 1980s, SEKA developed into a more complex industrial campus with workers' housing, social facilities, educational buildings, healthcare units, sports areas, and administrative structures.

After production ceased in 2005, the typological structure of the site changed significantly. Former industrial buildings were adapted for cultural, educational, and recreational uses, including the SEKA Paper Museum, Kocaeli Science Center, exhibition spaces, workshops, and performance

venues. The waterfront was reorganized through landscape interventions, pedestrian routes, and recreational public spaces. Overall, Figure 3 shows three main spatial layers: the Fordist production layer, the institutional industrial campus layer, and the post-Fordist cultural-recreational landscape layer.

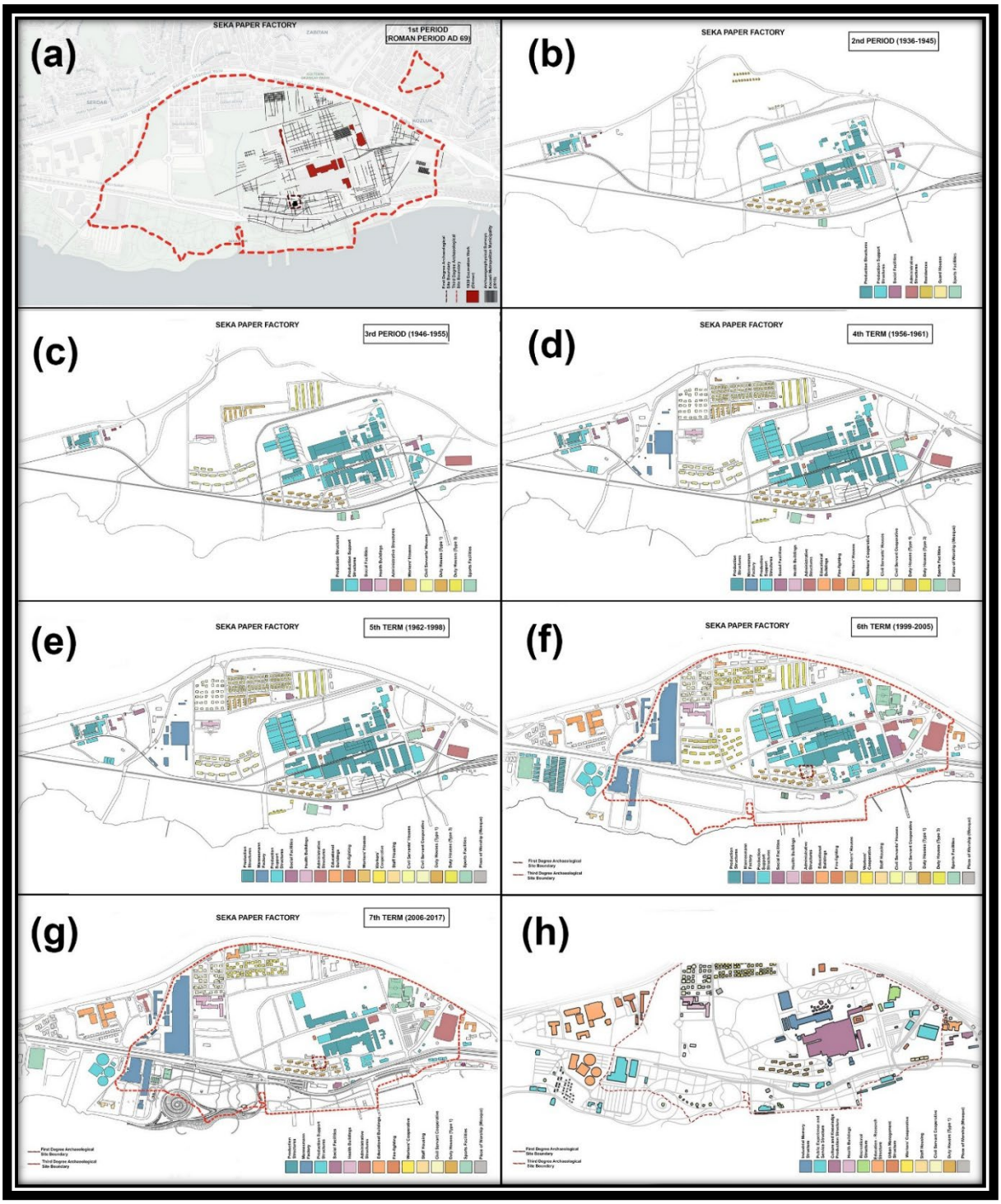

Figure 3 Temporal evolution of SEKA building typology and spatial development phases
Data sources: Historical archival plans, field observations (2025), OSM (2024). The map was produced by the author.

4.1.2. Current Use Status

The current use status of the SEKA–Sekapark area was classified as active, transitional, and idle. As shown in Figure 4, active uses are concentrated primarily along the waterfront and around major cultural and recreational facilities. Out of 280 analyzed building units, 64 buildings (22.9%) were identified as active and 216 buildings (77.1%) as transitional. No building was classified as idle in

the final dataset; however, the idle category was retained in the observation form for methodological completeness.

Active buildings include the SEKA Paper Museum, Kocaeli Science Center, Seka Stage, cultural facilities, recreational service units, and waterfront-related functions. Transitional buildings include adaptive reuse candidates, structures with limited or uncertain use, and buildings requiring further field-based interpretation after the automated OSM-based classification.

The dominance of transitional buildings suggests that the transformation is functionally incomplete at the building-stock level despite the strong public activation of the waterfront. This pattern indicates a staged post-industrial landscape in which the waterfront has been consolidated more strongly than the former production core.

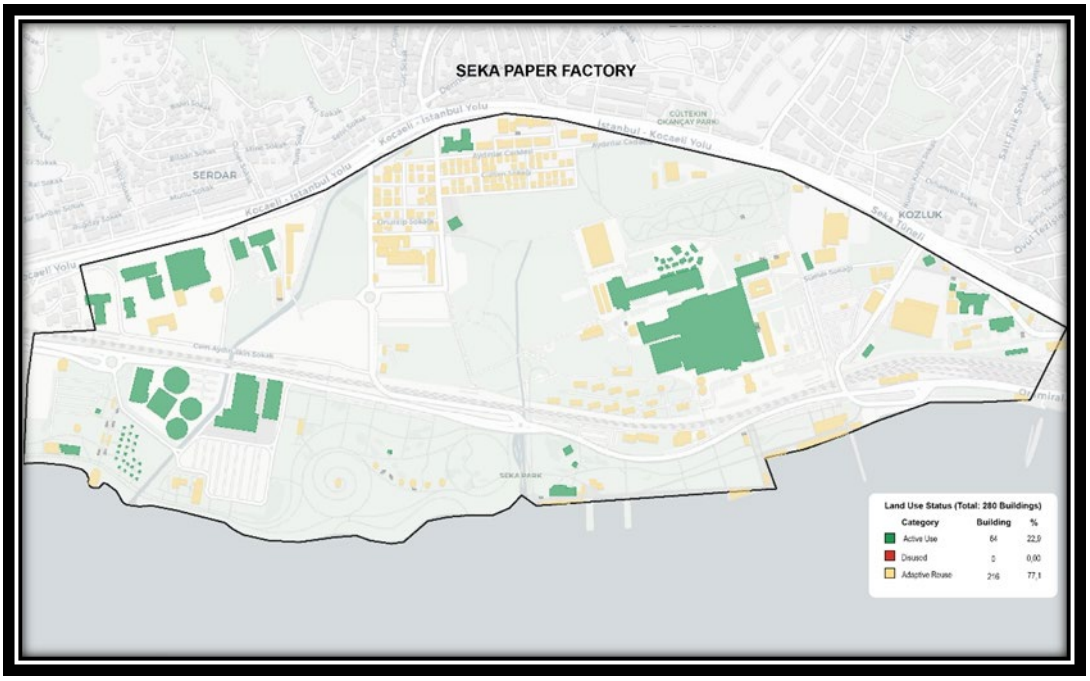

Figure 4 SEKA–Sekapark 2025 building use status
Data sources: Field observations (2025), OSM (2024), QGIS classification (2025). The map was produced by the author.

4.1.3. Building Condition and Intervention Priority

Building condition was evaluated through a five-level condition and intervention-priority score. In this scoring system, lower scores indicate higher intervention needs, while higher scores indicate stronger conservation or heritage-registration potential. Score 1 represents urgent intervention or demolition-level assessment; score 2 represents strengthening need; score 3 represents maintenance and repair; score 4 represents conservation potential; and score 5 represents registration or advanced conservation potential. The spatial distribution of the scores is presented in Figure 5.

The scoring indicates that the former production core contains structures requiring different levels of intervention, ranging from urgent intervention and strengthening to maintenance, conservation, and registration potential. Lower-score structures are mainly associated with areas where functional integration has remained limited, while higher-score structures are generally related to better-preserved or culturally significant buildings. The distribution of score classes indicates that buildings requiring maintenance and conservation are concentrated around the former production core, while registration-potential structures are associated with better-preserved heritage buildings.

This analysis does not represent an engineering-level structural safety assessment. Instead, it provides an indicator-based condition and intervention-priority reading of the building stock. The

results therefore support the identification of priority zones for conservation, strengthening, maintenance, and adaptive reuse within the SEKA–Sekapark transformation area.

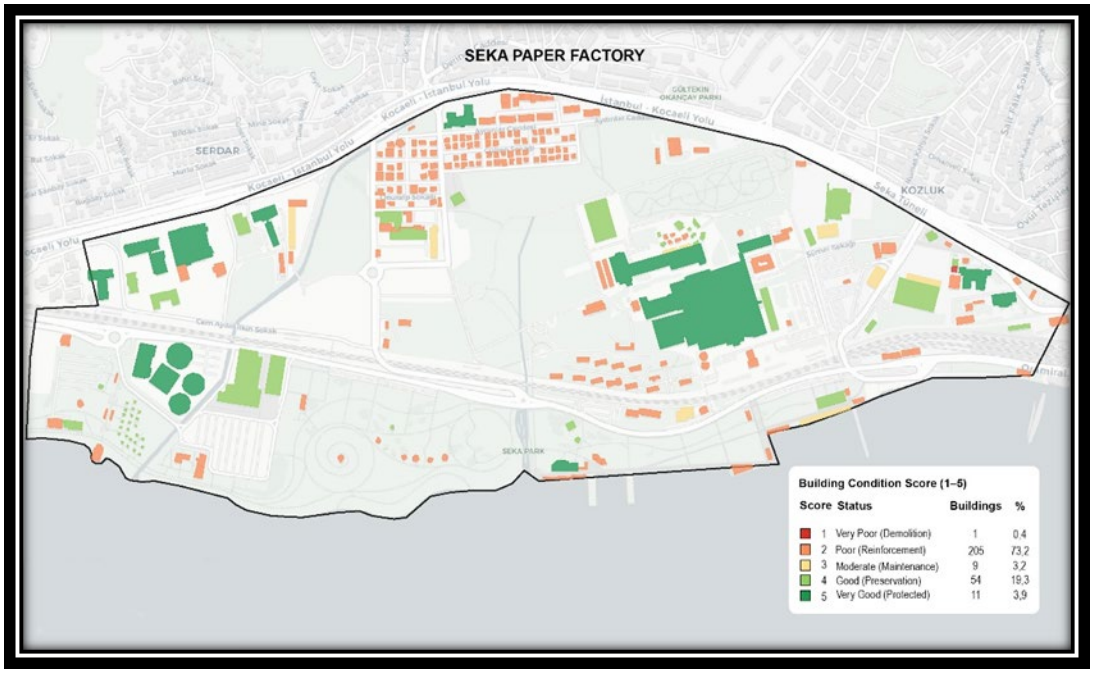

Figure 5 Building condition and intervention-priority score map of the SEKA–Sekapark area
Data sources: Field observations (2025), OSM (2024), QGIS classification (2025). The map was produced by the author.

4.2. Ecological and Environmental Characteristics

The ecological and environmental analysis focuses on vegetation development, landscape recovery, and elevation-based coastal vulnerability. The findings indicate that the transformation of SEKA into Sekapark produced a measurable ecological change, particularly after 2015. However, the low-elevation coastal position of the site also creates exposure that should be considered in long-term climate-adaptive planning.

4.2.1. NDVI-Based Vegetation Analysis, 2000–2025

The NDVI analysis for 2000, 2005, 2010, 2015, 2020, and 2025 reveals a gradual ecological transformation of the SEKA–Sekapark area. As shown in Figure 6, the 2000–2010 period reflects the predominantly impervious and industrial character of the site. Mean NDVI values remained very low during this period: 0.068 in 2000, 0.097 in 2005, and −0.018 in 2010. The vegetated surface ratio calculated using the NDVI > 0.30 threshold was 0% for these three years.

After 2015, NDVI values increased more clearly. Mean NDVI reached 0.162 in 2015, 0.233 in 2020, and 0.250 in 2025. The vegetated surface ratio increased from 12.1% in 2015 to 32.3% in 2020 and 36.3% in 2025. In terms of area, vegetated surfaces reached approximately 176,000 m² in 2015, 469,585 m² in 2020, and 528,295 m² in 2025.

These results indicate a broad increase in vegetation-related surface patterns after the transformation of the former industrial site into Sekapark. The increase in NDVI should be interpreted as a broad temporal vegetation pattern rather than precise pixel-level change detection because the analysis combines Landsat and Sentinel data with different spatial resolutions.

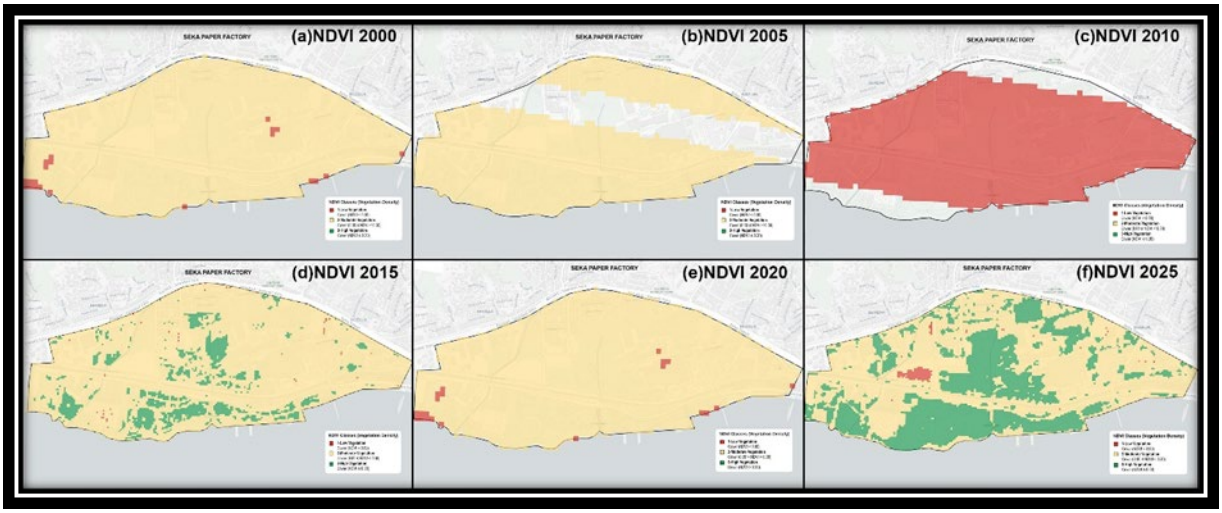

Figure 6 NDVI distribution in the SEKA–Sekapark area for the years 2000, 2005, 2010, 2015, 2020, and 2025
Data sources: USGS EarthExplorer and Copernicus satellite data. The maps were produced by the author.

4.2.2. Elevation-Based Coastal Vulnerability in the SEKA Coastal Zone

The SEKA–Sekapark coastal zone is located in a low-elevation waterfront environment facing the Sea of Marmara. Therefore, an elevation-based coastal vulnerability assessment was conducted using NASA SRTMGL1 DEM data with 30 m spatial resolution. The resulting exposure zones are presented in Figure 7. In this model, 0–1 m was classified as high exposure, 1–2 m as moderate exposure, and 2–3 m as low exposure.

The analysis identified low-lying coastal segments within the 0–3 m elevation range. The overlap between low-elevation zones and recreational waterfront areas indicates that future coastal planning should consider climate-adaptive landscape strategies, including flood-tolerant planting, improved drainage, and flexible public spaces.

Since the model is based only on DEM-derived elevation values, it should not be interpreted as a detailed engineering-level flood simulation. Rather, it provides a strategic spatial framework for identifying low-elevation coastal exposure patterns and guiding climate-sensitive landscape planning decisions.

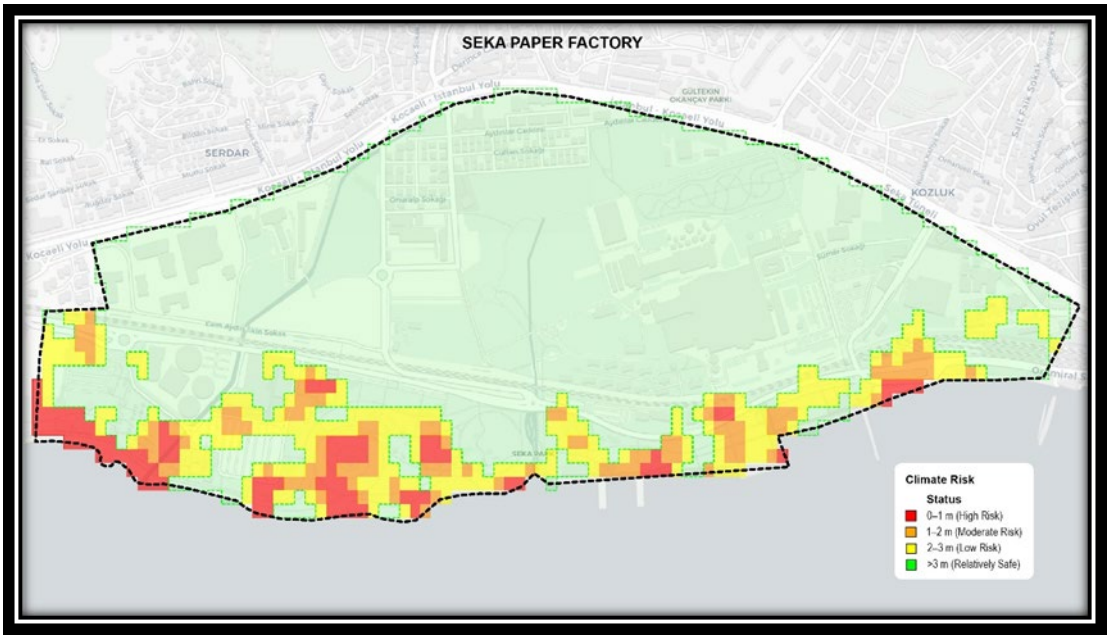

Figure 7 Elevation-based coastal vulnerability zones along the SEKA–Sekapark coastal corridor
Data sources: NASA JPL. (2025). The map was produced by the author.

4.3. Transport and Accessibility

Transport and accessibility are central indicators of post-industrial transformation because former industrial sites are often separated from the city by physical barriers such as railways, highways, walls, and restricted production zones. The SEKA–Sekapark transformation has changed this structure by opening the former industrial landscape to public use and connecting it to urban transport and pedestrian systems.

4.3.1. Public Transport Proximity

Public transport proximity was evaluated through stop-proximity buffers and transport-node distribution. As shown in Figure 8, tram and bus stop locations were mapped together with tram, bus, and railway routes. The analysis identified eight public transport stops around the SEKA–Sekapark area, including five tram stops and three bus stops. The average distance between stops ranged from approximately 350 to 500 m.

The 100 m and 200 m buffer zones around tram and bus stops indicate the areas of immediate pedestrian proximity to public transport nodes. The overlap between certain buffer areas, particularly around Seka Mosque and the western terminal entrance, indicates a strong public transport–pedestrian interface in this part of the site. The tram line runs parallel to the northern boundary of the area and strengthens the relationship between Sekapark and İzmit's urban mobility corridor, while bus routes support eastward connections and multimodal accessibility.

These findings show that SEKA–Sekapark is supported by a closely spaced public transport structure. However, the analysis should be interpreted as a stop-proximity assessment rather than a full network-based accessibility model.

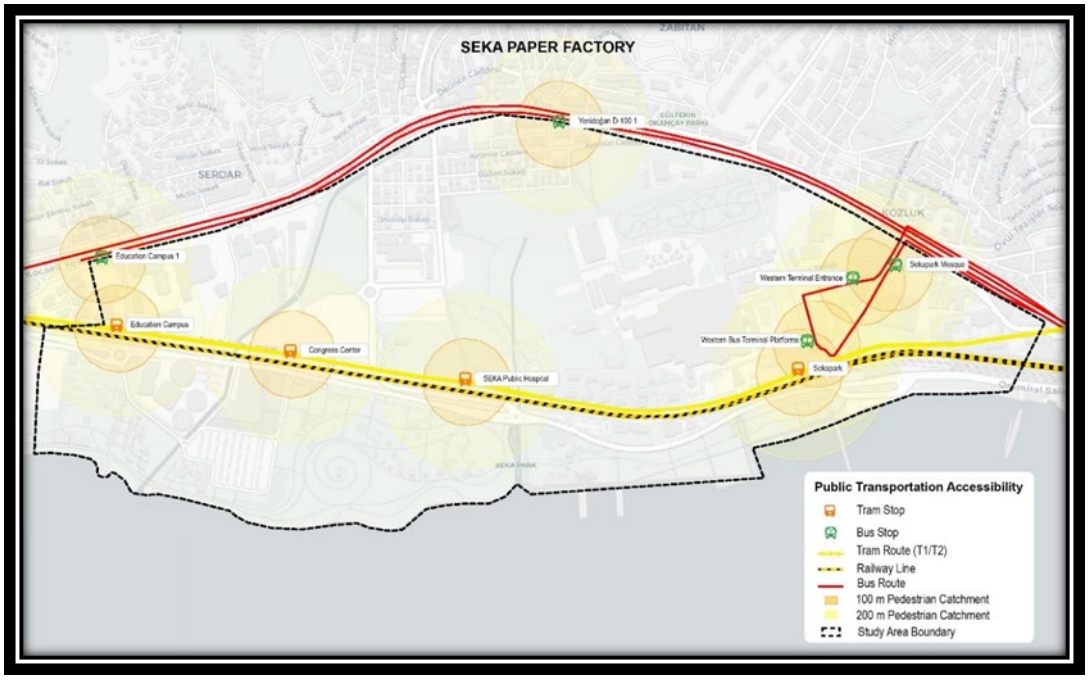

Figure 8 Public transport proximity analysis based on 100 m and 200 m stop buffers in the SEKA–Sekapark area Data sources: OSM (2024) and field observations (2025). The map was produced by the author.

4.3.2. Pedestrian Accessibility and Barrier Permeability

Pedestrian accessibility was assessed through route continuity, crossing points, and the ability of the network to overcome physical barriers. As shown in Figure 9, SEKA–Sekapark has a strong pedestrian structure organized around a linear coastal spine and a finer secondary network.

The OSM-based pedestrian network analysis identified 197 independent pedestrian paths, 42 pedestrianized street or boulevard segments, 17 overpasses, 14 stepped pedestrian routes, 2 pedestrian bridges, and 1 underpass within the SEKA–Sekapark area. This distribution indicates that

the site contains not only a linear coastal promenade, but also a multi-layered pedestrian system that supports internal circulation and connections across physical barriers.

The primary pedestrian route follows the coastline and creates a continuous east–west movement corridor connecting recreational spaces, cultural facilities, green areas, and public waterfront uses. Secondary pedestrian routes provide access between the coastal spine, inner buildings, parking areas, and surrounding urban neighborhoods. Barrier permeability is supported by pedestrian bridges, underpasses, staircase connections, and north–south access routes that reduce the separating effects of highway and railway corridors.

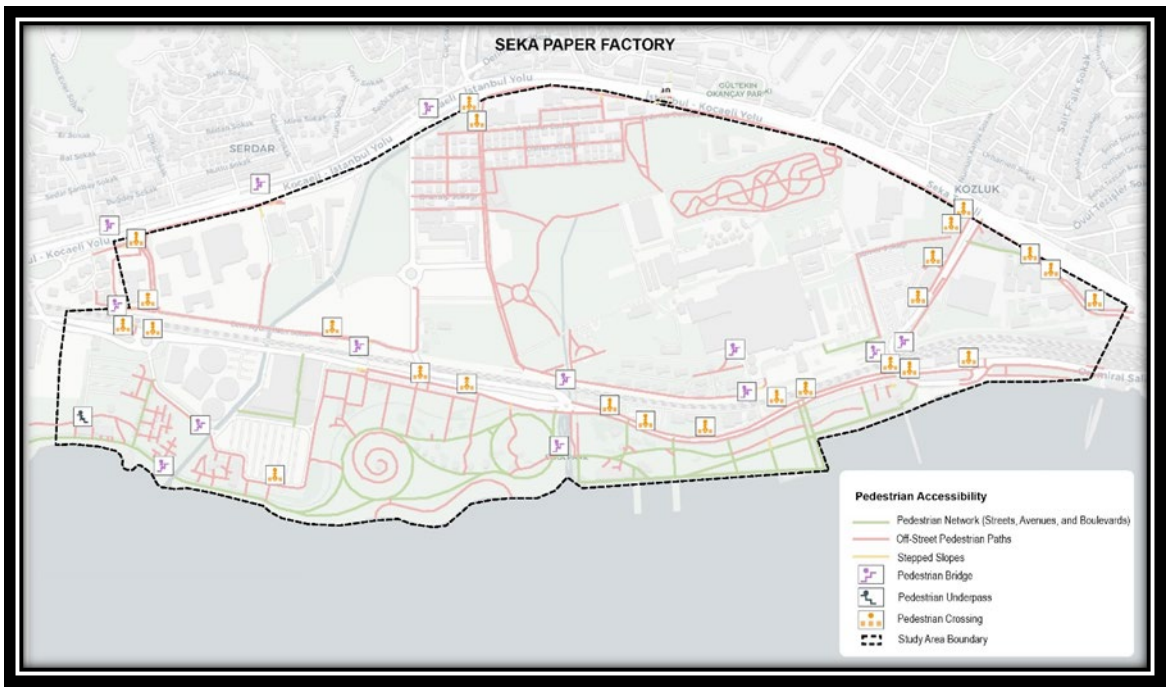

Figure 9 Pedestrian network, main pedestrian spine, and critical connection nodes in the SEKA–Sekapark area
Data sources: OSM (2024) and field observations (2025). The map was produced by the author.

4.4. Macro-Scale Criteria: Heritage and Urban Integration

Heritage and urban integration analysis examines how the SEKA–Sekapark transformation contributes to industrial heritage preservation, cultural identity, public image, and integration with the city center. These criteria are important because post-industrial transformation is not only a physical process but also a symbolic and urban-scale restructuring.

4.4.1. Cultural Heritage and Urban Image

The transformation of SEKA into Sekapark produced a multi-layered cultural landscape in which industrial memory and contemporary public life coexist. As shown in Figure 10, the main heritage and image components can be grouped into three categories: monumental industrial structures, cultural facilities, and tourist-public spaces.

Monumental industrial structures are concentrated around the former production core. The SEKA Paper Museum, preserved factory buildings, locomotive exhibition, and other industrial remnants function as material evidence of the site's production history. Cultural facilities, including the Science Center, exhibition areas, event spaces, performance venues, and workshops, reinterpret industrial heritage through educational and cultural programs. Tourist and public spaces, such as beaches, lawns, walking and cycling paths, amphitheaters, playgrounds, and recreational areas, are concentrated along the waterfront corridor.

Together, these three layers produce a hybrid urban identity. SEKA is no longer only an industrial memory site or a recreational park; it has become a cultural-industrial public landscape where heritage conservation, public use, and urban image-making interact.

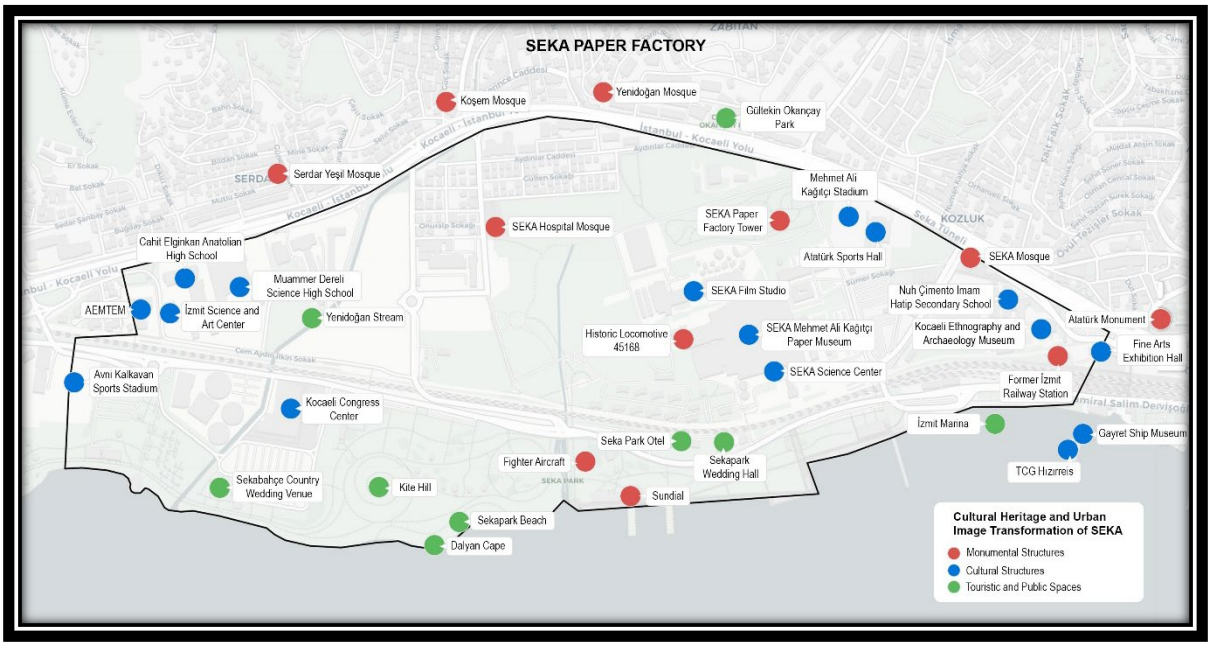

Figure 10 Cultural heritage classification of the SEKA–Sekapark area
Data sources: OSM (2024) and field observations (2025). The map was produced by the author.

4.4.2. Morphological and Functional Integration with the City Center

The relationship between SEKA–Sekapark and the city center was assessed through pedestrian flows, accessibility rings, functional nodes, and morphological permeability. As presented in Figure 11, the findings show that the transformation has strengthened the center–coast relationship and integrated the former industrial area into İzmit's everyday circulation system.

Three main pedestrian flow axes connect the city center with the waterfront. The first extends from Cumhuriyet Park and the Walking Path toward the coast. The second follows the tram corridor and connects central neighborhoods with Sekapark. The third links the Orhan neighborhood and surrounding urban fabric to the coastal area. These axes create a multi-directional movement structure rather than a single access route.

The 1 km and 2 km accessibility rings shown in Figure 11 indicate that Sekapark is reachable from central neighborhoods and functions as an embedded public node within the urban fabric. Functional nodes such as the SEKA Paper Museum, Kocaeli Science Center, Cumhuriyet Park, Yürüyüş Yolu, tram stops, and recreational waterfront areas are located at the intersection of movement corridors. Overall, SEKA–Sekapark strengthens its relationship with the city center through morphological permeability, pedestrian flow organization, and functional integration.

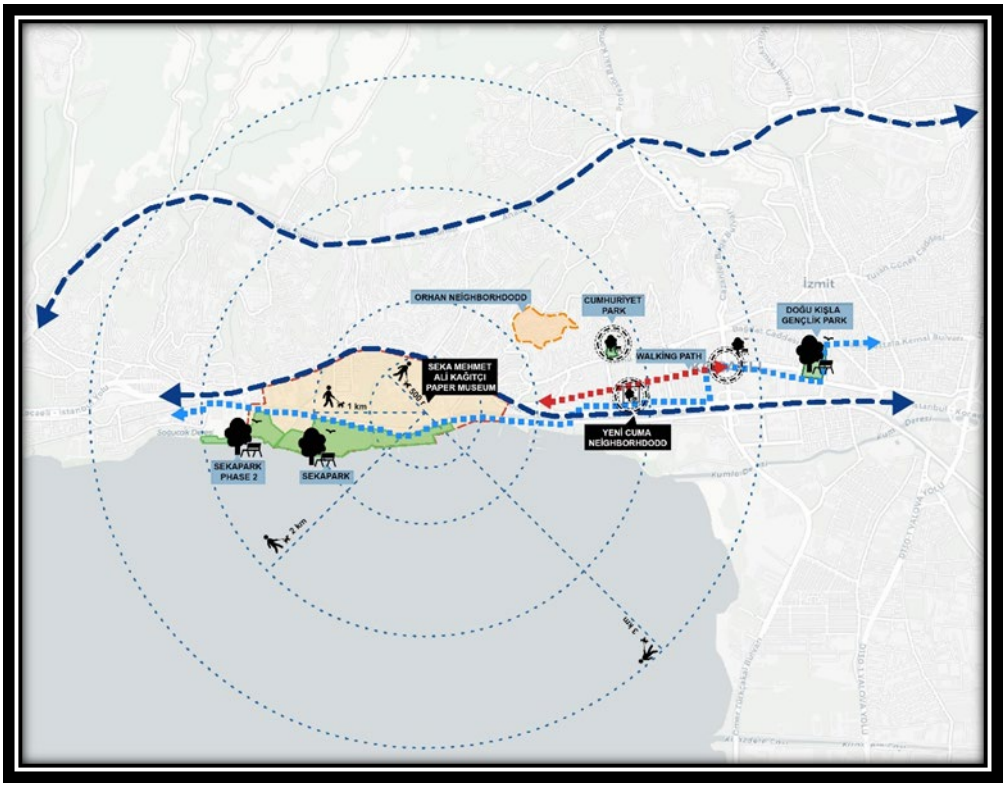

Figure 11 Pedestrian accessibility, orientation patterns, and functional linkages between SEKA–Sekapark and the city center
Data sources: OSM (2024) and field observations (2025). The map was produced by the author.

The principal measurable findings obtained from the physical–structural, ecological–environmental, transport–accessibility, and heritage-urban integration analyses are summarized in Table 6.

Table 6 Summary of Key Measurable Findings and Transformation Status in the SEKA–Sekapark Area

Dimension	Indicator	Main finding	Spatial interpretation	Transformation status
Physical–structural	Current use status	Of 280 building units, 64 buildings (22.9%) were classified as active and 216 buildings (77.1%) as transitional. The reported totals leave no building unit in the idle category.	Active cultural and recreational functions are concentrated primarily along the waterfront, whereas transitional buildings are more strongly associated with the former production core.	Partially consolidated
Physical–structural	Building condition and intervention priority	Buildings were evaluated using a five-level scale ranging from urgent intervention (Score 1) to registration or advanced conservation potential (Score 5).	Structures requiring intervention, strengthening, or maintenance are concentrated mainly within the former production core, while better-preserved and culturally significant structures display stronger conservation potential.	Partially consolidated
Ecological–environmental	NDVI-based vegetation change	Mean NDVI increased from 0.068 in 2000 to 0.250 in 2025. The vegetated surface ratio increased from 0% in 2000–2010 to 12.1% in 2015, 32.3% in 2020, and 36.3% in 2025.	Vegetation-related surface patterns increased substantially after 2015, indicating the ecological transformation of the former industrial landscape.	Largely consolidated
Ecological–environmental	Vegetated surface area	Vegetated surface reached approximately 176,000 m² in 2015, 469,585 m² in 2020, and 528,295 m² in 2025.	Vegetation expansion is associated with landscape interventions and the development of green public spaces within Sekapark.	Largely consolidated
Ecological–environmental	Coastal vulnerability	Coastal exposure was classified as high at 0–1 m, moderate at 1–2 m, and low at 2–3 m elevation.	Low-elevation segments overlap with recreational waterfront areas, indicating the need for climate-adaptive landscape planning.	Incomplete

Transport–accessibility	Public transport proximity	Eight public transport stops were identified around the site, including five tram stops and three bus stops. Average distances between stops range approximately from 350 to 500 m.	The tram line and closely spaced transport stops provide a strong public transport–pedestrian interface, particularly around Seka Mosque and the western terminal entrance.	Largely consolidated
Transport–accessibility	Stop-proximity buffers	Immediate public transport proximity was evaluated through 100 m and 200 m buffers around tram and bus stops.	Overlapping buffer areas indicate strong proximity to public transport nodes in specific parts of the site. The result represents stop proximity rather than full route-based accessibility.	Largely consolidated
Transport–accessibility	Pedestrian accessibility	The analysis identified 197 independent pedestrian paths, 42 pedestrianized street or boulevard segments, 17 overpasses, 14 stepped pedestrian routes, 2 pedestrian bridges, and 1 underpass.	A continuous coastal spine and a multi-layered secondary network support internal circulation and reduce the barrier effects of highway and railway corridors.	Largely consolidated
Heritage-urban integration	Cultural heritage and urban image	Heritage and image components were classified into three groups: monumental industrial structures, cultural facilities, and tourist–public spaces.	Preserved industrial structures maintain material memory, cultural facilities reinterpret industrial heritage, and public waterfront spaces integrate the site into everyday urban life.	Partially consolidated
Heritage-urban integration	City-center relationship	Three principal pedestrian flow axes connect the city center and surrounding neighborhoods with the waterfront. The analysis also included 1 km and 2 km accessibility rings.	Multi-directional pedestrian flows and the distribution of cultural and recreational nodes strengthen the morphological and functional relationship between Sekapark and İzmit city center.	Largely consolidated

Note: The transformation-status categories represent an interpretive synthesis of the spatial findings and do not constitute an additional numerical scoring system.

5. Discussion

The findings show that the SEKA–Sekapark transformation can be interpreted as a multi-layered post-industrial restructuring process in which industrial heritage conservation, ecological recovery, public accessibility, and cultural-recreational reuse intersect. The former Fordist production complex has been redefined as a post-Fordist public coastal landscape; however, the transformation is not spatially homogeneous. The waterfront has been strongly activated through cultural, recreational, and landscape-oriented functions, while parts of the former production core continue to display transitional use and intervention needs. This uneven spatial pattern is one of the key outcomes of the study.

The first implication concerns industrial heritage and adaptive reuse. The preservation and reuse of selected industrial buildings, particularly the SEKA Paper Museum and related cultural facilities, have allowed the industrial memory of the site to remain visible within the contemporary urban landscape. This supports the view that post-industrial transformation should not be understood only as physical redevelopment, but also as cultural reinterpretation. Nevertheless, the persistence of buildings requiring intervention within the former production core indicates that heritage-led transformation remains incomplete. Conservation strategies should therefore extend beyond the most visible or symbolically significant structures and include less prominent industrial buildings that still carry spatial and historical value.

The second implication relates to ecological transformation. The marked increase in vegetation after 2015 indicates that landscape interventions strengthened the ecological capacity of the former industrial site. However, the NDVI workflow combines different satellite sensors and does not include a separate cloud-cover threshold; therefore, the results should be interpreted as general temporal vegetation patterns rather than exact pixel-level change detection.

The third implication concerns accessibility and urban integration. Pedestrian accessibility analysis shows that SEKA–Sekapark is supported by a multi-layered walk network composed of pedestrianized streets, footways, steps, bridges, overpasses, and underpasses. Public transport analysis also shows a close distribution of tram and bus stops around the site. These findings confirm that accessibility is a decisive factor in transforming former industrial areas into active public landscapes. However, the public transport assessment is based on stop-proximity buffers rather than full route-based network accessibility, and this limitation should be considered when interpreting the results.

The fourth implication relates to coastal vulnerability. The 0–3 m elevation-based assessment using NASA SRTMGL1 DEM data shows that some recreational waterfront areas overlap with low-elevation exposure zones. This does not reduce the public value of Sekapark, but it reveals an important planning issue for the long-term resilience of the area. Since the analysis is based on 30 m DEM-derived elevation values rather than detailed hydraulic modeling, the results should be interpreted as a strategic coastal exposure assessment. The overlap between low-elevation zones and recreational waterfront areas indicates that future coastal planning should consider climate-adaptive landscape strategies, including flood-tolerant planting, improved drainage, and flexible public spaces.

Methodologically, the study contributes to post-industrial transformation literature by testing an adapted observation-form approach supported by GIS, remote sensing, DEM analysis, OSM-based spatial data, and field observations. Existing studies often examine building condition, vegetation change, accessibility, cultural heritage, and urban integration separately. In contrast, this study brings these indicators together within a single field-based evaluation framework. The application of the framework to 280 building units demonstrates that physical, ecological, accessibility-based, and heritage-urban integration indicators can be evaluated together at the site scale.

Several limitations should be acknowledged. First, the study is based on a single case, which limits generalizability. Second, some spatial data rely on OSM-based vector information, which may contain incomplete or inconsistent attributes; therefore, OSM data were interpreted together with field observations, Google Earth imagery, and historical plans. Third, NDVI analysis may be affected by image date, seasonal variation, atmospheric conditions, cloud cover, and satellite resolution. Fourth, the coastal vulnerability analysis is based on NASA SRTMGL1 DEM data with 30 m spatial resolution and should not be interpreted as an engineering-level flood-risk model. Fifth, the building condition score is an indicator-based condition and intervention-priority score rather than a detailed structural safety assessment. Finally, this study does not include detailed user surveys, economic impact analysis, visitor behavior, or social perception data. Future research should integrate these dimensions to better understand the social and economic outcomes of post-industrial transformation.

6. Conclusion and Recommendations

This study analyzed the transformation of the SEKA Paper Factory into Sekapark through measurable physical, ecological, accessibility-based, and heritage-urban integration indicators. By combining field observations, GIS-based spatial analysis, remote sensing, DEM-based elevation assessment, OSM-based network/proximity analysis, and archival interpretation, the research evaluated the transformation of a former Fordist industrial production complex into a post-Fordist cultural, recreational, ecological, and publicly accessible coastal landscape.

The findings demonstrate that SEKA–Sekapark is a significant example of post-industrial restructuring in Türkiye. The former industrial site has been redefined through cultural reuse, waterfront publicization, ecological improvement, and strengthened urban accessibility. However, the transformation is spatially uneven. The waterfront has been strongly activated through cultural and recreational functions, while parts of the former production core continue to display transitional use patterns and intervention needs. Therefore, the transformation should not be

interpreted as a fully completed process, but rather as a staged redevelopment that still requires targeted conservation, maintenance, strengthening, and adaptive reuse strategies.

The main methodological contribution of the study lies in the development and testing of an adapted observation-form framework. The framework brings together indicators that are often evaluated separately, including building typology, use status, condition/intervention priority, NDVI-based vegetation change, elevation-based coastal vulnerability, public transport proximity, pedestrian connectivity, cultural heritage value, and city-center integration. By applying these indicators to 280 building units, the study demonstrates that post-industrial transformation areas can be evaluated in a measurable, comparable, and spatially explicit manner.

Based on the findings, several recommendations can be proposed. Buildings assigned Scores 1–3 should be prioritized for urgent intervention, strengthening, maintenance, or adaptive reuse according to their specific condition. Ecological improvement should be extended beyond the waterfront through stronger green infrastructure and greater planting continuity. Low-elevation coastal segments should be redesigned through climate-adaptive landscape strategies, including flood-tolerant vegetation, improved drainage, and flexible public spaces. Pedestrian and bicycle connectivity should be strengthened, especially in fragmented or parking-dominated areas. Future management strategies should preserve the balance between industrial heritage, cultural programming, recreational use, and ecological resilience.

Future studies should test the proposed framework in other post-industrial transformation areas in Türkiye and comparable international cases to evaluate its transferability. Further research should also integrate user surveys, visitor behavior analysis, economic impact assessment, social perception data, higher-resolution DEMs, detailed structural assessments, and long-term monitoring of ecological and spatial change. Such additions would provide a more comprehensive understanding of how post-industrial transformation affects not only the physical landscape, but also social use, economic value, and urban identity.

In conclusion, the SEKA–Sekapark transformation demonstrates that former industrial areas can be evaluated through integrated and measurable spatial indicators. Successful post-industrial transformation requires more than the reuse of industrial buildings or the creation of public open space; it requires the coordinated evaluation of physical condition, ecological capacity, accessibility, cultural heritage, and urban integration. In this sense, SEKA–Sekapark offers both a valuable case for understanding industrial waterfront transformation in Türkiye and an adapted methodological framework for assessing similar post-industrial landscapes.

CRediT Authorship Contribution Statement

Aslıhan Uygun: Writing – original draft, Formal analysis, Investigation, Data curation, Conceptualization, Visualization. Elif Sağlık: Writing – review & editing, Methodology, Conceptualization, Supervision.

Declaration of Competing 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 paper.

Data Availability

Data will be made available on request.

Ethics Committee Approval

Ethics committee permission is not required.

Note: *This study is based on the first author's master's thesis, which was carried out under the supervision of the second author.*

References

CABERNET. (2006). *Sustainable brownfield regeneration: CABERNET network report*. University of Nottingham.

Church, A. (1988). Urban regeneration in London Docklands: A five-year policy review. *Environment and Planning C: Government and Policy*, *6*(2), 187-208. https://doi.org/10.1068/c060187

Detroit Future City. (2012). *Detroit future city: 2012 Detroit strategic framework plan*. Detroit Future City

Franz, M., Güles, O., & Prey, G. (2008). Place-making and "green" reuses of brownfields in the Ruhr. *Tijdschrift voor Economische en Sociale Geografie*, *99*(3), 316-328. https://doi.org/10.1111/j.1467-9663.2008.00464.x

Harvey, D. (1989). *The condition of postmodernity: An enquiry into the origins of cultural change*. Blackwell.

İzmitte SEKA. (n.d.). *İzmit SEKA'nın dönüşümü*. Retrieved from https://www.izmitteseka.com/

Jacobs, A., & Estensoro, M. (2020). Smart city development in Zorrotzaurre, Bilbao: A case analysis. *Urban Science*, *4*(1), 67. https://doi.org/10.3390/urbansci4010067

Jordan, L., & von Daniels, Y. (2019). *HafenCity Hamburg: A new model for social sustainability*? [Master's thesis, Copenhagen Business School].

Masierek, E. (2021). Urban regeneration of brownfield sites… and its impact on their immediate surroundings: A case study of Łódź (Poland). *Studia Regionalne i Lokalne*, *1*(83), 37_58. https://doi.org/10.7366/1509499518303

Mees, H. L. P., Driessen, P. P. J., & Runhaar, H. A. C. (2014). Legitimate adaptive flood risk governance beyond the dikes: The cases of Hamburg, Helsinki and Rotterdam. *Regional Environmental Change*, *14*(3), 671-682. https://doi.org/10.1007/s10113-013-0511-7

NASA JPL. (2025). *NASA Shuttle Radar Topography Mission Global 1 arc second V003*. NASA EOSDIS Land Processes DAAC.

Oğuz, D., Saygı, H., & Akpınar, N. (2010). Kent içi endüstri alanlarının dönüşümüne bir model: İzmit/Sekapark [A model for the transformation of inner-city industrial areas: İzmit/Sekapark]. *Coğrafi Bilimler Dergisi*, *8*(2), 157-167.

OpenStreetMap Wiki. (2024). *Key: Highway*. Retrieved from https://wiki.openstreetmap.org/wiki/Key:highway

Oral Aydın, B., & Çömlekçioğlu Kartal, G. (2010). Kocaeli SEKA I. Kağıt Fabrikası'nın mimari analizi ve yeniden kullanım olanakları [Architectural analysis and reuse possibilities of Kocaeli SEKA Paper Factory I]. *TÜBA-KED*, *8*, 45-60.

Plaza, B. (2000). Evaluating the influence of a large cultural artifact in the attraction of tourism: The Guggenheim Museum Bilbao case. *Urban Affairs Review*, *36*(2), 264_274. https://doi.org/10.1177/107808740003600206

Sobala-Gwosdz, A., & Gwosdz, K. (2017). "Katowice effect"? Regeneration of the site of the former Katowice coal mine through prestige cultural projects. *Urban Development Issues*, *56*, 27-40.

Tucker, C. J. (1979). Red and photographic infrared linear combinations for monitoring vegetation. *Remote Sensing of Environment*, *8*(2), 127-150.

Tunçelli, O., Muşkara, Ü., & Hülagü, K. T. (2020). Kocaeli bölgesi kültürel ve endüstriyel mirası geliştirme proje önerileri [Project proposals for the development of cultural and industrial heritage in the Kocaeli region]. *Sanat ve Tasarım Dergisi*, *6*(3), 697-717.

Vanolo, A. (2008). The image of the creative city: Some reflections on urban branding in Turin. *European Urban and Regional Studies*, *15*(1), 21-40. https://doi.org/10.1177/0969776407081275

Resume

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A morphological framework for delineating character areas in a coastal town: The case of Görele, Türkiye

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Yelda Aydın Türk**

Abstract

Urban morphology has long sought to translate the historical, environmental, and built-form structure of settlements into legible units that planning can act on. In practice, however, the connection between morphological analysis and planning has remained limited, particularly in topographically differentiated small towns where standard density controls fail to fully address the distinct character of areas that are formed through topography, historical development, and built form. This paper develops a method for delineating character areas within a historico-geographical framework that is applicable to planning practice. The method synthesizes three groups of analysis: historical development, natural environmental structure, and built form and land use, to delineate different character areas of the urban landscape. The rural-to-urban transect was then applied as a secondary assessment to question the character area classification. The method is applied to Görele, a small coastal town in northeastern Türkiye, selected for its topography and traceable urban development history since the start of the Republican era in 1923. After the synthesis, nine character areas are defined in Görele, each shaped by a specific overlay of development history, natural setting, plot pattern, density, and building form. Non-parametric tests confirm that the areas differ significantly in plot area, ground space index, floor area ratio, and number of storeys. A Spearman rank correlation along the main rural-to-urban sequence shows that plot size decreases and density values increase toward the urban core, but areas with similar density values can differ substantially in plot pattern, street structure, and historical depth. The findings show that character area delineation provides a more differentiated basis for planning than density categories alone and identifies areas where high-density development has occurred without adequate integration with the urban context. In coastal towns shaped by constraining topography and historical development, this approach can guide density control toward more adaptive and contextual urban planning.

Keywords: character area delineation, historico-geographical approach, rural-to-urban transect, urban density

1. Introduction

Urban form is the physical structure of a settlement, made up of streets, plots, blocks, and buildings (Moudon, 1997). Among its different dimensions, the physical built form is the most evident and persistent reference: buildings, plots, and streets usually change more slowly than land use, ownership, and activity patterns, which makes them a relatively stable basis for understanding how a settlement has developed and how it may be guided in the future (Moudon, 1997; Kropf, 2009, 2011, 2013a). Morphological research has a long tradition of evaluating the historical, functional, and environmental information condensed in this physical structure within a single interpretive framework (Kropf, 2009). In planning, spatial heterogeneity must be translated into legible units, such as plots, blocks, fabrics, and areas, through which regulation, conservation, and design control can be applied (Birkhamshaw & Whitehand, 2012; Monteiro & Pinho, 2022).

Character areas are among the main units through which urban form is interpreted and used in planning. In the historico-geographical approach, character areas are not only descriptive units.

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They also provide an explanatory basis for understanding the formation and transformation of urban landscapes. Thus, they can become practical tools to control urban growth and to inform planning decisions such as conservation, intensification, design control, or transformation. Yet, in practice, the connection between morphological research and planning has often been limited (Whitehand & Morton, 2004). This limitation is also evident in how character areas, as one of the central concepts in urban morphology, are defined and drawn (Oliveira & Yaygın, 2022).

In urban planning, boundaries are usually drawn along administrative borders, roads, or rivers, with little attention to urban form (Larkham & Morton, 2011). Detailed morphological analysis, on the other hand, is not equally useful at all planning scales. The problem, therefore, is not a lack of morphological knowledge, but how to turn this knowledge into boundaries that work both analytically and practically. This is more difficult in settlements that have a long history and are not fully consolidated (Oliveira & Yaygın, 2022). Defining boundaries is, thus a key step in studying character areas. The establishment of a character area boundary is not a simple process. A character area should show a clear order within its limits and distinct differences from surrounding areas. This determination cannot be based only on measurement; it also depends on the purpose, the scale, and the intended use of the results (Larkham & Morton, 2011). Built form is normally ambiguous, and the task is to handle this uncertainty in a structured way (Kropf, 2013b).

A further problem is that character area studies tend to give more emphasis to the built components of urban form, while natural characteristics are not always treated as a separate analytical layer. However, urban form does not develop independently of place. It is shaped by topography, the natural environment, and historical processes that influence settlements over time. Natural characteristics may become major determinants of urban form, especially in small and topographically differentiated settlements. It is important to comprehend the morphological dimension in the urban planning process. Areas with different historical, natural, and physical attributes should be considered when making decisions. It is evident in Türkiye, where urban space has increasingly been shaped by neoliberal policies and large-scale projects (Şengül, 2009) since the early 2000s, in line with contemporary neoliberal urban planning applications (Peck & Brenner, 2009). Tekeli (1994) states that planning cannot be considered separately from the processes through which urban space is produced. In practice, however, development has largely been controlled through density rights, with limited direct consideration of urban form and character. The Condominium Law No. 634, enacted in 1965, legally enabled the division of ownership within apartment buildings by allowing multiple independent units on a single plot. This arrangement made coordinated intervention at the area scale more difficult and allowed redevelopment to proceed on a plot-by-plot basis (Balamir, 1975). From the 2000s onwards, construction of high-density housing projects became the dominant type of building. In cities of different scale and/or historical background, this process resulted in increasingly similar forms of development despite the local context of the site (Ünlü, 2026).

This concern is directly related to current planning processes and regulations that have no strict rules regarding areas differing in their historical, natural, and physical characteristics. Adopting a character area methodology can make such contextual differences apparent through interpreting the urban landscape via its historical development, topography, and change patterns. With no methodology like this, densification could potentially weaken distinctions that shape urban form. Identifying such differences is of paramount importance for planning responding to local conditions, instead of treating urban land primarily as a future developmental area. In order to resolve this issue, the present study 1) builds a method for delineating character areas and 2) discusses its relevance regarding planning practice, and 3) suggests three analysis groups: development history, nature and environment, together with built form and land use.

2. Theoretical Framework

Urban morphology has been developing around ongoing intellectual knowledge, and the Conzenian School emerges as one of the most influential schools of thought for understanding the

historical formation of urban form. With its foundation in historico-geographical analysis, this tradition examines the urban landscape through the interaction of town planning, building fabric, and land use (Conzen, 1988). Each component has spatial information of successive periods of development. While early Conzenian work focused on morphological regions as units of analysis (Conzen, 1969), the concept of the character area has since gained importance for urban planning practices. A character area can simply identify and articulate the distinctive physical qualities of urban landscape. This shift becomes evident with cases such as Porto in Portugal (Oliveira, 2006) and Bath in England (Hall, 2008) to translate morphological knowledge into tools applicable to urban planning and design practice. On this basis, a character area can be understood as spatial units that represents internal coherence. This vocabulary translates the underlying Conzenian logic into a form more readily usable in planning and public discussion (Birkhamshaw & Whitehand, 2012; An & Gu, 2018). Character areas should not be solely used as descriptive units, but also as an explanatory basis for planning (Conzen, 1988). They therefore connect the analytical reading of urban form with planning questions such as conservation, intensification, design control, and transformation. Character area study cases such as Alnwick (England), Ludlow (England), Stratford-upon-Avon (England), Shanghai (China) together with Porto and Bath (Oliveira & Yaygın, 2022), represent its applicability. These studies show that character areas are not static or simply administrative units. Yet, they are interpretive units defined through the combination of historical development, town-plan structure (Streets, plots, and buildings), land use, and the degree of morphological coherence within an area, meaning that character area analysis depends on careful articulation of multiple sources of data.

Any type of morphological analysis generally requires (1) data that are not always ready for use, (2) extensive fieldwork, and (3) archival research due to the level of detail needed with respect to the related size increase when the analysis covers, for example, an entire town (instead of a historic core or a single neighborhood). Whitehand (2005) notes that the purpose and scope of a morphological study should be determined by its scale, resolution, and level of detail. The takeaway is that morphology can inform urban planning but methodological adaptations must also account for the context of the planning within which urban space is produced, regulated, and transformed.

2.1. Delineation of Character Areas

Recent morphological research in the body of literature studies the delineation of character areas generally in two different ways. The first case aims at a greater degree of transparency in the delineation process by using explicit criteria. For example, Arat (2023) identifies (1) town plans, (2) building fabrics, and (3) land use as separate criteria, while applying them in a structured sequence: Town plans are examined first, and followed by building fabrics and land use. Arat notes that clearly stating and ordering the criteria can reduce ambiguity in interpretation (as objectivity cannot be fully achieved). In a similar way, Oliveira and Yaygın (2022) observe that regionalization studies often do not illustrate their procedural steps in sufficient detail; steps that include (1) selection of criteria, (2) establishment of a hierarchy, (3) identification of form complexes, and 4) preparation of a map. Those authors note that these procedures should be stated explicitly, in order to prevent the method from functioning as a “black box”. Evidently, morphological analysis requires substantial fieldwork and archival material, and these requirements become more demanding when the analysis covers a whole town (rather than the aforementioned historical core or single neighborhood).

Regarding the aforementioned study of Whitehand (2005), comparative studies show that the three main approaches in urban morphology, the historico-geographical, process typological, and configurational, can be combined in a structured way. Combining these approaches allows for a more definitive analysis of the stable elements of urban form, such as the street network and plot pattern. It also allows for variation in the analysis of elements that are less resistant to change, such as buildings and their uses (Monteiro & Pinho, 2022). These studies show that methodological

integration does not require the abandonment of interpretive reading; rather, it depends on making the logic of combination more explicit.

The second approach is represented by quantitative and computational studies. Recent work has expanded the capacity of urban morphology to classify urban form systematically and at scale, developing scalable, data-driven approaches that support comparative analysis and typological interpretation using large datasets (Fleischmann et al., 2022; Vartholomaios, 2025; Fan et al., 2025). More recent machine-learning approaches detect urban form types where multidimensional datasets make manual classification difficult, with increasing attention to interpretability and spatial context. Part of this work has also returned to the cadastral plot as an analytical unit because of its continuing relevance to the historical and regulatory logic of urban form (Vartholomaios, 2025; Fan et al., 2025).

These strengths, however, are oriented primarily toward large-scale typological detection. They also depend on the availability of comprehensive datasets, which may be limited in small-sized settlements. The appropriate method of character area delineation depends on the study's scope and aim. Data-driven classification may not capture the distinctions relevant to planning decisions and may reduce complex character to density measures (Kropf, 2013b; Birkhamshaw & Whitehand, 2012). Thus, a mediating position is needed: analytical steps that are open to validation, combined with an interpretive, planning-informative reading of urban form.

2.2. Natural Setting and the Rural-to-Urban Transect

Natural characteristics, such as topography, have not usually been treated as a separate analytical layer in the historico-geographical tradition. However, where they are major determinants of urban form, they can be incorporated alongside historical development and current built form (Kropf, 2009). This is especially important in settlements where terrain, coastline, slope, drainage, and elevation thresholds shape the location, direction, and intensity of urban development. In such contexts, the natural environment is not only a background condition, but a fundamental dimension of morphological differentiation.

A parallel line of planning thought has approached the rural-urban relationship as a gradient rather than a binary. Formalized within the SmartCode tradition, the rural-urban transect arranges settlement zones along an ordered sequence, from natural and rural edges through suburban and general urban fabrics to centre and core conditions and links each position to corresponding built-form expectations (Duany & Plater-Zyberk, 2003). In this sense, the transect operates as both a descriptive and a prescriptive framework (Talen, 2002).

More recent studies propose that transect thinking can be used analytically rather than only as a regulatory code (Han, 2021; Musard, 2023; Talen, 2023). Quantitative research has also shown that transect zones can be operationalized to describe graded urban structure and morphologically differentiated urban areas, while studies in historical environments indicate that transect thinking can also be adapted to typo-morphological analysis and decision support (Jachimowicz, 2022; Boyko et al., 2021; Aydin et al., 2024).

In this wider context, character area analysis may also be effective in resilience adaptations in urban planning, because it helps distinguish parts of the settlement with different physical conditions, development histories, and spatial constraints. Such distinctions can inform more contextual planning and urban management. Yet the present study does not adopt the transect as a primary method of delineation. Character areas are instead derived through historical development, natural-environmental conditions, and built form and land use analyses. The transect is used here as a secondary evaluative perspective through which the resulting character areas can be interpreted. In topographically differentiated settlements, where transitions between rural and urban environments are often gradual, uneven, and shaped by terrain, the transect provides an additional way of assessing whether the delineated character areas form a legible sequence across the settlement.

2.3. Conceptual Framework of the Study

To address this issue, four concepts are used to develop the analytical framework. First, urban form refers to the arrangement of plots, streets, blocks, and buildings as it evolves over time, and provides the basis on which regulation, conservation, and design control operate (Moudon, 1997; Kropf, 2009). Second, character area refers to a morphologically coherent part of this form that is internally consistent and externally distinct, and thus defines a scale at which planning decisions can be specified (Birkhamshaw & Whitehand, 2012). Third, the natural-environmental and topographical layer, which includes terrain, coastline, slope, drainage, and elevation thresholds, is analyzed as a fundamental dimension of morphological differentiation alongside town plan, building fabric, and land use (Kropf, 2009). Fourth, the rural-to-urban transect is understood as an ordered gradient from rural to urban conditions (Duany & Plater-Zyberk, 2003) and is applied here to situate and evaluate the delineated character areas in planning terms.

This conceptual framework therefore combines the historico-geographical reading of urban form with an explicit concern for natural setting and planning interpretation. It aims to make the process of character area delineation more transparent without reducing it to a purely quantitative classification. In this respect, the study follows the interpretive logic of urban morphology, but organizes the analysis through clearly defined layers and evaluative steps. This provides a basis for examining whether character areas can operate not only as descriptive units of urban form, but also as practical units for planning decisions in small-sized and topographically differentiated settlements.

3. Aim and Scope

The aim of this study is to develop a methodology for delineating character areas within a historico-geographical framework and to examine its applicability to planning practice. The methodology is based on three lines of analysis: historical development, natural-environmental structure, and built form and land use. These analyses are synthesized to delineate character areas within the study area. In this way, the resulting areas are understood as reflecting town plan units, building fabric, and land use in relation to topographic factors and phases of historical development. Within this scope, the study focuses on three objectives: (1) to identify distinct character areas through the proposed framework, (2) to examine whether these areas can also be interpreted along a rural-to-urban gradient, and (3) to assess whether density variables on their own are sufficient to explain the resulting pattern.

For assessing the internal coherence of the delineated areas and the differences between them, statistical tests are used; the results of which are interpreted from historico-geographical and planning perspectives.

The method is applied to Görele (a small coastal town in Giresun Province, northeastern Türkiye), which was selected as an illustrative case of coastal settlements beside the Eastern Black Sea, where urban development has been shaped by the relationship between coast, river valleys, and steep topography (Emecen, 2020). Initially, Görele was built on the eastern side of a river valley and later expanded westward across the valley plain, and the town also has a history of continuous urban development, while its built environment mirrors successive planning periods after the establishment of the Republic of Türkiye.

4. Methodology

The method proposed in this paper has seven steps: (1) define study boundary and data, (2) analyze historical development, (3) analyze natural-environmental, (4) analyze built form and land use analysis, (5) delineate three-layer synthesis, (6) interpret statistical evaluation and transect, and (7) interpret planning. Historical, environmental, and built form analyses that can identify character

areas across the planned area are the preliminary set of analyses in line with historico-geographical analysis (Figure 1).

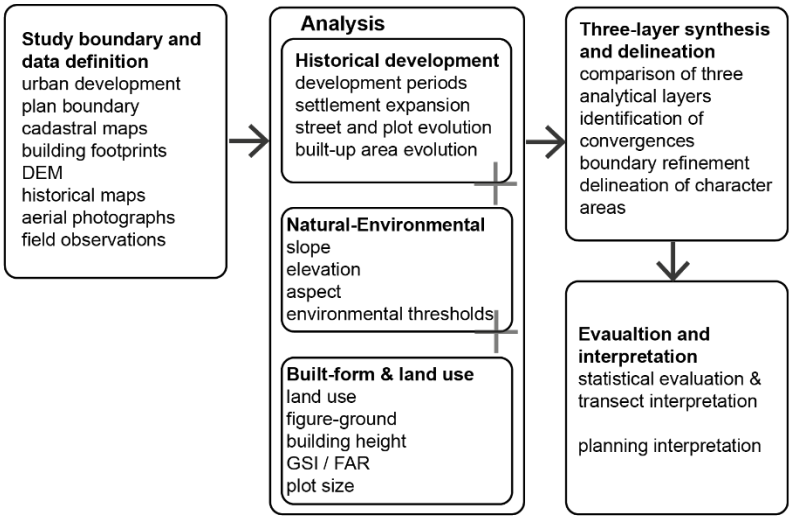

Figure 1 Steps of the proposed framework

4.1. Study Area

Görele is a small town located in the Eastern Black Sea region of Türkiye, as aforementioned, with a population of 18,238 (Turkish Statistical Institute [TurkStat], 2025). It is located approximately midway between the two main regional centers, 62 km east of Giresun and 70 km west of Trabzon (Figure 2). The town is formed along a narrow coastal plain created by the alluvial deltas of the Görele and Çömlekçi streams. The landscape is characterized by steep ridges and valleys, as is typical of coastal towns and cities in the Black Sea region (Emecen, 2020).

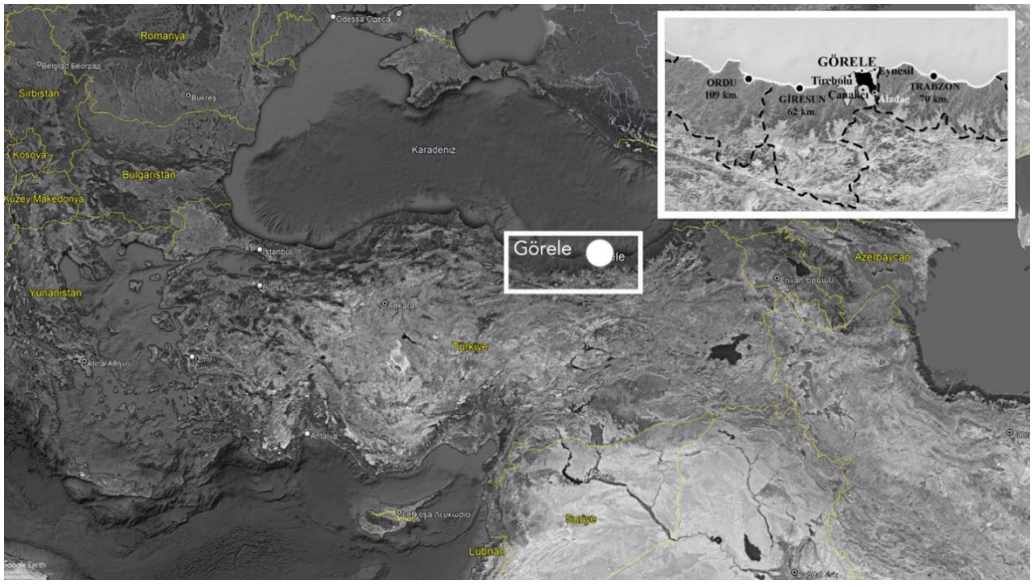

Figure 2 Location of Görele

The case study town of Görele was selected for several reasons: (1) it is representative of many coastal settlements in the region, (2) both archival and current digital data are available, (3) its urban history can still be deciphered through clear periods of growth, with areas representing these periods remaining visible. Görele's character is evident in its historical continuity, topographic constraints, and recent planned urban expansion within a clearly defined development plan perimeter. These conditions have impacted urban growth along the east–west coastal axis, while the sloping areas to the south have maintained their rural characteristics (Figure 3). In this way, Görele provides an illustrative case for examining the interactions of historical development,

environmental structure, and built form in the outline of character areas designated for urban planning.

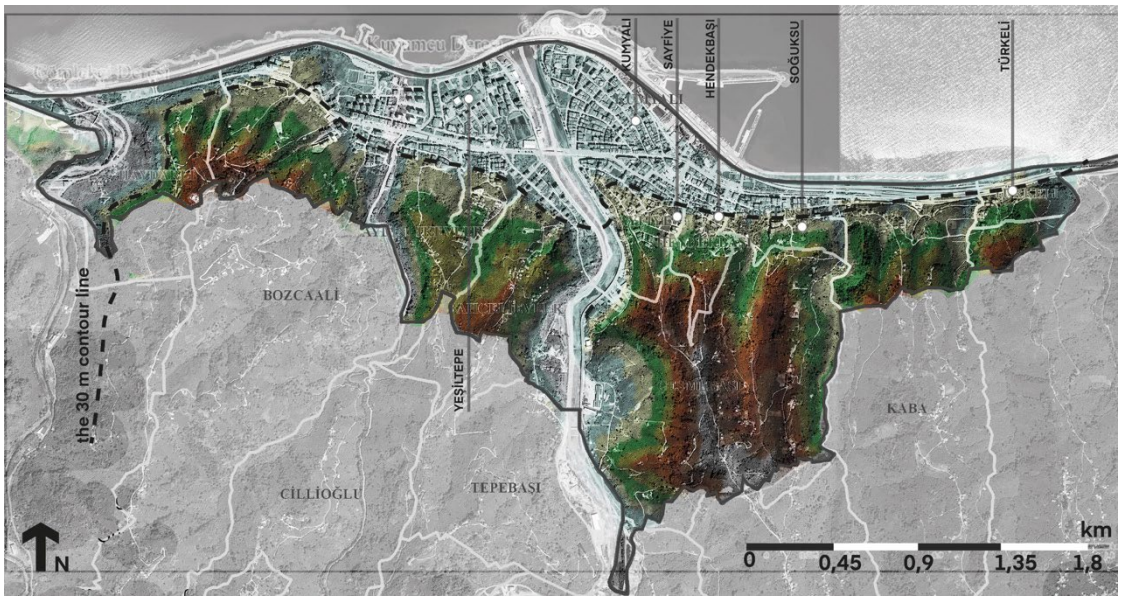

Figure 3 Hillshade and elevation profile of Görele

All analyses were effected within the perimeter of Görele's current urban development plan (hereinafter termed the study area), so that the identified character areas corresponded to the scale of any planning decisions. Neighborhood perimeters were used solely for orientation. The historical transformation of Görele is examined in the findings section of this paper, and includes its compact coastal form before the Republican Period and its later expansion through infrastructure investments, planning decisions, migration, construction of the state highway, construction of the Black Sea Coastal Road, sea-fill reclamation, and the opening of publicly-owned land for development.

The main data sources were: (a) municipal cadastral maps containing 6,755 plot polygons; (b) building footprints digitized from orthophotographs and checked against municipal building records (n = 2,607 buildings); (c) a 5 m resolution digital elevation model (DEM) that was generated from base and contour data using Topo to Raster tool in ArcGIS Spatial Analyst; and (d) georeferenced aerial photographs and historical maps from years 1946, 1955, 1975, 2009, and 2020. All vector data were projected in ITRF96 / TM30 (EPSG:5254). The number of storeys in a building, construction year of a building, and land use of each building were attached to its plot polygon.

4.2. Analysis

Historical development

The historical development analysis of the settlement was the first analytical component, from the first available cartographic phases up to the present day. Historical maps, aerial photographs, plans, cadastral records, and written sources were used to (1) split up urban development into appropriate time periods and (2) trace changes in the built-up area, such as growth direction, street and plot structure, and the general expansion pattern. For each time period, the built-up area, the main building types, plot subdivision, street hierarchy, major public investments, and planning regulations were recorded. Thus, the historical layer used in the synthesis was created.

Natural-environment

The environmental structure that has shaped settlement form and spatial expansion provided the second analytical component that was examined. Slope, elevation, and aspect were derived from the DEM and reclassified for comparative analysis. The three raster layers were combined

using the Weighted Overlay function with equal weights. The resulting composite raster was converted into polygonal units and refined using plot perimeters and road center lines as Snap References. This step produced the natural-environmental layer used later in the synthesis.

Built form and land use

The third analytical component was the built form and land use analysis, applied at the plot scale. Land use, figure-ground relations, building height, GSI (Ground Space ındex), FAR (Floor Area Ratio), and plot size were recorded and classified on the basis of cadastral data, building footprints, and municipal building records. Unbuilt and underdeveloped plots were also noted to identify incomplete consolidation. All layers were compared spatially in ArcGIS. In the final step, plot attributes were combined through a composite mapping procedure using land use, FAR class, GSI class, building height class, and plot size class. This produced the built form and land use layer used in the three-layer synthesis.

4.3. Synthesis and Delineation

Character areas were delineated through the combined reading of the three analytical layers: historical development, natural-environmental structure, and built form and land use patterns. Rather than functioning as a basic GIS overlay, the synthesis was used to identify character areas of internal coherence and external difference. Boundaries were drawn where changes occurred in at least two of the three layers.

The delineation was carried out at a single resolution level relevant to zoning and density decisions across the entire planned area. The natural-environmental layer was used as the initial spatial framework. Within this framework, the built form and land use layer was used to distinguish different built-up patterns. The historical layer was then used to compare these distinctions with the broader sequence of settlement development. For the character area delineation, plot boundaries and road centre lines were used in built-up areas, while ridges, valleys, stream corridors, and other natural thresholds were used in the rural parts of the study area. The output of this step was the final map of character areas.

4.4. Statistical Evaluation and Transect Interpretation

Statistical tests were used to compare plot-level variables across the delineated character areas. Normality was assessed with the Shapiro-Wilk test. Because most variables did not meet parametric assumptions, non-parametric methods were used throughout. Plot area, GSI, FAR, and number of storeys were compared between areas with the Kruskal-Wallis H test. Statistical tests were applied to built-up plots (n = 1,832).

To test the rural-to-urban gradient, the six character areas forming the main transect sequence were arranged in ordinal form, and their association with the plot-level variables was assessed with Spearman's rank correlation. Consistent with the framework in Section 2.3, the transect was used as an evaluative perspective, not as a delineation criterion. All statistical analyses were performed in Python using SciPy, on Google Colab.

4.5. Planning Interpretation

Following the statistical evaluation and transect interpretation, the resulting character areas were interpreted from a planning perspective. This step examined how the delineated areas could inform decisions related to conservation, intensification, design control, transformation, and development management. The planning interpretation considered the relationship between density variables, built form, historical development, and natural-environmental constraints. In this way, the character areas were treated as practical units for differentiating planning decisions across the study area.

5. Findings

The findings are presented in three stages. First, the three analytical layers, namely historical development, natural-environmental structure, and built form and land use, are analyzed individually to identify the main dimensions of differentiation across the study area. These layers are then combined in the synthesis step to define character areas. Finally, the delineated areas are evaluated through statistical analysis, transect and planning interpretations.

5.1. Formation and Historical Development of Görele

The historical development of Görele is interpreted through five periods defined by major changes in settlement form, infrastructure, and planning decisions. In this first part of the findings, the historical development of Görele is examined through the spatial references of 1946, 1955, 1975, 2004, and 2020. Archival and written sources are used to understand the main stages of urban growth, the changing directions of expansion, and the transformation of the town's spatial structure. Görele's urban form (see Figure 4) has transformed from a concentrated coastal municipality into an extended urban development with a form that was shaped over time by infrastructural enhancements, planning interventions, and topographic restrictions.

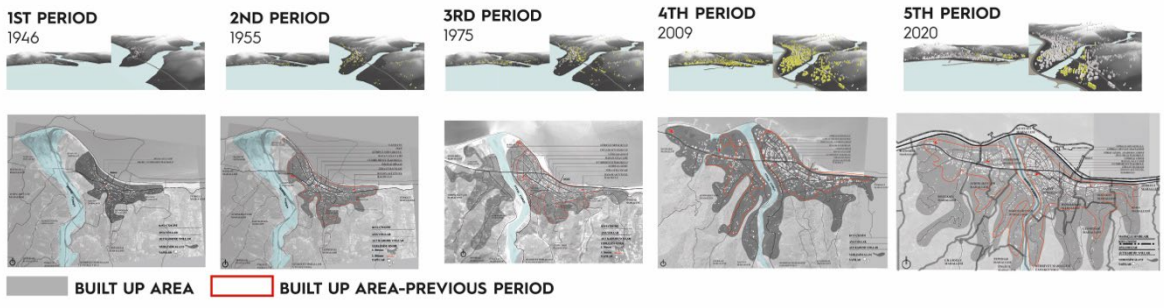

Figure 4 Görele's urban growth, 1946–2020

One of the earliest spatial sources used in the present study is an aerial photograph taken in 1946. Görele was founded as a compact coastal town with municipal administrative functions and served as a market place for the surrounding villages. Its built-up area was 30 ha, and the center approximately15 ha (Figure 5). Before the Republican period, land connections were limited, and the town was more connected by the sea than by roads (Emecen et al., 2019).

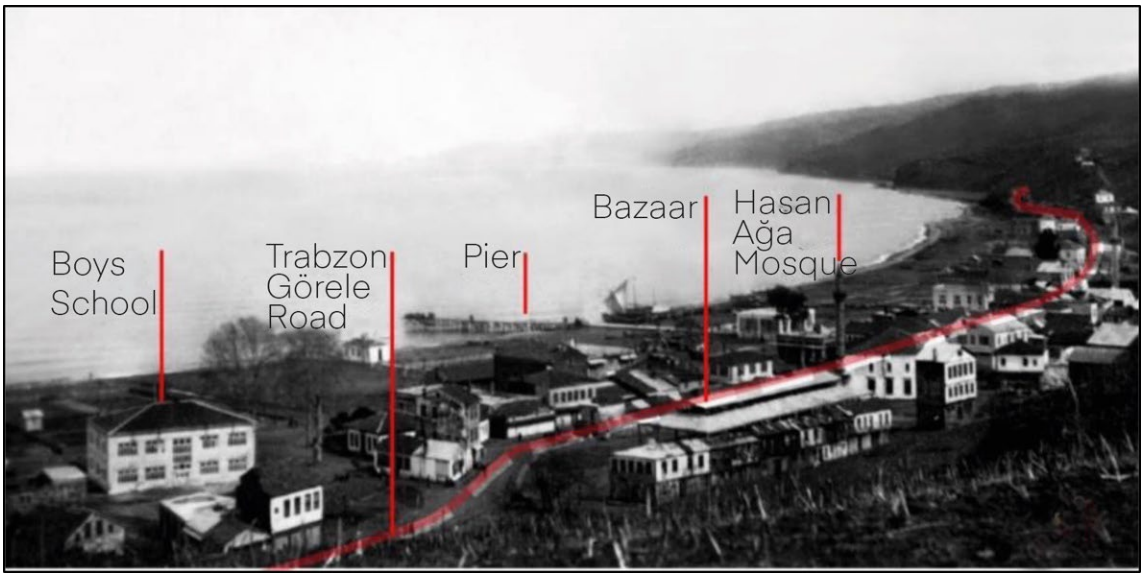

Figure 5 Görele in the 1930s

The commercial area was concentrated along two streets running parallel to the coast, while the earliest residential quarters (Sayfiye, Hendekbaşı, and Soğuksu) were located on the southern ridges above the 30 m contour. These areas consisted mainly of detached two storey houses within garden plots and reflect the early influence of topography on settlement form (Bilir, 2001). By this period, Görele already functioned as a local service center, concentrating public services, commercial activities, and transport functions.

The town retained its rural character until the 1960s, when the road connecting the town to nearby settlements was built. During this period, it was still a small, low-density town with a semi-rural character, and its built-up area showed little growth (Arslan, 1973). New development extended mainly east and west along the coast, with limited growth south toward Çeşmebaşı. On the plain areas, development followed the roads parallel to the shore, while on the slopes it extended upward along the ridges. Without a comprehensive planning framework, the town grew mainly through incremental building activity and scattered public investment. New housing remained low-density, with buildings typically rising two or three storeys. The first westward extensions emerged in Kumyalı and Aydınlıkevler neighborhoods.

Between the mid-1950s and the mid-1970s the built up area of the town expanded to the west. Aerial photographs from 1975, with archival and written sources show that this growth occurred mainly toward the west and along the east-west coastal axis. Despite this expansion, much of the area kept its garden city and rural character. In this period the first spatial plans were implemented. Accordingly, base maps were prepared, the first development plan was approved, and new road connections improved accessibility across the region. At the same time, commercial, residential, and institutional land uses begin to form an administrative and modern town center. The pier, the town's earlier main entry point, had long provided maritime access and was still present during this period, but it was later demolished during the sea-fill works that were carried out as part of the Black Sea Coastal Road project during the 2000s.

Between 1984 and 2004 the initial urban development plans are actualized. Thus, this period can be termed as the "planned period". The first comprehensive urban development plan was made for Görele by İller Bankası (public development / investment bank in Ankara) in 1984 that extends over the built up area of current developed area today. The limits of the city expanded noticeably compared to its state in 1975. Yet, much of this designated area remained unbuilt in the following years. The area along the Görele river, was developed mainly with residential areas as well as institutional areas and Kumyalı district also developed as the new housing area through land reclamation. Some of the reclaimed land was allocated to recreation and small industry uses, while agricultural land at the southern end of the city remained largely outside the main urbanized area. The 1998 Additional Urban Development Plan later expanded the planned area and revised the earlier scheme. Overall, this phase reflects the growing influence of formal planning, land reclamation, and allocation on Görele's spatial development.

By 2020, the town center had become denser, and high-rise development was more evident in the urban fabric. Since 2000, this increase in density had occurred mainly through infill development, leaving only a small number of unbuilt parcels within the core area. Commercial activity remained mainly along the two main streets already established in earlier periods. This phase was shaped by the 2016 Environmental Plan and the 2017 Master Development Plan. High-rise apartment blocks emerged around the stadium and the hospital area on the western part of the town. The Black Sea Coastal Road project had started to transform the natural coastal edge by removing the former pier and creating new reclaimed land along the shoreline. This development became evident mainly in Kumyalı and part of Yeşiltepe districts.

Görele's historical development can be understood as a sequence of continuity, extension, planning intervention, and intensification, as summarized in Table 1. Throughout these phases, the traditional center developed into the administrative center of Görele, while later developments in the west changed the urban form from a small coastal town into a more developed urban area. This

layered pattern of development provides the historical basis for the character area differentiation discussed in the following sections.

Table 1 The Historical Development Periods of Görele

Period	Extent	Plot–building–street relation	Dominant building type	Relevance for character differentiation
Pre-1946 / 1946 Compact centre	Compact center and traditional districts on the southern slopes	Front setback from the road on flat areas No front setback from the Road large garden plots on slopes;	1–2 storey detached houses with gardens; small mixed-use/public buildings in the center	Historical core and early garden-based slope fabric
1946–1955 Limited expansion	Limited growth along existing roads and coastal direction	Detached houses in large garden plots; no/limited front setback on steep areas; setbacks and garden walls on flatter plots	2–3 storey buildings in the center; 1–2 storey detached houses in rural/slope areas	Last dominant phase of low-density garden-based structure
1955–1975 First westward expansion	Growth along Görele Stream and east–west road axis	Development along the major roads; buildings generally without front setbacks; narrow gaps between buildings	4–5 storey residential buildings along roads; attached mixed-use buildings in the center	First road-related apartment development and expansion of housing areas
1984–2004 Planned growth and apartment development	Westward planned growth; public facilities; apartment development in vacant areas	Garden plots on flatter land replaced by apartment plots; higher plot coverage; limited garden use	4–5 storey apartment buildings; first 6–8 storey mass housing blocks; institutional buildings	Spread of apartment development and weakening of garden-based fabric
2004–2020 Infill and high-rise development	Densification in the center; high-density development on greenfield to the west	Center: small fragmented plots, high intensity, no front setback. West: large plots with detached high-rise/point type apartment blocks	12–15 storey point type apartment blocks in the west; dense mixed-use/residential buildings in the center	Distinction between dense center, western high-rise development, and remaining garden fabrics

5.2. Natural-Environmental Structure

The terrain of Görele formed by a coastal plain, steep slopes on the south, and stream valleys running across the settlement. These features affected the formation and the location of urban development. As shown in Figure 6, the town is formed around the coastal plain, mostly on the reclaimed land of Görele River valley. Historically, however, much of the housing was located on the north-facing slopes. The natural environment was therefore one of the factors shaping the urban form.

Elevation and slope indicate a break in the building pattern at the 30 m contour. Below this level, the land is relatively flat and suitable for urban development. This zone includes the center as well as later expansion areas such as Kumyalı and Yeşiltepe neighborhoods. South of the 30 m contour, the terrain becomes steeper. In some places, slopes reach 40%, and the land is divided by narrow valleys and ridgelines. This typical natural character generates more linear and fragmented formation. The flatter coastal land contains denser and more continuous development, while for the steeper southern areas the settlement pattern is more fragmented (see Figure 6).

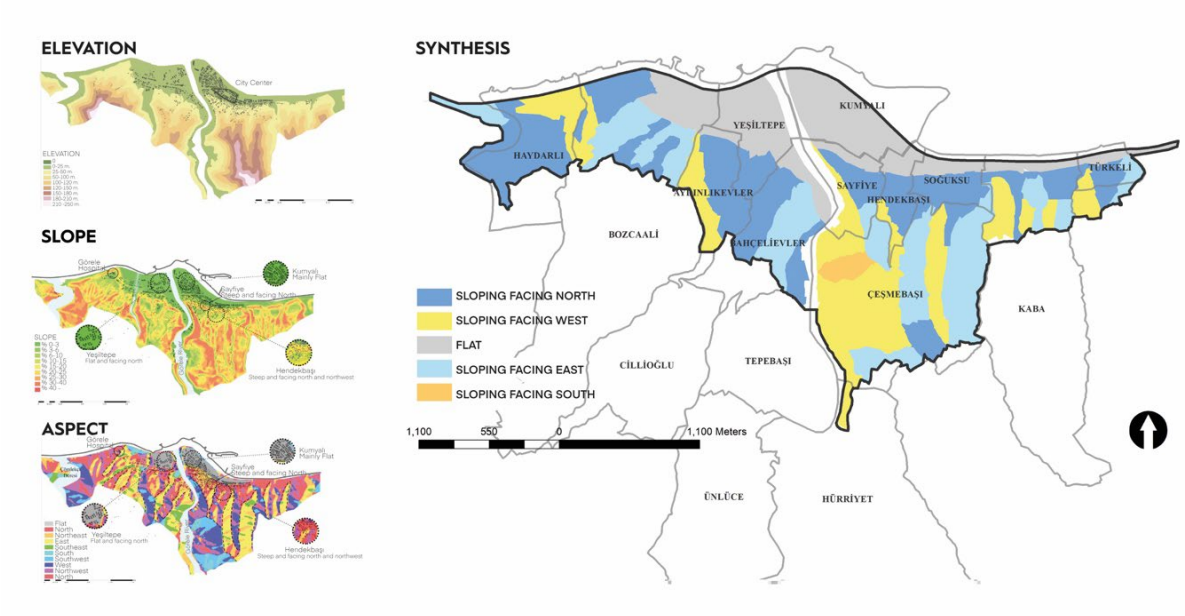

Figure 6 Natural–environmental analysis of Görele

Aspect analysis was effected in order to examine any impact of slope orientation on urban form. The typical coastal town of Görele has a sloping terrain facing north (Figure 6). The coastal zone (areas largely reclaimed following sea-infill) is relatively flat, with the higher and steeper parts of the settlement being distributed across slopes with different aspects. They include largely north-, east-, west-, and south-facing slopes, each forming a different topographic setting within Görele's ridge and valley structure. It is noteworthy that the natural structure of Görele is shaped by elevation and slope, as well as aspect.

Hence, 5 natural character areas have been defined - (1) flat areas, (2) north-facing slopes, (3) west-facing slopes, (4) east-facing slopes, and (5) south-facing slopes (see Figure 6). Flat areas correspond largely to the center and later coastal development zones, while the sloping areas define more fragmented residential and rural edges. In that, built form patterns were created and differentiated by the natural structure.

5.3. Built Form and Land Use Structure

Among Görele's compact center, fragmented expansion areas, and rural southern parts a clear contrast has been revealed using analyses of built form and land use. Land use remains predominantly residential, while commercial and mix use functions are concentrated in the center and continue as roadside trade to the east and west. More than 60% of the planning area remains unconstructed, thus indicating the continuance of the southern areas' rural character (see Figure 7).

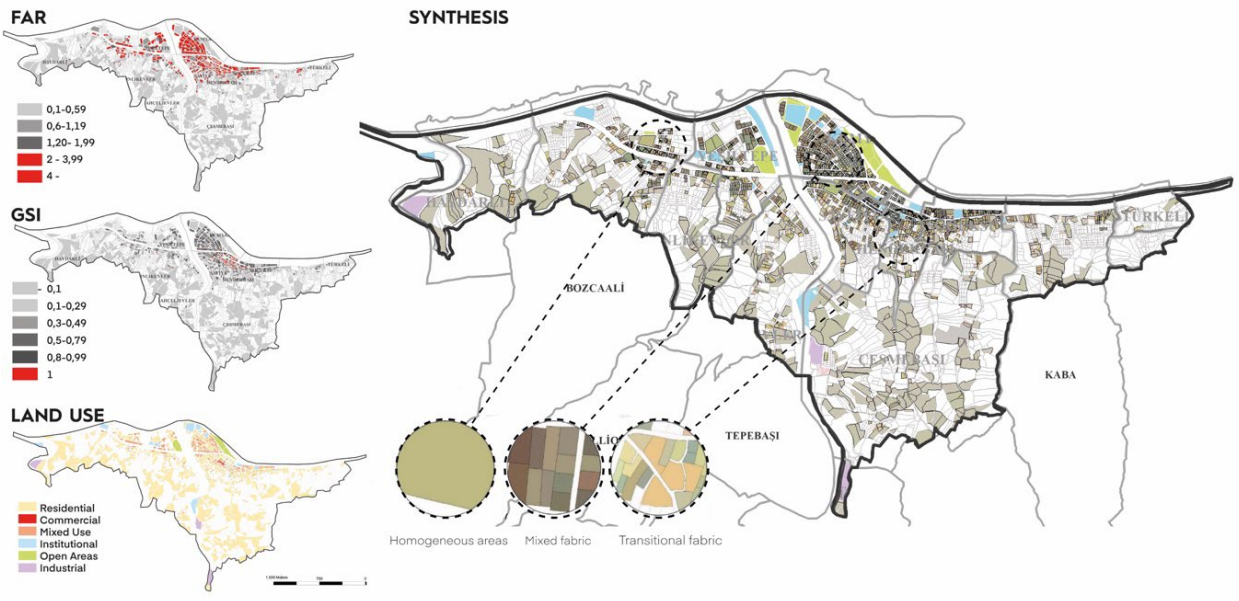

Figure 7 Built form and land use structure of Görele based on FAR, GSI, land use, and synthesized built form patterns

The center is the most dense part of the settlement, while the eastern and western expansion areas are more fragmented. Rural settlements on the southern ridges are sparse and along the roads. Plot size, FAR, GSI, and building height also vary clearly across the study area. Smaller-sized plots and higher density values dominate the center and the Kumyalı district, while larger-sized plots and lower densities are concentrated in the peripheral and rural areas. The newest high-rise development is visible in the Yeşiltepe district (see Figure 7).

The synthesis of plot size, floor area ratio (FAR/KAKS), ground space index (GSI/TAKS), building height, and land use all revealed recurring plot-level patterns (interpreted as homogeneous, mixed-fabric, and transitional-fabric built form areas). As shown in Figure 7, this layer guided the distinction of built form differences within the broader natural and historical structure and provided the third basis for the delineation of character areas later in the study (see Figure 7).

5.4. Synthesis and Delineation of Character Areas

The three analytical layers were evaluated in unison in order to identify areas where convergence of historical development, natural structure, and built form characteristics occurs. The final delineations were not derived from a single variable, but were drawn rather where the historical, natural, and built form analyses showed consistent spatial differentiation. The resulting character areas are presented in Figure 8.

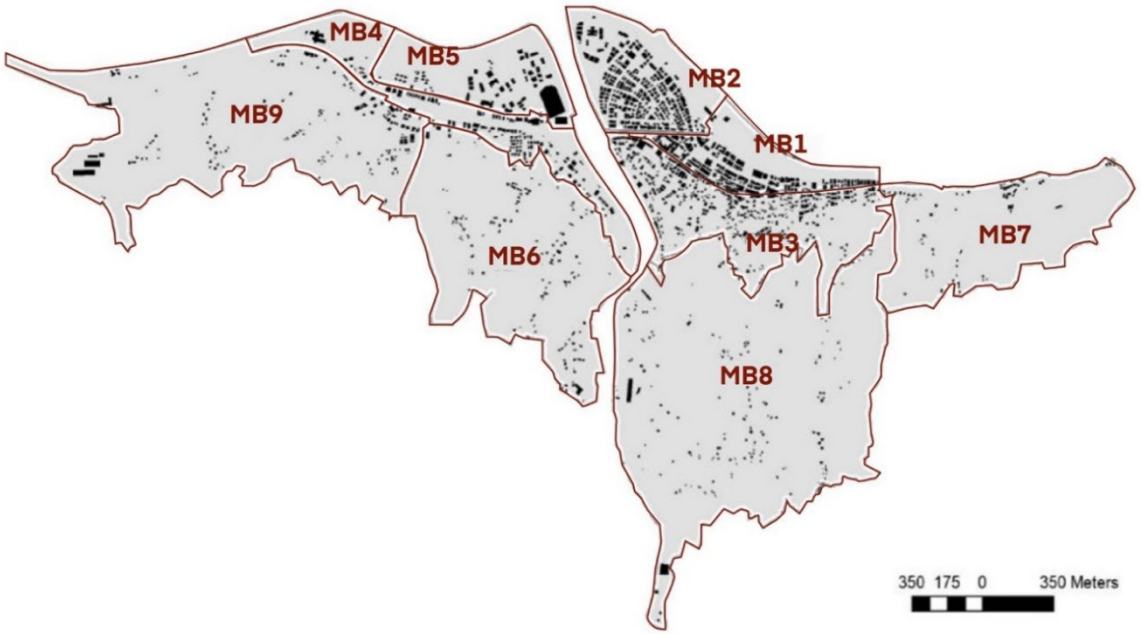

Figure 8 Görele–delineation of character areas

The synthesis yielded 9 character areas (see Figure 8) which have differences in their topography, development period, plot structure, density, and building pattern. Some areas represent the dense and historically layered town center, while other areas show planned expansion, linear growth, or rural and semi-rural character; thus, delineation is not based solely on density. The synthesis also shows how historical development, environmental conditions, and built form vary across Görele. The morphological basis of the delineation is summarized in Table 2 as per the characteristics of each character area: (1) location, (2) street pattern, (3) land use and building form, and (4) plot-density.

Table 2 Character Areas in Görele

Character area	Location	Street pattern	Land use and building form	Plot structure and density
MB1	Central flat historical core	Grid	Commercial and mixed use; attached and detached buildings	Small plots; highest ground coverage (median GSI 0.88, median FAR 3.42); median 4 storeys
MB2	West of the center on flat reclaimed land; Kumyalı	Arc-shaped grid	Planned residential area with ground-floor commercial use along main roads	Medium-sized plots; compact residential fabric; median GSI 0.50, median FAR 2.90; median 5 storeys
MB3	South of the centre on sloping ridges; Soğuksu, Sayfiye, and Hendekbaşı	Organic/linear ridge roads with dead-end streets	Residential area with traditional houses, family apartments, and highrise apartment blocks	Medium-sized plots; lower density than the centre; median GSI 0.40, median FAR 1.20; median 3 storeys
MB4	West of the centre along the main road corridor; part of Yeşiltepe	Linear	Mixed residential, roadside commercial use, and some production uses	Medium-sized plots; linear roadside growth; median GSI 0.39, median FAR 1.92; median 5 storeys
MB5	West of the centre on flat delta land; Yeşiltepe	Incomplete	Recent high-rise residential area with detached and block development	Large plots; high intensity but incomplete consolidation; median GSI 0.40, median FAR 3.50; median 7 storeys
MB6	Southwestern slope area; Aydınlıkevler and Bahçelievler	Linear ridge roads with dead-end streets	Residential area with rural garden houses and scattered clusters	Large plots; low density; median GSI 0.08, median FAR 0.19; median 3 storeys

MB7	Eastern sloping area near the coast; Türkeli	Linear ridge roads with dead-end streets	Residential area with rural character	Large plots; low density; median GSI 0.10, median FAR 0.22; median 2 storeys
MB8	Southern steep rural zone; Çeşmebaşı	Linear north–south ridge roads	Sparse residential and rural garden houses, with tall apartment blocks along the valley road	Largest plots; lowest density; median GSI 0.03, median FAR 0.06; median 2 storeys
MB9	Western peripheral slope area; Haydarlı	Linear ridge roads with dead-end streets	Mixed residential and commercial uses with rural characteristics	Large plots; low density; median GSI 0.16, median FAR 0.34; median 3 storeys

The Table 2 shows that the identified areas can be grouped into compact central areas (MB1–MB2), historically layered and transitional areas (MB3–MB4), a recent high-rise development area (MB5), and lower-density rural or semi-rural peripheral areas (MB6–MB9). The character areas were delineated according to differences in historical development, natural setting, and spatial structure.

5.5. Statistical Evaluation and Transect Interpretation

In the final part of the findings, the character areas were tested statistically to see whether they also differed in plot structure and development intensity. For this purpose, non-parametric tests were applied to plot area, GSI, FAR, and number of storeys. The results are given in Table 3.

Table 3 Statistical Evaluation of the Character Areas and the Main Rural-to-Urban Gradient

Variable	**Kruskal–Wallis H**	**p**	**Spearman[1] rho**	**p**	**Trend along the gradient**
Plot area	796.115	< 0,001	- 0.500	< 0.001	decreases toward the urban end
GSI (TAKS)	903.307	< 0,001	0.653	< 0.001	increases toward the urban end
FAR (KAKS)	813.867	< 0,001	0.620	< 0.001	increases toward the urban end
Building Height (Number of storeys)	489.797	< 0,001	0.401	< 0.001	increases toward the urban end

The Kruskal-Wallis H test showed significant differences among the character areas for all four variables: plot area ($H = 796.115$, $p < 0.001$), GSI ($H = 903.307$, $p < 0.001$), FAR ($H = 813.867$, $p < 0.001$), and number of storeys ($H = 489.797$, $p < 0.001$). These results represent that the character areas also differ statistically in terms of selected building and plot variables. However, this does not mean that the same boundaries could be drawn using these variables alone. The areas were delineated through a combined reading of historical development, natural-environmental structure, and built form. Therefore, the statistical analysis supports the delineation but does not replace the synthesis.

The character areas were also examined along a rural-to-urban gradient introduced earlier as an evaluative planning lens. Moving toward the urban centre, plot sizes decrease, while GSI, FAR, and building height increase. is illustrated by The sequence: MB8, MB6, MB3, MB4, MB2, MB1 (see Figure 9) illustrates this transition from low-density peripheral and rural areas to the dense urban core. The gradient highlights the general sequence of transition and reveals points where spatial patterns shift.

[1] Spearman correlations were calculated for the ordered subset of character areas included in the main rural-to-urban sequence.

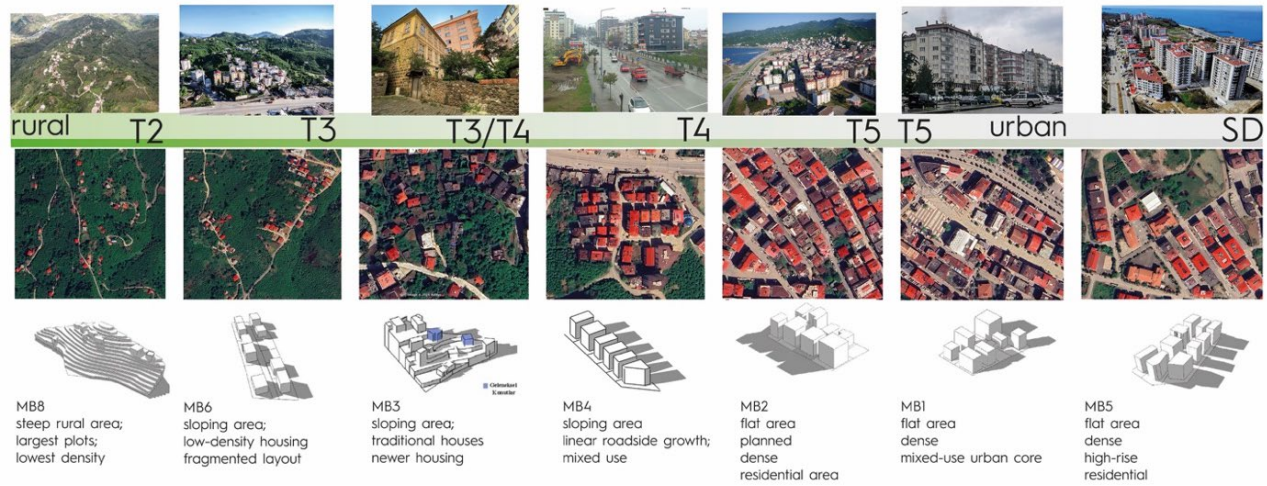

Figure 9 Transect interpretation in Görele

Also analytically important finding, not all character areas could be placed within this ordered sequence, in that MB5, MB7, and MB9 indicate where the settlement departs from a balanced gradient and where recent development has resulted in consolidated forms that are fragmented or incompletely consolidated. For instance, MB5 is a recently developed high-rise area with density values similar to the urbanized part of the transect. However, the plot structure, incomplete road system, and unfinished development of MB5 distinguish it from the dense urban core. In that, identification of continuity and imbalance within the settlement is assisted in this study by the transect.

5.6. Planning Interpretation of Character Areas

Here, the present authors summarize 3 implications for urban planning practice:- (1) character area delineation proposes a more differentiated basis for planning than solely density categories because even when there are density values over areas, any appropriate planning response may be different. (2) the methodology can identify positioning of misaligned density, form, and context, thus highlighting areas have occurrence of high-density growth with no adequate integration into the urban context. (3) the methodology operates at a scale that is relevant to the urban planning process and creates units that remain legible across the entire planned area, which would subsequently guide zoning and development. Where plot-level planning decisions on density are required, these areas can be further subdivided; but, the broader delineation is important for preserving the settlement character that has developed over time.

6. Discussion

The case of Görele shows that character areas can be delineated through the combined reading of historical, natural, and built form layers, and that the resulting areas are usable in planning terms. In this respect, the study returns to the foundations of the historico-geographical tradition: the delineation follows the logic of morphological regionalization established by Conzen (1969), in which the town plan, building fabric, and land use are read together as historically layered components of the urban landscape. Nine character areas were identified, ranging from the compact mixed-use centre and planned residential expansion to recent high-rise development and rural or semi-rural slope areas. After, Statistical analysis demonstrates that these boundaries are not arbitrary; however, the delineation was not based on any single layer, and boundaries were drawn only where at least two of the three layers changed together. Making these steps explicit responds to recent calls for procedural clarity in regionalization studies (Oliveira & Yaygın, 2022). At the same time, existing procedural frameworks remain largely confined to the built components of urban form; the present study extends them by using the natural setting as a primary layer of the delineation.

The findings also indicate what is gained when the natural setting is treated as a primary analytical layer rather than a background condition. In Görele, the 30 m contour, the stream valleys, and the ridge structure carried a substantial part of the character area perimeters, and the natural-environmental layer formed the initial spatial framework of the synthesis undertaken. This supports the argument of Kropf (2009) that natural elements can be embodied in morphological analysis in unison with historical development and built form, and promotes the fact that in topographically constrained settlements this incorporation is necessary to provide a coherent delineation.

This is also applicable to the transect interpretation, whereby the main sequence from (a) the rural southern slopes to (b) the dense coastal core confirms that the delineated areas form a coherent slope. However, areas MB5, MB7, and MB9 could not be placed in this sequence although they proved more informative (analytically) than the sequence itself, indicating where recent development has produced fragmented or poorly consolidated forms. This information can be interpreted to indicate that the transect is more valuable as an analytical / evaluative aspect in morphological research, and not simply as a prescriptive code (Talen, 2002), especially regarding where the rural-to-urban transition is uneven and shaped by terrain in settlements.

It is noteworthy that the above findings are particularly relevant in the Eastern Black Sea with its topographically constrained coastal towns are created by strong internal contrasts within (1) a limited urban area steep terrain, (2) narrow coastal plains, and (3) reclaimed land, whereby the historical, environmental, and morphological character that shapes the adaptive capacity of the town is threatened by any density-driven development. The focus on Görele in the present study gives empirical support for the concern that data and density-based classifications could potentially reduce any complex characters to solely density measures (Kropf, 2013b; Birkhamshaw & Whitehand, 2012). In that, several areas have similar density values but these areas differ greatly in (1) plot pattern, (2) street structure, and (3) historical development, and would need different planning responses as a result. In the planning context pertinent to Tükiye, with development controlled largely through density rights and that usually proceeds plot by plot (Balamir, 1975; Ünlü, 2026), character area delineation would certainly provide a viable means to make these differences clearly visible at the pertinent scale where important zoning decisions are established.

This study has some noteworthy limitations. (1) The delineation process involves interpretive decisions, especially in transition areas, and this is a common feature of urban character analysis and should not be perceived as a flaw inherent only in this method. (2) As this study has a focus on one case in particular, in future studies the methodology needs to be tested in other coastal and topographically differentiated settlements before defining broader generalizations. (3) The dependence of the methodology on cadastral and archival data may also limit its direct transfer to settlements with incomplete records. (4) The scope of the present study diverts from conventional morphological regionalization: the methodology lacks accurate historical data on how the street and plot systems changed over time when covering the overall planned area, and as a result does not trace plan-unit evolution in great detail. Rather, the study prioritizes applicability over morphogenetic depth by linking the established urban morphology methodology to the urban planning process.

7. Conclusion

In the present study, a methodology was developed and tested for delineating character areas in a coastal town named Görele which has been shaped by historical development, topographic constraints, and recent urban growth. The study results demonstrate that character areas cannot be explained by using solely density variables. While there were significant differences concerning plot size, GSI, FAR, and building height among the areas, the final delineation had great reliance on the combined interpretation of historical formation, natural setting, street pattern, plot structure, land use, and building form.

This case study demonstrates that character area analysis can be useful in urban planning for distinguishing among areas with different developmental pressures and spatial capacities, including (1) dense historical center, (2) planned residential expansion areas, (3) recent high-rise development zones, and (4) rural or semi-rural areas. The transect interpretation confirmed a general sucession from rural gradient areas to the dense urban core, while also pinpointing areas that do not comply with a simple linear gradient. Character area delineation can therefore support planning decisions that respond more closely to local topography, urban form, and development pressure. It also provides a framework that can be applied in other small settlements where formal planning has treated morphologically distinct areas as uniform developable land. Where specific planning provisions apply, land is regulated accordingly; elsewhere, however, areas are often treated as equivalent despite their morphological and environmental differences. The character areas proposed in this paper are not intended to replace existing planning provisions, but to complement them by making these differences more visible within the planning process.

CRediT Authorship Contribution Statement

Beyza Karadeniz: Writing – review & editing, Writing – original draft, , Methodology, Investigation, Formal analysis, Data curation, Conceptualization, Data visualization. Yelda Aydın Türk: Writing – review & editing.

Declaration of Competing 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 paper.

Data Availability

Data will be made available on request.

Ethics Committee Approval

Ethics committee permission is not required.

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References

An, X., & Gu, K. (2018). Urban intensification and the character of urban landscape: A morphological perspective. *International Journal of Architectural and Environmental Engineering*, *12*(9), 898-902.

Arat, M. (2023). *Morphological regionalization*. Springer.

Arslan, M. (1973). *Görele coğrafya, tarih, folklor, yönetim*. San Matbaası.

Aydin, S., Çelebioğlu, B., & Aytuğ, A. (2024). Morphological analysis of historical urban landscape through heritage transect: A computational model. *Journal of Digital Landscape Architecture*, *9*, 354-364.

Balamir, M. (1975). Kat mülkiyeti ve kentleşmemiz. *ODTÜ Mimarlık Fakültesi Dergisi*, *1*(2), 295-319.

Bilir, A. (2001). *Geçmişten günümüze tüm yönleriyle Görele*. Simurg Yayınları.

Birkhamshaw, A. J., & Whitehand, J. W. R. (2012). Conzenian urban morphology and the character areas of planners and residents. *Urban Design International*, *17*(1), 4-17. https://doi.org/10.1057/udi.2011.22

Boyko, D., Zuev, A., & Parygin, D. (2021). Land plot data usage for urban transect zones delimitation in case of Tula. In *XXVIII International Seminar on Urban Form (ISUF 2021): Urban form and the sustainable and prosperous cities*.

Conzen, M. R. G. (1969). *Alnwick, Northumberland: A study in town-plan analysis* (2nd ed.). Institute of British Geographers.

Conzen, M. R. G. (1988). Morphogenesis, morphological regions and secular human agency in the historic townscape, as exemplified by Ludlow. In D. Denecke & G. Shaw (Eds.), *Urban historical geography: Recent progress in Britain and Germany* (pp. 253-272). Cambridge University Press.

Duany, A., & Plater-Zyberk, E. (2003). *The SmartCode and manual*. New Urban Publications.

Emecen, F. M. (2020). *Karadeniz kıyı kentleri tarihi* (1st ed.). Turkuvaz Kitap.

Emecen, F. M., Yüksel, A., & Keskin, İ. (2019). *Görele tarihi*. Görele Belediyesi Kültür Yayınları.

Fan, Y., Zou, H., Zhao, T., Fan, B., & Cheng, Y. (2025). Typological mapping of urban landscape spatial characteristics from the perspective of morphometrics. *Land*, *14*(9), 1854. https://doi.org/10.3390/land14091854

Fleischmann, M., Feliciotti, A., Romice, O., & Porta, S. (2022). Methodological foundation of a numerical taxonomy of urban form. *Environment and Planning B: Urban Analytics and City Science*, *49*(4), 1283-1299. https://doi.org/10.1177/23998083211059835

Hall, P. (2008). The form-based development plan: Bridging the gap between theory and practice in urban morphology. *Urban Morphology*, *12*(1), 77-95.

Han, S. (2021). The use of transects for resilient design: Core theories and contemporary projects. *Landscape Ecology*, *36*(5), 1567-1582. https://doi.org/10.1007/s10980-020-01172-9

Jachimowicz, A. M. (2022). Morphology of Warsaw city structure using urban indexes and GIS tools. *Land*, *11*(1), 135. https://doi.org/10.3390/land11010135

Kropf, K. (2009). Aspects of urban form. *Urban Morphology*, *13*(2), 105-120.

Kropf, K. (2011). Morphological investigations: Cutting into the substance of urban form. *Built Environment*, *37*(4), 393-408.

Kropf, K. (2013a). Evolution and urban form: Staking out the ground for a more mature theory. *Urban Morphology*, *17*(2), 136-149.

Kropf, K. (2013b). Ambiguity in the definition of built form. *Urban Morphology*, *18*(1), 41-57.

Larkham, P. J., & Morton, N. (2011). Drawing lines on maps: Morphological regions and planning practices. *Urban Morphology*, *15*(2), 133-151.

Monteiro, C., & Pinho, P. (2022). Comparing approaches in urban morphology. Journal of Urbanism: *International Research on Placemaking and Urban Sustainability*, *15*(4), 491_518. https://doi.org/10.1080/17549175.2021.1936602

Moudon, A. V. (1997). Urban morphology as an emerging interdisciplinary field. *Urban Morphology*, *1*(1), 3-10. https://doi.org/10.51347/jum.v1i1.4047

Musard, C. (2023, July 10). *Theorizing the rural_urban transect*. CNU. https://www.cnu.org/publicsquare/2023/07/06/theorizing-rural-urban-transect

Oliveira, V. (2006). The morphological dimension of municipal plans. *Urban Morphology*, *10*(2), 101-113. https://doi.org/10.51347/jum.v10i2.3929

Oliveira, V., & Yaygın, M. A. (2022). The concept of the morphological region: Developments and prospects. *Urban Morphology*, *24*(1), 35-52.

Peck, J., Theodore, N., & Brenner, N. (2009). Neoliberal urbanism: Models, moments, mutations. *SAIS Review of International Affairs*, *29*(1), 49-66.

Şengül, H. T. (2009). *Kentsel çelişki ve siyaset: Kapitalist kentleşme süreçlerinin eleştirisi*. İmge Kitabevi.

Talen, E. (2002). Help for urban planning: The transect strategy. *Journal of Urban Design*, *7*(3), 293-312. https://doi.org/10.1080/1357480022000039349

Talen, E. (2023). Transect-based coding: A methodology. In H. Kamalipour, P. Aelbrecht, & N. Peimani (Eds.), *The Routledge handbook of urban design research methods* (1st ed.). Routledge. https://doi.org/10.4324/9781003168621

Tekeli, İ. (1994). Şehir planlama mimarlık üzerine sürülen bir krema değildir. *Planlama*, 10-21.

Turkish Statistical Institute. (2025). *Population of province/district centers and towns/villages by province and district* [Data set]. TurkStat Data Portal. https://veriportali.tuik.gov.tr/tr/databrowser/tuik/TR,DF_ADNKS_T22,1.1

Ünlü, T. (2026). İdeallerin Kenti'nden parçalanan Kent'e: Türkiye kentlerinde değişim ve dönüşüm. In A. Gürün & P. Çobanyılmaz (Eds.), *Cumhuriyetin 100. yılında planlama*. İdealKent Yayınları.

Vartholomaios, A. (2025). Detection and clustering of urban form types with machine learning: Insights into Thessaloniki's urban planning and evolution. *Computational Urban Science*, *5*(1), 51. https://doi.org/10.1007/s43762-025-00206-9

Whitehand, J. W. R. (2005). Understanding and shaping urban landscape character. *Urban Morphology*, *9*(2), 1-3. https://doi.org/10.51347/jum.v9i2.5139

Whitehand, J. W. R., & Morton, N. J. (2004). Urban morphology and planning: The case of fringe belts. *Cities*, *21*(4), 275-289. https://doi.org/10.1016/j.cities.2004.04.001

Resume

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Reading spatial inequality in Gaza through UNRWA reports: Displacement and urban fragmentation

Areen Soboh*
Bengi Su Ertürkmen**

Abstract

The escalation of conflict in Gaza in October 2023 has intensified a humanitarian crisis marked by mass displacement and the disruption of essential services, producing new forms of spatial inequality and heightened human vulnerability. To understand and analyze this crisis, this study draws on UNRWA situation reports from October 2023 to December 2025. It uses these reports as a lens to examine spatial conditions and how space is organized and transformed during the crisis. In this context, the study develops a spatial reading by identifying and interpreting how space is articulated within these reports. This includes the development of analytical visual representations derived from the data, translating textual and numerical information into spatial patterns across time and regions, and enabling a clearer understanding of displacement dynamics and spatial inequality. In doing so, it not only treats these reports as data but also critically examines how such textual, numerical, and visual outputs construct, represent, or fail to capture spatial inequalities. Through the analysis of these reports, the study identifies five temporal phases. Within each phase, a qualitative approach is adopted to analyze patterns of population movement, shelter overcrowding, and variations in service availability, allowing for a comparison of how crises intensify or recede over time and how specific challenges become more dominant in particular phases. The analysis is structured around three main aspects: access to services, the condition of infrastructure, and the uneven impact of humanitarian aid across different areas. The findings show that repeated displacement, damaged services, and limited aid intensify spatial inequalities over time, with certain vulnerabilities becoming more pronounced in specific phases.

Keywords: Gaza, spatial inequality, displacement, access to services, UNRWA reports

1. Introduction

The escalation of the Israeli–Palestinian conflict in October 2023 caused a severe humanitarian crisis in Gaza (Figure 1). It led to widespread destruction, large-scale displacement, and the disruption of essential services, such as food systems, health services, and basic infrastructure. However, it is important to note that this crisis did not begin in 2023. Instead, the war intensified long-standing structural vulnerabilities shaped by a 17-year blockade and repeated military escalation (Hassoun et al., 2024).

As the war that began on October 7 continued, the healthcare system in Gaza experienced near-total collapse. Most hospitals and primary healthcare facilities were either destroyed or forced to cease operations. By April 2024, approximately 84% of health facilities were damaged or destroyed, while hospital system functionality declined to nearly 14% and never exceeded one-third of its pre-war capacity after December 2023 (Mills et al., 2026). At the same time, internal displacement reached unprecedented levels, and food insecurity worsened dramatically across the Gaza Strip. Several areas, particularly northern Gaza, approached famine conditions, with many families resorting to animal feed and wild plants for survival. Recent studies describe the situation as one of

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the world's most severe hunger crises and warn that the population was on the verge of famine[1], if not already experiencing it (Hassoun et al., 2024; Mills et al., 2026).

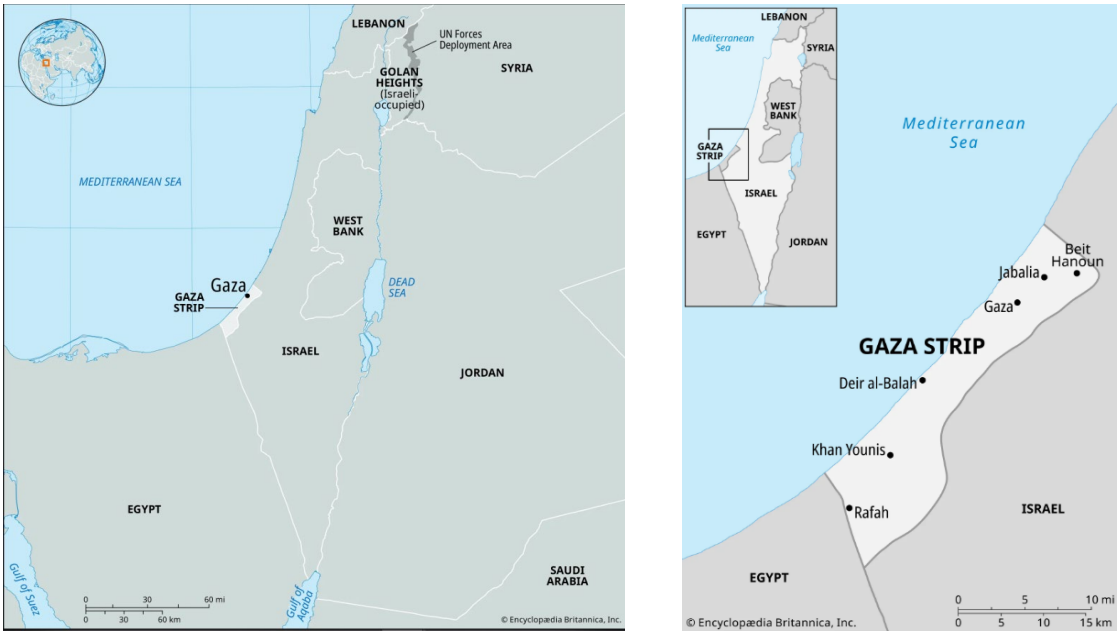

Figure 1 Geographical location of the Gaza Strip (Encyclopædia Britannica, n.d.)

Before the escalation of the conflict in October 2023, the United Nations Relief and Works Agency for Palestine Refugees (UNRWA) played an important role in providing basic services for Palestine refugees in Gaza. As the main humanitarian organization, UNRWA operated 22 primary health-care centers that served approximately 1.3 million registered refugees and provided large numbers of daily medical consultations (UNRWA, 2023a). The agency also ran a wide education system with 278 schools, making it one of the largest school networks in the region (UNRWA, 2023b). In addition, UNRWA provided regular food assistance to approximately 1.7 million people every three months, helping to reduce food insecurity among refugee families (UNRWA, 2023c). However, even before 2023, the system was already under pressure due to high population density, limited resources, and growing demand for services, showing existing structural weaknesses before the escalation of the conflict.

After October 2023, UNRWA expanded its role to respond to the widespread destruction of health facilities and the collapse of essential service systems in Gaza. The agency opened new medical points inside shelters and coordinated with international organizations, such as the World Health Organization (WHO) and UNICEF, to restore critical health services under emergency conditions (Aljadba et al., 2025). At the same time, UNRWA scaled up its emergency nutrition response, distributing food parcels and screening tens of thousands of children for malnutrition (Alkhammash et al., 2025). UNRWA's situation reports and operational data quickly became crucial sources of information on deaths, displacement, service disruptions, and disease trends, establishing the agency not only as a central service provider but also as an institutional witness documenting the crisis through systematic reports, data collection, and public advocacy (Al-Jadba et al., 2024; Bakri et al., 2025).

[1] Several scholars describe this situation as a deliberate or manufactured humanitarian catastrophe and emphasize its devastating impact on public health and global development goals, particularly Sustainable Development Goal 2 (SDG 2)[1] on ending hunger (Bakri et al., 2025).

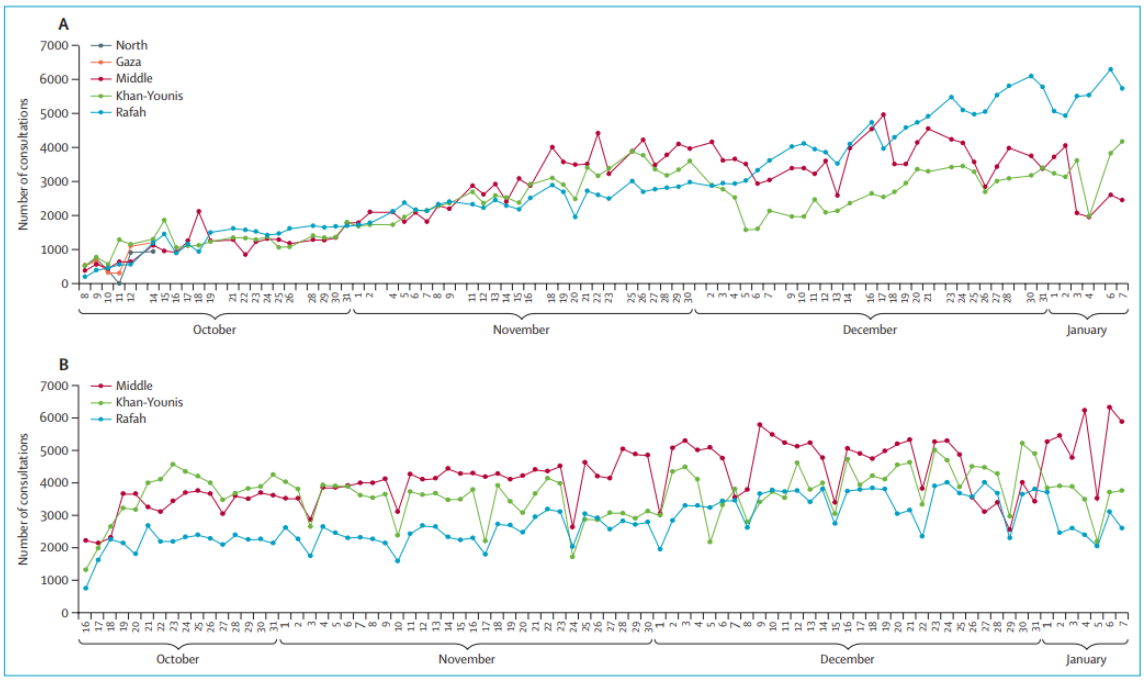

Figure 2 Spatial concentration of UNRWA health services in southern Gaza following the October 2023 war (Al-Jadba et al., 2024)

For example, Figure 2 illustrates the spatial concentration of healthcare services in southern Gaza after October 2023. As northern areas became inaccessible due to bombardment and movement restrictions, the UNRWA continued to operate health services mainly in the three southern governorates. This uneven geographical distribution of medical services demonstrates how displacement and conflict intensified spatial inequality in access to life-saving care (Al-Jadba et al., 2024).

Early in the war, drawing on UNRWA reports and field observations, Seita and Al-Jadba (2023) warned that Gaza was rapidly approaching a humanitarian catastrophe. They argued that the declaration of a "complete siege" exacerbated the already fragile situation, creating an immediate life-threatening emergency. Their commentary highlighted the collapse of basic services, including water, sanitation, and healthcare, as well as rising mental health needs, functioning as an urgent call for humanitarian access and international intervention (Seita & Al-Jadba, 2023).

The war has reshaped urban space in Gaza, turning everyday environments into spaces of destruction and survival, where urban warfare involves the active "modeling" and modification of the city through intervention and destruction of its social infrastructure (Mendonça, 2024). Damage to civilian infrastructure has been widespread and highly concentrated, particularly along designated evacuation routes, forcing civilians into overcrowded and unsafe areas with severely limited services (Asi et al., 2024). In this context, the destruction of educational and residential spaces has altered the social function of the urban environment, where schools are no longer centers of learning but have become shelters for the displaced populations. Consequently, large parts of Gaza now operate as "spaces of elimination," where urban space is reorganized around survival rather than normal civic life (Dader et al., 2024).

At the level of everyday spatial conditions, armed conflict further reorganizes space through forced displacement, overcrowded sheltering, restricted access to services, and intensified spatial control, all of which deepen inequality and vulnerability (Asi et al., 2024). These processes have been further conceptualized in the literature as forms of colonial spatial violence that disproportionately affect women, children, and refugees, undermining access to dignified and secure living conditions (Ajour, 2025). Severe housing inadequacies, together with limited access to electricity and clean water among displaced populations, further demonstrate how spatial control

mechanisms contribute to the persistence of long-term humanitarian crises and structural social inequalities (Sabah, 2025).

Beyond these immediate humanitarian and spatial consequences, the ongoing destruction raises questions about the long-term historical and spatial transformation of Gaza. From a broader historical perspective, Veracini (2025) situates the ongoing transformation of Gaza within the trajectory of settler colonialism, questioning whether current developments represent a turning point in, rather than simply a continuation of, this historical process. More specifically, Piletić (2026) describes Gaza's urban destruction as a process of spatial restructuring in which containment, destruction, and speculative redevelopment are interconnected. Through the concept of "(un)creative destruction," Piletić further argues that redevelopment may be advanced through devastation rather than only emerging in its aftermath, drawing attention to the simultaneity of destruction and anticipation of future spatial transformation. This relationship is particularly visible in proposals for Gaza's postwar reconstruction. In this context, Bshara (2025) interprets Trump's proposal to "own Gaza" and transform it into a "Riviera" not simply as a redevelopment vision, but as a real-estate project in which postwar reconstruction becomes a means of reimagining and reorganizing Palestinian space.

Building on these spatial interpretations of the crisis, this study adopts an architectural perspective, placing it in dialogue with spatial justice theory and humanitarian document analysis to argue that spatial injustice in Gaza extends far beyond the physical destruction of buildings, and is produced through patterns of displacement, uneven access to services, and the uneven distribution of humanitarian aid.

Spatial justice builds on Lefebvre's "right to the city" (Lefebvre, 1996) and Soja's work on spatial inequalities (Soja, 2010), focusing on how power relations produce unequal access to resources, decision-making, and the ability to shape space (Moroni & De Franco, 2024). Lefebvre argued that urban space is not neutral but socially produced through everyday life, economic processes, planning, and state power. In this sense, the "right to the city" refers to the right of all urban inhabitants to access and participate in shaping urban space (Purcell, 2003). Soja extends this argument by showing that space both reflects and produces inequality, making spatial injustice visible in patterns such as unequal service distribution and socio-spatial segregation (Soja, 2010). Together, these perspectives highlight the deep relationship between space, power, and inequality.

Within this framework, displacement is approached in this study as a multi-layered concept that is understood differently across humanitarian and academic literature rather than as a single fixed condition (Echevarria-Coco & Gardeazabal, 2020). On the one hand, humanitarian organizations such as UNRWA and UNHCR define displacement primarily as the forced movement of people from their homes due to conflict, violence, or crisis. It is commonly measured through the number of internally displaced persons (IDPs) and their presence in shelters (Al-Jadba et al., 2024; Echevarria-Coco & Gardeazabal, 2020). This definition is essential for humanitarian response, as it helps identify immediate needs such as shelter, food, water, and health services.

On the other hand, critical urban and migration studies conceptualize displacement in a broader and more prolonged sense, viewing it not only as a singular event of movement but as an ongoing condition that reshapes everyday life over time (Feldman, 2012). From this perspective, displacement includes the loss of home, stability, and routine urban life, even after relocation to "safer" areas, extending beyond physical movement to encompass sustained insecurity, instability, and disruption of everyday existence (Murcia, 2020). Building on these complementary perspectives, this study adopts a combined understanding of displacement, referring both to the number of people recorded as displaced in humanitarian reports and to the wider spatial condition characterized by repeated movement, instability, and unequal access to services over time.

The spatial conditions examined in this study, loss of home, overcrowding, and sheltering, are understood as interconnected dimensions of urban disruption that collectively produce spatial inequality rather than isolated categories. The loss of home refers to ruptures in belonging and

everyday spatial continuity, while overcrowding and sheltering reflect the concentration of displaced populations within limited and often inadequate infrastructures, where space and resources are unevenly distributed. At the urban scale, these interconnected conditions are part of a broader spatial and demographic restructuring, as forced displacement and the destruction of the built environment reshape population distribution, access to services, and the organization of urban space (Maghrabieh, 2026). This broader restructuring is also manifested in everyday urban life through constrained mobility, altered routines, and differentiated exposure to risk and resources, through which spatial inequality becomes embedded in daily spatial experience (Trovato & Ariss, 2025; Maghrabieh, 2026). Thus, the combined understanding of displacement allows UNRWA reports to be read not only as numerical records, but also as spatial narratives that show how the crisis develops and affects urban life.

Humanitarian action operates within fragmented environments, where access to affected populations and the delivery of essential services depend on changing political and military conditions. Kool et al. (2021) describe this through the concept of shifting "micro-spaces," in which humanitarian actors must continuously adapt to unstable and restricted areas of operation. These conditions complicate aid delivery, as movement restrictions and security constraints create unstable zones of access that hinder consistent service provision across affected populations. Overall, these dynamics demonstrate how humanitarian response, everyday survival, and the organization of space become closely intertwined during conflict.

Studies on housing, health, and WASH (water and sanitation) further show that infrastructure damage and service disruption are unevenly distributed and concentrated in specific areas, thereby intensifying inequalities among displaced populations (Sabah, 2025; Sabah & Abuzerr, 2025). Satellite and infrastructure studies further document widespread damage to homes, schools, hospitals, and water systems, leaving severely limited functional urban spaces (Holail et al., 2024; Asi et al., 2024). Viewed within a broader historical context, these spatial conditions can be understood as part of a longer trajectory shaped by decades of siege, repeated military attacks, and externally controlled infrastructures. These processes have produced overlapping spaces of crisis characterized by restricted movement and limited access to essential services (Hynek & Ter-Ghazaryan, 2025; Agha et al., 2024).

UNRWA reports provide detailed datasets on these conditions, including variations in housing, access to water and electricity, and damage to essential services (Sabah, 2025; Asi et al., 2024; Hamamra et al., 2025). Rather than treating these reports as descriptive accounts, this study uses them as raw empirical material to reconstruct spatial inequalities through systematic analysis, allowing the uneven geographies of vulnerability and hardship across Gaza to be examined over time.

Discussions in architecture, urban studies, and spatial justice have increasingly treated inequality as something produced and organized through space. Research has extensively examined how spatial arrangements shape unequal access to public facilities, services, and opportunities, and how urban environments reproduce broader social and economic inequalities (Wu & Liu, 2022; Sarkar et al., 2024). In contrast, a smaller body of humanitarian and conflict-related scholarship has explored how humanitarian interventions contribute to the production of spatial orders, exclusions, and inequalities. Studies have shown that humanitarian practices often rely on specific spatial forms and governance mechanisms that structure access, mobility, and assistance in conflict settings (Prinz & Schetter, 2020; Kool et al., 2021). Other research argues that the spatial implications of displacement and humanitarian action have frequently been overlooked, with place treated mainly as background rather than as a central object of analysis (Fawaz et al., 2022).

In response to these gaps, this study examines how spatial inequality in Gaza is constructed and represented in UNRWA reports published after October 2023, treating these reports as primary material through which recurring spatial conditions can be analytically interpreted within the humanitarian discourse and institutional responsibility. From this perspective, the analysis is

structured around three interconnected questions that guide the inquiry into how UNRWA reports describe spatial conditions in Gaza after October 2023, what forms of spatial inequality emerge in relation to displacement, shelter, and access to services, and how these reports operate as forms of institutional witnessing during the war.

To address these questions, this article analyzes UNRWA situation reports issued after October 2023, along with related supporting documents, as key institutional texts through which the humanitarian crisis in Gaza is narrated and spatialized. While UNRWA reports do not represent all lived experiences in Gaza, they provide insight into one of the Strip's most influential humanitarian knowledge systems and illustrate how it articulates spatial injustice. Rather than evaluating humanitarian performance, the analysis focuses on how space is described and made visible within humanitarian discourse. This approach contributes to broader debates on spatial justice, humanitarian governance, and the role of architecture in contexts of prolonged conflict.

2. Methodolgy

This study draws on UNRWA Situation Reports from Gaza, published between October 2023 and December 2025, for a mixed-methods (qualitative and quantitative) analysis of how urban space changes and is reshaped during the conflict. While such reports continue to be published beyond this period, including after ceasefire announcements, this timeframe is selected to capture the period from the initial escalation of the conflict and its most acute phases of spatial and humanitarian change. To examine spatial inequality in Gaza, this study focuses on how displacement, sheltering, restricted access to services, and the transformation of everyday urban environments reshape urban life during conflict. By examining reports over time, the study aims to identify broader transformations in spatial conditions.

More than 200 UNRWA reports were published during the study period (UNRWA, n.d.). From these, 45 reports were purposefully selected. The selection of the 45 reports was based on the fact that UNRWA issues situation reports on a regular weekly basis, with each report covering approximately one week of humanitarian developments. Accordingly, the selected reports were distributed across the study period at relatively regular temporal intervals to ensure balanced coverage of the 2023–2025 period. This approach allowed for the inclusion of key moments of intensified humanitarian change while maintaining a structured temporal representation of the overall dataset. Reports providing clear descriptions of spatial conditions, such as shelter status, infrastructure damage, access restrictions, and population movement, were prioritized to capture major shifts in displacement patterns, service disruption, and humanitarian conditions across the broader temporal development of the conflict.

During the preliminary review of the reports, five major phases of the humanitarian crisis were identified based on changes in displacement patterns, humanitarian access, military escalation, and the condition of essential services (Table 1). This temporal classification was developed to support a comparative analysis across different stages of the conflict and examine how spatial conditions evolved over time.

Table 1 Phases and Associated Reports

Phase	Time Period	Selected Reports
Phase 1	Oct–Nov 2023	#1, #4, #10, #16, #20, #26, #32, #38, #40
Phase 2	Dec 2023–Feb 2024	#50, #57, #60, #63, #68, #71, #74, #78, #82
Phase 3	Mar–Jun 2024	#83, #86, #90, #94, #98, #102, #107, #111, #115
Phase 4	Jul–Dec 2024	#118, #123, #126, #132, #136, #141, #145, #149, #153
Phase 5	2025	#156, #161, #166, #171, #176, #183, #187, #192, #202

To interpret changes across reports and phases systematically, a semi-quantitative scoring system based on three analytical indicators was developed. Each report was evaluated using an ordinal scale from 0 to 3 to reflect the level of spatial impact, where 0 indicates no impact, 1 indicates minor impact, 2 indicates moderate impact, and 3 indicates severe impact. For each report, the highest observed level of impact was recorded to preserve critical conditions and avoid masking severe spatial disruptions through averaging.

Thus, the methodology links humanitarian reporting with urban and spatial theory by treating UNRWA reports not only as descriptive humanitarian documents, but also as spatial narratives that reveal how urban space is reorganized, restricted, and experienced during conflict. This approach allows for a systematic examination of how war reshapes urban environments, affects population movement, and produces uneven access to infrastructure and essential services across the Gaza Strip.

3. From Data to Spatial Interpretation

UNRWA reports are analyzed as spatial documents that reflect the reorganization of urban life during conflict. The analysis focuses on recurring references to movement, sheltering, infrastructure damage, access restrictions, and everyday survival, interpreting them as indicators of broader spatial conditions rather than isolated humanitarian descriptions. Numerical data and qualitative observations are therefore used to identify patterns of spatial change across the conflict period.

Accordingly, the analysis is organized into three stages: data compilation from UNRWA reports, involving the systematic extraction of key observations related to spatial conditions; spatial patterns across temporal phases, focusing on the comparison of severity levels and changes in displacement, access, and infrastructure across the identified crisis phases; and reframing temporal phases through spatial injustice, where recurring conditions are interpreted as expressions of unequal spatial access and differentiated vulnerability across Gaza.

3.1. Data Compilation from UNRWA Reports

Table 2 Raw Data

Phase / Period (Reports)	Timeframe	Displaced People (IDPs)	UNRWA Shelters / Capacity	Health Services	WASH (Water & Sanitation)	Casualties / Deaths	Notes / Key Observations
Phase 1 – (Reports #1–#43)	07/10/2023 – 30/11/2023	Rapid increase from 20,000 to 1.8 million (80% of Gaza population displaced)	3,400 to 1.1M in 156 shelters; average 9,500 per shelter (4–20× capacity)	0 to 600,000+ patients treated; daily consultations 10,700; post-natal/high-risk pregnancy cases 1,100+; 11,622 children vaccinated	8 water wells + water trucking; solid waste collection ongoing; partial reliance on solar due to fuel shortage; some desalination plants limited	Gaza fatalities ~100 to >15,000 (6,150 children & 4,000 women); UNRWA staff 0 to 111	Extreme overcrowding occurred in shelters in Gaza City and North Gaza became largely inaccessible, leading to displacement toward Deir al-Balah and Khan Younis. This increased disease spread, worsened hygiene, and deepened mental health strain. Humanitarian aid remained limited due to conflict, fuel shortages, and damaged infrastructure, though psychosocial support reached 81,102 people, and 375,000 children received recreational activities. Temporary humanitari an pauses (November 24–29) allowed limited aid access, while northern shelters remained highly restricted.
Phase 2 – (Reports #50–#82)	7 Dec 2023 – 24 Feb 2024	~1.7M IDPs (over 75% population); multiple displacement s common	150–155 shelters operation al; severely congested ; capacity exceeded	7 health centres operational; 539–708 staff; >2.4M consultations cumulatively; vaccinations ongoing; psychosocial support for 148,000+ IDPs	WASH services limited due to conflict; infrastructure damaged; water/sanitation access restricted	Gaza Strip: 29,514 killed (70% women & children), 69,616 injured; UNRWA shelters: 403 IDPs killed, 1,385 injured; UNRWA staff fatalities: 158	Heavy fighting occurred in Khan Younis, Deir al-Balah (Middle Area), and Northern Gaza, while mass displacement caused extreme overcrowding in Rafah, where the population exceeded 1.5 million. Repeated displacement became common as schools, shelters, distribution centres, and IDP sites were repeatedly affected. Hospitals, including Nasser Hospital in Khan Younis, were under siege. Humanitarian aid was severely restricted to about 98 trucks per day (vs. 500 pre-war), limiting access to Northern Gaza and worsening the crisis.

Phase 3 – (Reports #83–#115)	1 Mar 2024 – 24 Jun 2024	≈1.63M IDPs (over 75–80% population; multiple displacements continue)	186–188 shelters impacted; severely congested; >1,600 IDPs per shelter on average; some shelters destroyed or rendered inaccessible	66 medical points/centres operational; ≈953 staff; 15,000–15,600 weekly consultations; vaccinations ongoing; MHPSS reached 680,000 IDPs including 430,000 children; post-natal & high-risk pregnancy care ongoing	WASH updates limited due to security and internet disruptions; critical fuel shortages affecting water pumping and sanitation; infrastructure damaged	UNRWA staff killed: 193; IDPs killed in shelters: 508; IDPs injured in shelters: 1,559; Gaza total fatalities: 36,479–37,396; injuries: 82,777–85,523	Severe disruption of aid through the Kerem Shalom Crossing and Rafah limited humanitarian access and increased the risk of famine. Continued displacement occurred between Rafah, Deir al-Balah, and Khan Younis due to changing security conditions. Hospitals were overwhelmed, while airstrikes on health and education facilities further weakened services. Fuel shortages critically affected WASH and health systems, and psychosocial support became essential. Over 446 incidents impacted UNRWA premises, reflecting a highly unstable humanitarian environment.
Phase 4 – (Reports #118–#153)	Jul 2024 – 31 Dec 2024	~1.5–1.6M IDPs (≈80–90% of Gaza population; repeated displacements common)	200+ shelters impacted; overcrowding severe; some destroyed or inaccessible	3 of 22 UNRWA health centres operational; 97 mobile medical teams; 1,189 health staff; 14,952 consultations/day (Dec 29); post-natal & high-risk pregnancy care; 7M+ consultations cumulatively since start; vaccinations: 560,000 children <10; MHPSS: 278,981 sessions for 730,000 displaced	Emergency WASH: water wells maintained, desalination systems, water trucking; hygiene kits distributed; 38,000 m³ water distributed (early Dec); 1,972 tons solid waste collected (first 2 weeks Dec); winterization ongoing	Gaza fatalities ~33,000–35,000 (est.); UNRWA shelters: 745+ IDPs killed, 2,202 injured; UNRWA staff killed since Oct 7: 263	Israeli evacuation orders affected over 80% of Gaza, causing repeated displacement across the Strip. Attacks on shelters and hospitals, including Kamal Adwan Hospital, continued, while hospitals remained overwhelmed. Harsh winter conditions in Rafah increased risks, such as neonatal hypothermia, with approximately 7,700 newborns lacking care. Aid was severely restricted (approximately 76 trucks/day vs. 500 pre-war), and WASH and energy systems further deteriorated. Despite this, psychosocial support reached over 730,000 displaced people (520,000 children), and food aid reached approximately 1.46 million people.
Phase 5 – (Reports #156–#202)	1 July 2025 – 23 December 2025	~1.33 million IDPs, including ~79,000 in UNRWA collective shelters and the rest in damaged or informal sites	150–160 shelters, most severely congested; some destroyed or within militarized areas	8–10 health centres + 103 mobile medical teams; ~56,000 consultations per week; ~1,100–1,200 health staff; high-risk pregnancy care and vaccination ongoing	35,000–40,000 m³ of water distributed to 300,000–1.4 million people; ~3,500 tons of solid waste collected; 400–500 cleaning campaigns; maintenance of water wells and desalination systems ongoing	~30,000–40,000 killed, ~50,000–60,000 injured; 50–60 UNRWA staff killed	A prolonged crisis continues with widespread displacement and movement across Rafah, Khan Younis, and central Gaza. Severe shortages of food, water, and health services persist, along with outbreaks of skin and communicable diseases, reflecting worsening conditions. Schools and hospitals remain heavily damaged, infrastructure is largely degraded, and humanitarian access is limited. UNRWA facilities face ongoing risks, while psychosocial support continues to reach tens of thousands of affected people.

Across the five phases, the data reveal a clear and consistent transformation in Gaza's humanitarian geography. Displacement progressively shifts from northern Gaza toward central and southern regions, particularly Deir al-Balah, Khan Younis, and eventually Rafah, reflecting repeated forced movement under deteriorating security and loss of habitable areas. At the same time, essential services, including shelters, health systems, and WASH infrastructure, remain under continuous strain, with capacity increasingly misaligned with the growing concentration of displaced populations. Although humanitarian assistance expands over time, it remains unable to compensate for the scale and repetition of displacement and infrastructure collapse. Overall, the data indicate a widening spatial imbalance between concentrated humanitarian needs and fragmented service delivery, producing an increasingly unequal geography of survival across the Strip.

Building on these observations, Figure 3 visually synthesizes the evolving relationship between displacement pressure, shelter overcrowding, insecurity, and access to essential services across the five phases of the conflict, while also highlighting regional differences in humanitarian conditions throughout Gaza.

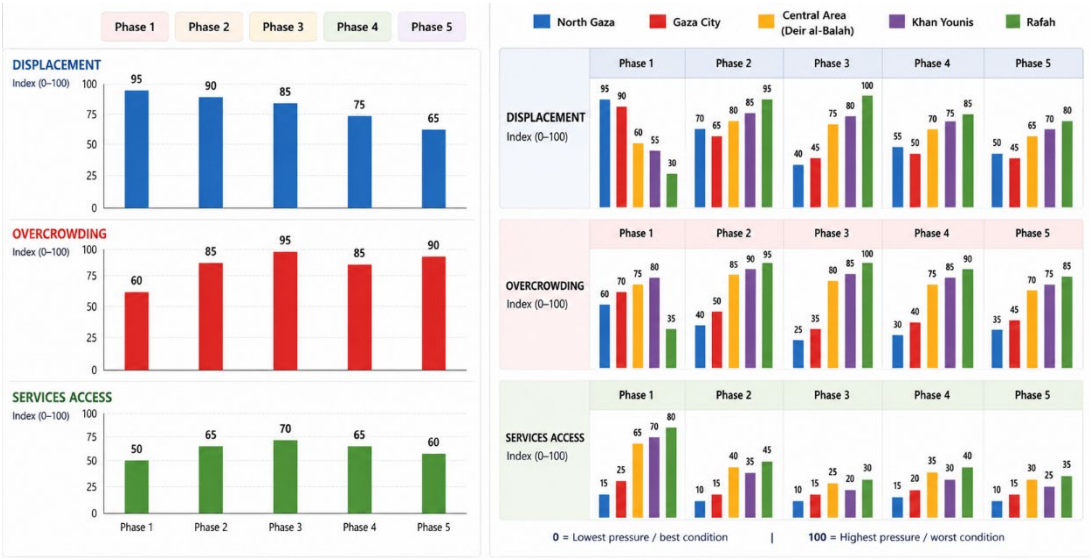

Figure 3 Evolution of humanitarian conditions across Gaza (2023–2025)

Figure 3 presents a combined temporal and regional analysis of the humanitarian conditions in Gaza. It illustrates persistent displacement and shelter overcrowding, alongside declining access to essential services across the five phases of the conflict. Regionally, it shows a gradual shift in humanitarian pressure from northern Gaza toward the central areas and Rafah in the south. Together, these patterns highlight how humanitarian conditions have evolved across both time and space, forming a foundation for subsequent spatial analysis. By translating UNRWA reports into comparable visual patterns, the figure marks an important step from descriptive humanitarian reporting to a spatial interpretation of the crisis.

Following the temporal patterns illustrated in Figure 3, Figure 4 provides a structured comparison of humanitarian pressure across northern, central, and southern Gaza over five phases.

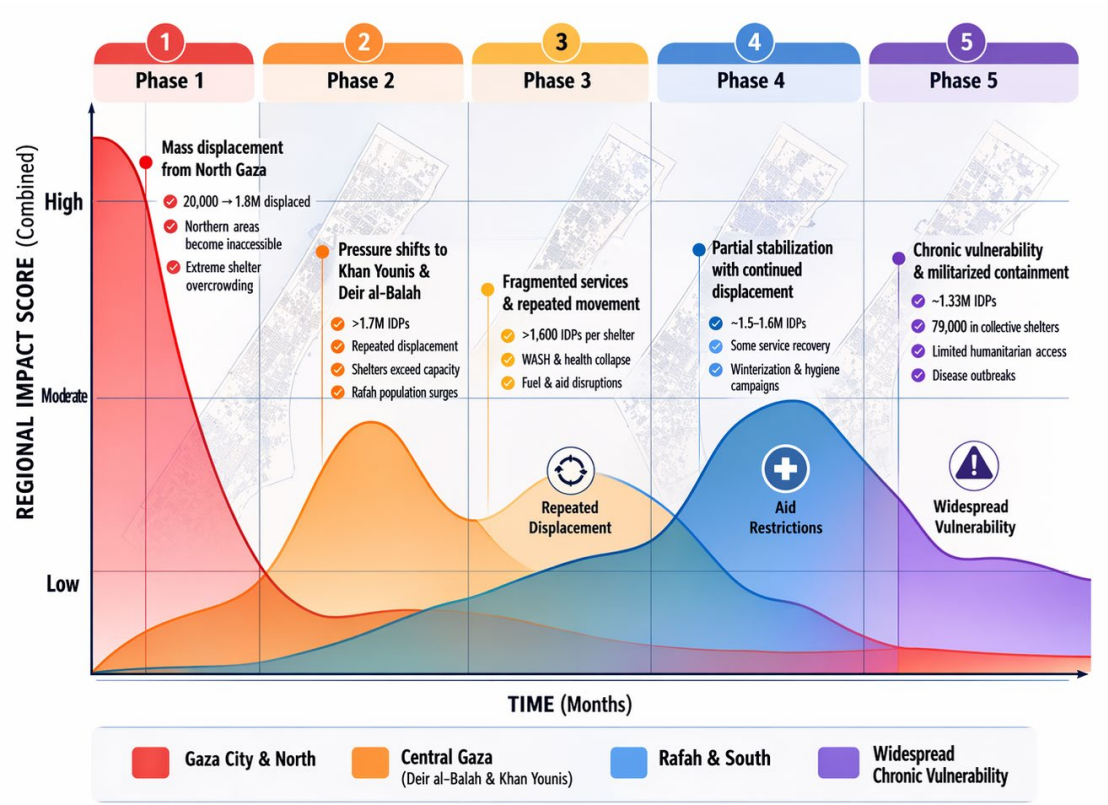

Figure 4 Spatial ınequality and humanitarian pressure in Gaza: A five-phase regional trend analysis (2023–2025)

Figure 4 translates the temporal findings of this study into a comparative spatial framework across the five phases of the conflict. This enables a relational reading of humanitarian conditions by situating northern, central, and southern Gaza within a single spatial system rather than treating them as isolated units. The visualization reveals a progressive spatial reconfiguration of vulnerability: northern Gaza transitions from a displacement origin to a largely inaccessible zone, central Gaza functions as a transitional buffer under increasing pressure, while southern Gaza, particularly Rafah, emerges as the main concentration area for displaced populations and humanitarian stress. Overall, the figure demonstrates that spatial inequality is produced through continuous redistribution of population and resources within a shrinking and increasingly constrained spatial system. These patterns inform the subsequent analytical framework, which organizes the findings into a structured scoring system.

3.2. Spatial Patterns Across Temporal Phases

The scoring system in Table 3 is based on a structured qualitative reading of UNRWA Situation Reports, identifying recurring textual evidence related to severity, frequency, and spatial intensity across four key indicators: Average Displacement Score, Average Health Services Score, Average WASH Score, and Average Humanitarian Access Score. Building on the findings presented earlier in Table 2, Figure 3, and Figure 4, Table 3 was developed to synthesize these dimensions into a comparative analytical framework across the five phases.

In this way, Table 3 translates narrative humanitarian descriptions into comparable indicators, allowing a systematic comparison of changes in displacement pressure, service conditions, and humanitarian access over time.

Table 3 Data Analysis Using a Scoring System

Phase	Avg Displacement Score	Avg Health Services Score	Avg WASH Score	Avg Humanitarian Access Score	Key Trends / Spatial Patterns
Phase 1	3.0	2.5	2.8	2.2	Rapid mass displacement across Gaza, extreme shelter overcrowding, northern areas often inaccessible, early outbreaks of disease, and sporadic emergency aid deliveries.
Phase 2	2.8	2.8	3.0	3.0	Overcrowding remains critical; multiple displacements; health services strained; WASH limited due to conflict; aid deliveries blocked; fighting concentrated in Khan Younis, the Middle Area, Northern Gaza, and Deir al Balah.
Phase 3	2.5	3.0	3.0	3.0	Severe congestion in shelters, multiple displacements, continued disruption of water, sanitation, and health infrastructure, fuel shortages, high risk of famine, and incidents affecting UNRWA facilities are widespread.
Phase 4	2.3	2.7	2.6	2.7	Slight stabilization in IDPs, but repeated displacements continue; some health and WASH services partially restored; winterization and hygiene campaigns implemented; northern and central Gaza heavily affected; psychosocial support scaled up.
Phase 5	2.0	2.5	2.5	2.5	Chronic crisis with persistent displacement; 79,000 in collective shelters; continued strain on health services; WASH coverage improves but is still limited; humanitarian access blocked in militarized zones; outbreaks of communicable diseases; damage to schools and hospitals widespread; psychosocial support for tens of thousands ongoing.

Drawing on a structured qualitative reading of UNRWA Situation Reports, Table 3 presents a scoring system based on recurring textual evidence related to severity, frequency, and spatial intensity across four key indicators: Average Displacement Score, Average Health Services Score, Average WASH Score, and Average Humanitarian Access Score.

To further spatialize the displacement dynamics identified in the scoring analysis, Figure 5 map visualizes the directional movement and concentration of displaced populations across Gaza throughout the five phases of the conflict.

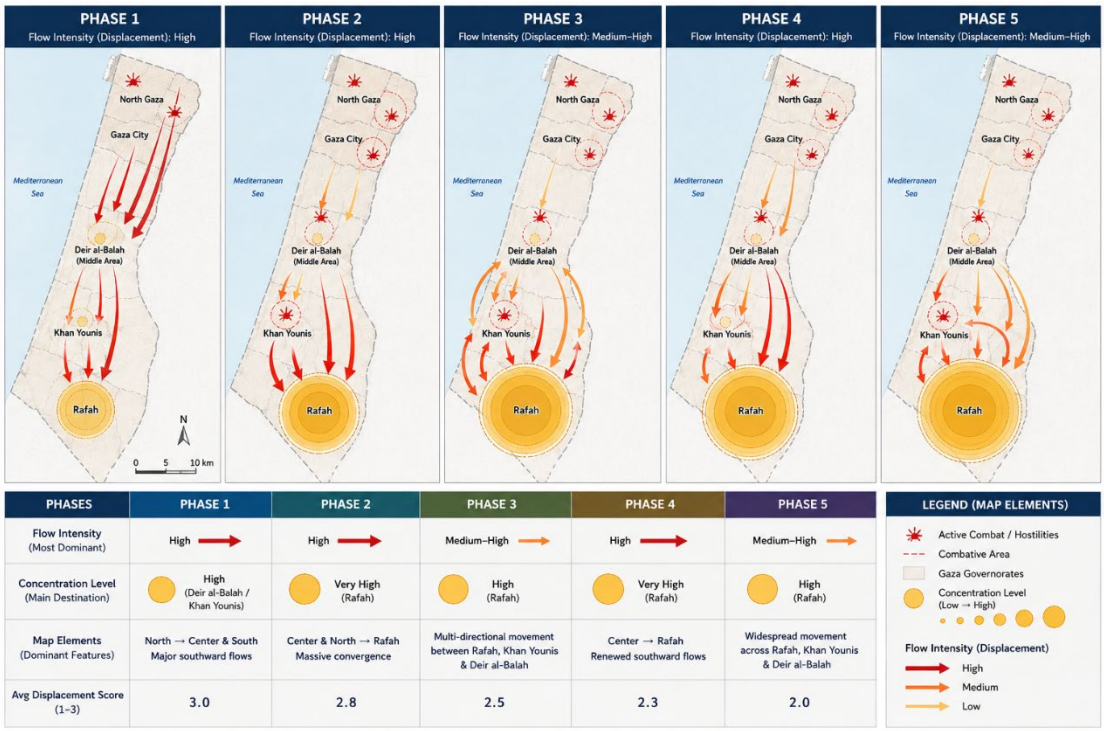

Figure 5 Displacement flow map

Figure 5 illustrates how repeated displacement flows gradually shifted the population pressure from northern Gaza toward central and southern regions, particularly Deir al-Balah, Khan Younis, and Rafah. Rather than depicting a single directional movement, the visualization reveals recurring cycles of evacuation, temporary concentration, and secondary displacement driven by insecurity, restricted mobility, and the continuous loss of habitable areas. This process demonstrates how mobility itself became a key mechanism through which humanitarian pressure and spatial inequality were redistributed across the Gaza Strip. In relation to these displacement dynamics, Figure 6 examines how the repeated accumulation of displaced populations generated severe and uneven patterns of shelter overcrowding across different regions over time.

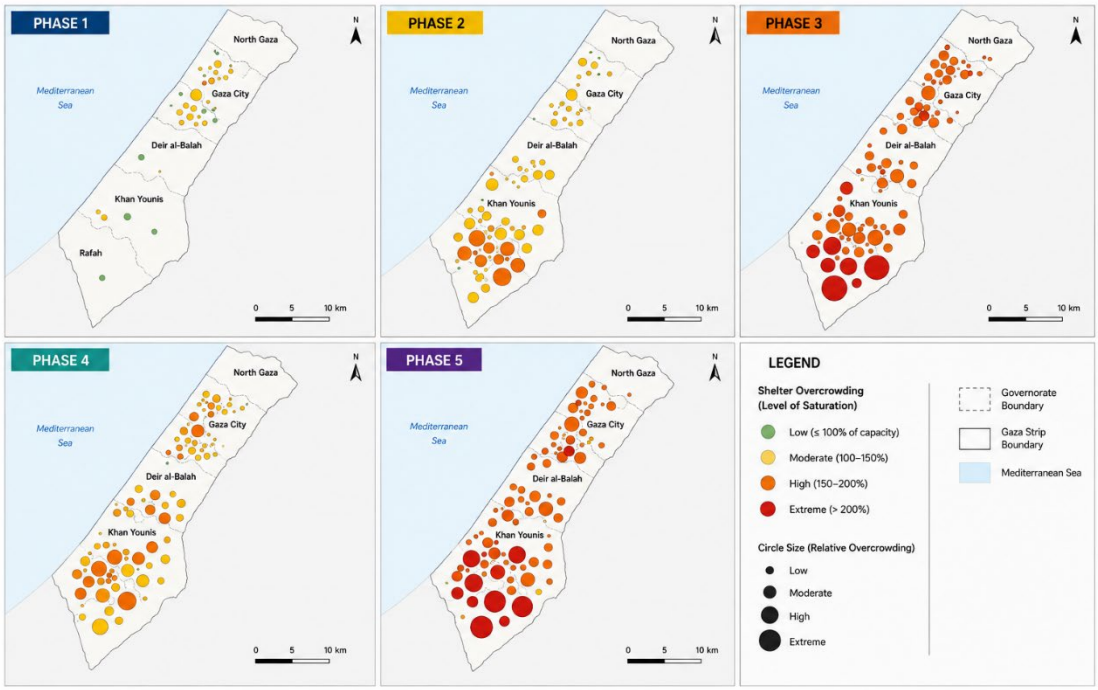

Figure 6 Spatial distribution of shelter overcrowding

This figure illustrates spatial variations in shelter overcrowding across Gaza, revealing a progressive shift in population concentration from central areas toward southern locations, particularly Rafah. Phase 1 shows relatively localized overcrowding within central Gaza, while Phase 2 reflects increasing pressure in southern areas as displacement flows intensify and available shelter capacity becomes more constrained. Phase 3 and 4 demonstrate a further escalation of overcrowding in southern zones, accompanied by widening pressure across multiple urban centers, indicating a transition from concentrated to more spatially diffused high-density conditions. Overall, the comparison highlights how displacement pressure accumulates unevenly across space, producing concentrated humanitarian stress in specific areas rather than a uniform distribution. This pattern demonstrates that shelter overcrowding is driven by continuous population compression into increasingly limited viable locations, reinforcing emerging forms of spatial inequality.

The northern areas experienced severe service disruption due to infrastructure damage, restricted mobility, and limited humanitarian access, while central and southern regions faced growing pressure from the concentration of displaced populations. The maps reveal that essential services remained spatially fragmented and unable to match the scale and distribution of humanitarian needs, reinforcing broader patterns of displacement pressure, overcrowding, and spatial inequality across the territory. Taken together, Figures 3, 4, 5, and 6 provide a spatial interpretation of how displacement, shelter overcrowding, and uneven service accessibility collectively reorganized the conditions of vulnerability across Gaza.

4. Discussion: Reframing Temporal Phases Through Spatial Injustice

Building on the raw data, scoring analysis, and spatial mapping, this final section reframes the five phases through a spatial justice perspective by examining recurring patterns of displacement, service disruption, overcrowding, and restricted access across Gaza. Rather than treating the phases as only chronological stages, the analysis identifies dominant spatial conditions within each phase to show how humanitarian inequality progressively evolved into a prolonged and structurally uneven geography of vulnerability (Table 4).

Table 4 Spatial Injustice Across Phases

Phase	Phase Title	Spatial Justice Theme	Observations / Examples	Implications
Phase 1	**Initial Escalation**	Initial loss of safe space	Rapid IDP movement from 20,000 to 1.8M; 156 shelters overcrowded (4–20× capacity); northern shelters often inaccessible; limited WASH and health services; psychosocial support reached 81,102 people	Rapid spatial rupture from distributed urban living to an extreme concentration of population in limited shelter nodes. Early infrastructure collapse produces a severe mismatch between spatial demand and service capacity, establishing the foundational condition of spatial vulnerability.
Phase 2	**Mass Displacement**	Spatial concentration and contested space	Over 1.7M IDPs; shelters exceeded capacity; repeated displacements; fighting in Khan Younis, Middle Area, Northern Gaza, Deir al Balah; aid deliveries blocked; hospitals under siege	Increased spatial inequality as access to shelters, health, and water becomes uneven; high-risk zones emerge near conflict lines; contested urban spaces limit humanitarian movement
Phase 3	**Service Collapse**	Fragmentation of service space	1.63M IDPs; 186–188 shelters severely congested; >1,600 IDPs per shelter; fuel shortages disrupt WASH and health; over 446 UNRWA facilities impacted; hospitals overwhelmed	Fragmented access to essential services; shelter density creates health hazards; spatial segregation intensifies between safe vs high-risk zones; humanitarian access heavily restricted
Phase 4	**Ongoing Crisis**	Partial reclamation of space	~1.5–1.6M IDPs; 200+ shelters impacted; some WASH and health services restored; winterization campaigns; northern and central Gaza heavily affected; psychosocial support scaled up	Partial and uneven recovery of services produces differentiated spatial conditions. Repeated displa cement cycles maintain instability, preventing the consolidation of spatial recovery and sustaining long-term spatial inequality.
Phase 5	**Chronic Crisis**	Militarized containment and protracted displacement	~1.33M IDPs; 79,000 in collective shelters; many shelters in militarized zones; limited humanitarian access; outbreaks of communic able diseases; schools and hospitals damaged; UNRWA facilities exposed	Transition from acute crisis to structural spatial injustice. Populations become spatially contained within high-risk, overcrowded environments, indicating the lon_term normalization of infrastru ctural collapse and chronic marginalization.

Taken together, Table 4 demonstrates that the humanitarian crisis in Gaza cannot be understood as a linear sequence of events, but rather as a continuous process of spatial restructuring under conflict conditions. Across all five phases, three interrelated dynamics persist: the concentration of displaced populations in increasingly limited areas, the fragmentation and overloading of essential services, and the progressive restriction of access to safe and functional urban spaces.

These dynamics indicate that spatial inequality is structurally reproduced throughout the conflict through repeated cycles of displacement and service disruption. While the intensity and geographic focus of violence shift over time, the underlying pattern remains stable: the compression of the population into shrinking safe zones alongside the erosion of service capacity.

From a spatial justice perspective, the findings reveal a persistent mismatch between population needs and the spatial distribution of infrastructure and humanitarian access, producing chronic spatial inequality. This inequality evolves from acute disruption in the early phases to long-term spatial containment and vulnerability, becoming embedded in the everyday production of urban space through unequal access to safety, services, and mobility.

As shown in Table 4, the phase names were derived from the analysis and interpretation of the data presented in Tables 2 and 3, rather than being adopted from an existing classification. They reflect the dominant spatial conditions observed during each period, including displacement levels, service disruption, infrastructure damage, and access to humanitarian support.

The findings of this study demonstrate that the humanitarian crisis in Gaza should not be understood as a linear sequence of humanitarian phases, but rather as a progressively intensifying process of spatial reconfiguration in which displacement, infrastructure breakdown, and restricted access to services continuously reshape the urban system. What emerges across the five phases is not simply a change in scale or severity but a fundamental transformation in how space itself functions: from a relatively distributed urban system during Phase 1 to a highly compressed, fragmented, and ultimately militarized geography of survival by Phase 5. In this sense, spatial inequality is not a background condition of the crisis, but its central mechanism, continuously produced through the interaction between forced displacement patterns and the uneven collapse of urban infrastructure. As Soja (2010) argues, spatial injustice becomes most visible not in static conditions, but in the way spatial systems are actively reorganized through uneven development and crisis dynamics.

The comparison across Phases 1 to 3 reveals a gradual but critical shift in the spatial logic of displacement and vulnerability. During Phase 1, displacement was massive but was still partially distributed across central Gaza, allowing areas such as Deir al-Balah and Khan Younis to function as temporary absorption zones; however, by Phase 2, this buffering capacity had largely collapsed as repeated waves of displacement intensified pressure on the same limited areas, producing highly concentrated spatial stress and transforming central and southern Gaza into primary zones of survival. By Phase 3, this concentration evolved into extreme overcrowding combined with repeated exposure to infrastructural collapse and conflict, particularly in southern Gaza and Rafah, where vulnerability became spatially accumulated rather than evenly distributed. Importantly, this stage demonstrates that proximity to humanitarian aid and services does not necessarily reduce vulnerability, but may instead coincide with higher exposure due to density, repeated displacement, and systemic breakdown, thereby challenging conventional humanitarian assumptions about the protective role of spatial proximity.

A further transformation becomes evident in Phases 3 and 4, where the crisis shifts from concentrated spatial clustering to systemic fragmentation of the urban and humanitarian system. Instead of a single dominant overcrowded zone, Gaza begins to exhibit multiple disconnected and partially functioning humanitarian spaces in which healthcare, water, shelter, and mobility systems operate intermittently and unevenly. This fragmentation indicates that spatial inequality is no longer produced primarily through concentration, but through the breakdown of connections between places, infrastructures, and services. As Lefebvre (1996) suggests, urban space is produced

through both material structures and the continuity of social and functional relations; when these relations collapse, urban space itself becomes fragmented. Accordingly, vulnerability in this phase depends not only on location, but also on the degree to which spatial and infrastructural linkages remain operational or severed.

The transition to Phase 5 reflects a further shift toward chronic spatial containment, where displacement appears relatively stabilized but does not indicate recovery, rather, it indicates long-term entrapment within damaged, fragmented, and heavily constrained urban environments. At this stage, mobility is severely restricted and access to services remains uneven, meaning that spatial inequality becomes structurally embedded in everyday urban life rather than being produced through continuous mass movement. What characterizes this phase is a shift from movement-driven inequality to containment-driven inequality, where deprivation becomes fixed within deteriorated urban spaces. Taken together, the comparison across all five phases reveals a consistent but evolving spatial logic in which Gaza's urban system becomes progressively compressed, fragmented, and immobilized over time, demonstrating that spatial inequality is not simply a by-product of humanitarian crises but a constitutive process through which urban space itself is continuously reorganized.

From a spatial justice perspective, these dynamics reveal a persistent contradiction between humanitarian response mechanisms and the actual production of space under crisis conditions. Although humanitarian interventions expand in scale and technical capacity over time, they remain spatially concentrated within already overburdened zones, which inadvertently reinforce existing inequalities rather than alleviating them. Access to healthcare, shelter, water, and aid increasingly depends on spatial position within a fragmented urban system, meaning that location itself becomes a determinant of survival. Ultimately, the trajectory from distributed urbanity in Phase 1, to concentrated survival zones in Phases 2 and 3, to fragmented humanitarian spaces in Phase 4, and finally to chronic containment in Phase 5, demonstrates that the crisis cannot be reduced to a progression of severity levels, but instead reflects a deeper restructuring of urban spatial order under prolonged conflict, where inequality becomes embedded in the very production and organization of space itself.

5. Conclusion

This study demonstrates that the humanitarian situation in Gaza should be understood as a continuous dynamic spatial process rather than a series of isolated humanitarian events. The analysis is organized around five analytically derived phases identified through a systematic examination of UNRWA Situation Reports and named according to observed changes in displacement patterns and other forms of spatial inequality, including shelter overcrowding, service disruption, and infrastructure collapse. Across these phases, displacement remained consistently high, with populations increasingly concentrated in limited geographic areas under the sustained humanitarian pressure. In this context, spatial inequality emerges not as a temporary condition, but as a continuously reproduced process shaped by the interaction between population movement, infrastructural breakdown, and unequal access to essential services. Over time, this process has produced interconnected spatial conditions characterized by concentration, fragmentation, and long-term containment, resulting in persistent and evolving geographies of vulnerability across Gaza.

This raises a central question: How does displacement lead to spatial inequality? The findings suggest that displacement progressively reorganizes urban spaces through concentration, fragmentation, restriction, and containment, ultimately producing an uneven geography of vulnerability.

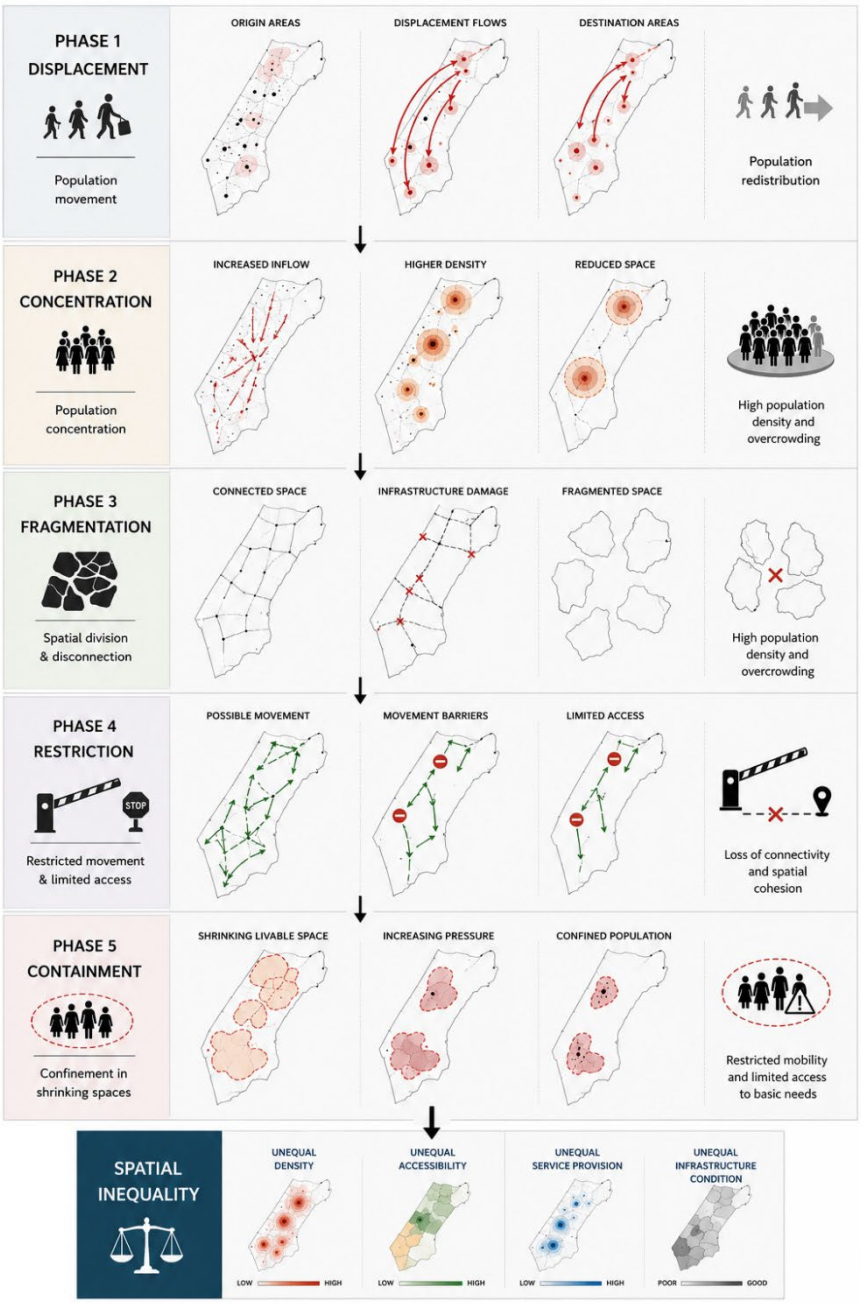

Figure 7 From displacement to spatial inequality: A conceptual spatial transformation

Taken together, these phases (Figure 7) reveal that displacement progressively transforms the spatial distribution of vulnerability. As populations become increasingly concentrated, fragmented, restricted, and contained, spatial inequalities in density, accessibility, services, infrastructure, and living conditions become more pronounced. This progression highlights an important finding of the study: spatial inequality emerges not only from the destruction of the built environment but also from the way displacement itself reorganizes where people can live, move, and access essential resources.

These findings can be further understood in relation to the broader patterns of spatial disruption documented in other conflict-affected urban contexts. In Ukraine, studies of wartime urbanization have documented how the destruction of civilian and social infrastructure contributes simultaneously to displacement, service disruption, and the reconfiguration of urban space, including the emergence of less visible geographies of internal displacement and fragmented urban environments (Haque et al., 2022; Havryliuk, 2022; Mezentsev & Mezentsev, 2022). The experience of Bosnia and Herzegovina similarly demonstrates how forced displacement and territorial

fragmentation can extend beyond the immediate period of conflict and contribute to the longer-term processes of spatial reconfiguration (Dahlman & Tuathail, 2005; Aquilué & Roca, 2016). These cases reinforce the broader relevance of examining displacement not only as a demographic outcome of conflict, but also as a spatial process associated with changing patterns of access, concentration, and urban fragmentation.

However, the Gaza case and the methodological approach adopted in this study offer a distinctive analytical perspective. While previous studies of Ukraine and Bosnia provide important evidence of the relationships between destruction, displacement, infrastructure disruption, and spatial reconfiguration, this study traces these relationships longitudinally through UNRWA Situation Reports and organizes them into five analytically derived phases. This temporal approach makes it possible to examine how humanitarian pressure is continuously redistributed across Gaza rather than treating displacement and service disruption as isolated consequences of conflict. The integration of humanitarian reporting with visual and spatial analysis further enables the study to identify changing concentrations of displaced populations, service pressures, and spatial inequalities across regions and phases. In this respect, the comparison does not position Gaza as identical to Ukraine or Bosnia, rather, it demonstrates how insights from other conflict settings can strengthen the interpretation of Gaza while underscoring the value of a systematic spatial and temporal approach to tracing the evolving geography of humanitarian vulnerability.

While UNRWA Situation Reports provide important time-based operational data for tracking displacement patterns, shelter conditions, and service provision over time, their capacity to represent the spatial complexity of these processes remains limited. In particular, the reports provide limited spatial details on local variations in vulnerability, accessibility, and service pressure. Within this context, this study identifies the limited use of detailed spatial representation as a significant gap in existing humanitarian reporting, highlighting the need for more precise spatial analytical tools to strengthen the understanding of humanitarian conditions and response strategies.

Therefore, Visualisation and and visual analysis therefore play a crucial role in illustrating changes in displacement flows and the distribution of services across regions and phases. By revealing the interconnected and spatially dynamic nature of humanitarian pressures, they provide a means of tracing the continuous redistribution of vulnerability, access, and humanitarian burden across the territory.

Thus, this study emphasizes the importance of integrating spatial analysis with humanitarian data to better understand the long-term urban consequences of conflict. By combining humanitarian reporting with a spatial justice perspective, this study enables an analysis that goes beyond identifying where humanitarian needs exist, to also examine how spatial inequalities are produced and reproduced through unequal access to space, services, mobility, and safety.

CRediT Authorship Contribution Statement

Areen Soboh: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Data visualization, Writing – original draft, Writing – review & editing. Bengi Su Ertürkmen: Supervision, Conceptualization, Methodology, Writing – review & editing.

Declaration of Competing 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 paper.

Data Availability

The data used in this study are derived from publicly available UNRWA Situation Reports and related publicly accessible sources.

Ethics Committee Approval

Ethics committee permission is not required.

References

Agha, Z., Esson, J., Griffiths, M. & Joronen, M. (2024) Gaza: A decolonial geography. *Transactions of the Institute of British Geographers*, *49*, e12675. https://doi.org/10.1111/tran.12675

Ajour, A. (2025). Unveiling the colonial violence of space in the Gaza genocide. *European Journal of Cultural Studies*, *28*, 1249-1263. https://doi.org/10.1177/13675494241310778

Aljadba, G., Elkhatib, Z., Hamad, K., Shah, S., Zeidan, W., Albeik, S., & Seita, A. (2025). UNRWA's health service in Gaza: Challenges and response to the October 2023 crisis. Eastern Mediterranean Health Journal = La Revue de Santé de la Méditerranée Orientale = al-Majallah al-Sihhiyah li-Sharq al-Mutawassit, *31*(2), 73-76. https://doi.org/10.26719/2025.31.2.73

Al-Jadba, G., Zeidan, W., Spiegel, P. B., Shaer, T., Najjar, S., & Seita, A. (2024). UNRWA at the frontlines: Managing health care in Gaza during catastrophe. *Lancet*., *403*(10428), 723_726. https://doi.org/10.1016/s0140-6736(24)00230-7

Alkhammash, H., Najjar, S. A., Tabaza, A., Horino, M., Chen, J., Jaffal, R., Jadba, G. A., & Seita, A. (2025). Integrating emergency nutrition into UNRWA's humanitarian response in Gaza. *Eastern Mediterranean Health Journal = La Revue de Santé de la Méditerranée Orientale = al-Majallah al-Sihhiyah li-Sharq al-Mutawassit*, *31*(4), 274-280. https://doi.org/10.26719/2025.31.4.274

Aquilué, I., & Roca, E. (2016). Urban development after the Bosnian War: The division of Sarajevo's territory and the construction of East Sarajevo. *Cities*, *58*, 152-163. https://doi.org/10.1016/j.cities.2016.05.008

Asi, Y. M., Mills, D., Greenough, P. G., Kunichoff, D., Khan, S., Hoek, J. V. D., Scher, C., Halabi, S., Abdulrahim, S., Bahour, N., Ahmed, A. K., Wispelwey, B., & Hammoudeh, W. (2024). "Nowhere and no one is safe": Spatial analysis of damage to critical civilian infrastructure in the Gaza Strip during the first phase of the Israeli military campaign, 7 October to 22 November 2023. *Conflict and Health*, *18*, Article 30. https://doi.org/10.1186/s13031-024-00580-x

Bakri, D. A., Khader, Y., Khatib, R., Al-Hammouri, F., Aabed, M., Abed, Y., Zureikat, Y., Lattouf, O., Shatat, A., Husseini, A. S., Nsour, M. A., & Bashier, H. (2025). The war on Gaza and its impact on public health: Challenges and pathways to recovery. *Frontiers in Public Health*, *13*. https://doi.org/10.3389/fpubh.2025.1664850

Bshara, K. (2025). Settler colonialism rebranded: Trump's Gaza plan and the capitalist logic of war. *Journal of Palestine Studies*, *54*(1), 62-70. https://doi.org/10.1080/0377919X.2025.2489264

Dader, K., Ghantous, W., Masad, D., Joronen, M., Kallio, K., Riding, J., & Vainikka, J. (2024). Topologies of scholasticide in Gaza: Education in spaces of elimination. *Fennia - International Journal of Geography*. https://doi.org/10.11143/fennia.147002

Dahlman, C., & Tuathail, G. Ó. (2005). The legacy of ethnic cleansing: The international community and the returns process in post-Dayton Bosnia–Herzegovina. *Political Geography*, *24*(5), 569-599. https://doi.org/10.1016/j.polgeo.2005.01.007

Echevarria-Coco, J., & Gardeazabal, J. (2020). A spatial model of internal displacement and forced migration. *Journal of Conflict Resolution*, *65*(2-3), 591-618. https://doi.org/10.1177/0022002720958470

Encyclopædia Britannica. (n.d.). *Gaza Strip* [Image]. https://www.britannica.com/place/Gaza-city-Gaza-Strip#/media/1/227443/100799

Fawaz, M., Al-Hage, C., & Harb, M. (2022). Unplanned links, unanticipated outcomes: Urban refugees in Halba (Lebanon). *Environment and Planning D: Society and Space*, *40*(3), 486_507. https://doi.org/10.1177/02637758211070565

Feldman, I. (2012). The humanitarian condition: Palestinian refugees and the politics of living. *Humanity: An International Journal of Human Rights, Humanitarianism, and Development*, *3*(2), 155-172. https://doi.org/10.1353/hum.2012.0017

Hamamra, B., Mahamid, F., & Mayaleh, A. (2025). Childhood under siege: Battling malnutrition, disease, and despair during genocide in Gaza. *Journal of Health, Population, and Nutrition*, *44*, Article 948. https://doi.org/10.1186/s41043-025-00948-6

Haque, U., Naeem, A., Wang, S., Espinoza, J. C., Holovanova, I., Gutor, T., Bazyka, D., Galindo, R., Sharma, S., Kaidashev, I., Chumachenko, D., Linnikov, S., Annan, E., Lubinda, J., Korol, N., Bazyka, K., Zhyvotovska, L., Zimenkovsky, A., & Nguyen, U.-S. D. T. (2022). The human toll and humanitarian crisis of the Russia-Ukraine war: The first 162 days. *BMJ Global Health*, *7*(9), Article e009550. https://doi.org/10.1136/bmjgh-2022-009550

Hassoun, A., Al-Muhannadi, K., Hassan, H. F., Hamad, A., Khwaldia, K., Buheji, M., & Jawaldeh, A. A. (2024). From acute food insecurity to famine: How the 2023/2024 war on Gaza has dramatically set back Sustainable Development Goal 2 to end hunger. *Frontiers in Sustainable Food Systems*. https://doi.org/10.3389/fsufs.2024.1402150

Havryliuk, O. (2022). Spaces of internal displacement: Understanding the hidden urban geographies of armed conflict in Ukraine. *Moravian Geographical Reports*, *30*(1), 2-21. https://doi.org/10.2478/mgr-2022-0001

Holail, S., Saleh, T., Xiao, X., Xiao, J., Xia, G.-S., Shao, Z., Wang, M., Gong, J., & Li, D. (2024). Time-series satellite remote sensing reveals gradually increasing war damage in the Gaza Strip. *National Science Review*, *11*(8). https://doi.org/10.1093/nsr/nwae304

Hynek, N., & Ter-Ghazaryan, L. (2025). Gaza's spatial complexity: Liberation, catastrophe, compensation. *Annals of the American Association of Geographers*, *115*, 2243_2261. https://doi.org/10.1080/24694452.2025.2527311

Kool, L., Pospíšil, J., & Van Voorst, R. (2021). Managing the humanitarian micro-space: The practices of relief access in Syria. *Third World Quarterly*, *42*(7), 1489_1506. https://doi.org/10.1080/01436597.2021.1896359

Lefebvre, H. (1996). *Writings on cities*. Blackwell.

Maghrabieh, A. (2026). Forced displacement for urban regeneration - Gaza Strip case. *International Review of Migration and Refugee Studies*, *5*(1), 71-91. https://izlik.org/JA67UJ83AK

Mendonça, M. (2024). Guerra urbana em Gaza. *Ensaios de Geografia*, *11*(24). https://doi.org/10.22409/eg.v11i24.61784

Mezentsev, K., & Mezentsev, O. (2022). War and the city: Lessons from urbicide in Ukraine. *Czasopismo Geograficzne*, *93*, 20. https://doi.org/10.12657/czageo-93-20

Mills, D., Asi, Y., Kunichoff, D., Nelson, E., Nasser, J., Barkley, S., Delafosse, R. A., Scher, C., Tanous, O., Hammoudeh, W., Wispelwey, B., Bahour, N., Peeperkorn, R., Evers, E., Gonsalves, L., Van Den Hoek, J., & Greenough, P. G. (2026). Hospital functionality in the Gaza Strip: Analysis of the World Health Organization health resources and services availability monitoring system database, 7 Oct 2023 to 31 Oct 2024. *Conflict and Health*, *20*, Article 772. https://doi.org/10.1186/s13031-026-00772-7

Moroni, S., & De Franco, A. (2024). Spatial justice: A fundamental or derivative notion? *City, Culture and Society*, *38*, Article 100593. https://doi.org/10.1016/j.ccs.2024.100593

Murcia, L. E. P. (2020). "Physically sheltered but existentially homeless": Losing home in the aftermath of conflict and displacement. Migration Studies, 9(3), 1361_1379. https://doi.org/10.1093/migration/mnaa020

Piletić, A. (2026). Theorising the conjuncture through Gaza: Urban destruction and the intensification of authoritarian neoliberalism. *Antipode*, *58*(3), Article e70165. https://doi.org/10.1111/anti.70165

Prinz, J., & Schetter, C. (2020). Spatial-moral ordering in the War on Terror: Ungoverned spaces as a challenge to humanitarianism. *Journal of Intervention and Statebuilding*, *15*(1), 96_113. https://doi.org/10.1080/17502977.2019.1709771

Purcell, M. (2003). Citizenship and the right to the global city: Reimagining the capitalist world order. *International Journal of Urban and Regional Research*, *27*(3), 564-590. https://doi.org/10.1111/1468-2427.00467

Sabah, F. Y. (2025). Assessing housing and basic services access for internally displaced persons in conflict-affected Gaza Strip: A mixed_methods study. *Frontiers in Public Health*, *13*. https://doi.org/10.3389/fpubh.2025.1483253

Sabah, F. Y., & Abuzerr, S. (2025). Relationship between housing and health in conflict-affected Gaza and policy implications for reducing health inequities. *Eastern Mediterranean Health Journal = La Revue de Santé de la Méditerranée Orientale = al-Majallah al-Sihhiyah li-Sharq al-Mutawassit*, *31*(2), 141-147. https://doi.org/10.26719/2025.31.2.141

Sarkar, S., Cottineau-Mugadza, C., & Wolf, L. (2024). Spatial inequalities and cities: A review. *Environment and Planning B: Urban Analytics and City Science*, *51*(6), 1391_1407. https://doi.org/10.1177/23998083241263422

Seita, A., & Al-Jadba, G. (2023). Gaza is facing a humanitarian catastrophe. *The Lancet*, *402*(10414), 1745. https://doi.org/10.1016/S0140-6736(23)02401-7

Soja, E. (2010). *Seeking spatial justice*. University of Minnesota Press. https://doi.org/10.5749/minnesota/9780816666676.001.0001

Trovato, M., & Ariss, B. E. (2025). Ongoing crises in Beirut: Resistance and resilience as everyday life. *City*, *30*(3), 495-523. https://doi.org/10.1080/13604813.2025.2477328

United Nations Relief and Works Agency for Palestine Refugees in the Near East. (n.d.). *Reports*. https://www.unrwa.org/resources/reports

United Nations Relief and Works Agency for Palestine Refugees in the Near East. (2023a). *Health department annual report: Primary health care services in Gaza*. https://www.unrwa.org/resources/reports/health-department-annual-report-primary-health-care-services-gaza-2023

United Nations Relief and Works Agency for Palestine Refugees in the Near East. (2023b). *Education in emergencies: Annual report 2023*. https://www.unrwa.org/resources/reports/education-emergencies-annual-report-2023

United Nations Relief and Works Agency for Palestine Refugees in the Near East. (2023c). *Food assistance programme: Quarterly update 2023*. https://www.unrwa.org/resources/reports/food-assistance-programme-quarterly-update-2023

Veracini, L. (2025). Genocide in Gaza and the end of settler colonialism. *The Journal of Imperial and Commonwealth History*, *53*(4), 953-968. https://doi.org/10.1080/03086534.2025.2501221

Wu, P., & Liu, M. (2022). A framework for the spatial inequality in urban public facility for urban planning, design and management. *Land*, *11*(9), Article 1429. https://doi.org/10.3390/land11091429

Resume

Areen Soboh holds a Bachelor's degree in Architecture from Erciyes University (2019–2024) and is currently pursuing a Master's degree in Architecture at Gazi University (2024–present). Her academic and professional interests focus on architectural design, research, the integration of architecture with technology and artificial intelligence, and the interplay between social and spatial structures in shaping the built environment.

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Interior comfort performance and improvement approaches of temporary housing units in disaster zones

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Abstract

Temporary housing units are developed to meet the urgent shelter needs emerging after disasters, and container structures are widely used due to their features such as low cost, rapid production, and portability. However, in post-disaster housing processes, quantity and speed often take precedence; the indoor quality and comfort conditions of the provided temporary units are largely ignored. Yet, in the post-trauma recovery processes of disaster victims, the physical quality and indoor spatial characteristics of the space they live in play a determining role. The aim of this study is to evaluate the indoor comfort of temporary housing units in container cities established after the February 6, 2023 Kahramanmaraş earthquakes based on user experiences, to reveal the main indoor spatial problem areas, and to develop improvement strategies in line with human-centered interior architecture approaches. The research was conducted in the Osmangazi Neighborhood container city established in the İslahiye district of Gaziantep province. As a method, field observations were conducted along with a survey study involving 90 users. Within the scope of the survey, thermal comfort, visual comfort and lighting, auditory (acoustic) comfort, indoor air quality, and ergonomics and spatial design parameters were evaluated. In the analysis of the obtained data, alongside descriptive statistics, One-Way Analysis of Variance (ANOVA) was used to determine the effect of demographic variables on comfort perception. The findings prove that noise, odor, inadequate air conditioning, and spatial limitations reduce the quality of life; ANOVA results prove that as household size increases (especially in families of 6-7 people), comfort satisfaction decreases, and education level is a determining factor in perception. The study contributes to the field by presenting a holistic interior architecture and improvement framework that prioritizes indoor quality and user comfort for post-disaster temporary housing units.

Keywords: anova analysis, comfort performance, disaster, indoor environment, temporary housing units

1. Introduction

The need for shelter that emerges after natural disasters represents a multi-layered problematic that cannot be reduced merely to providing physical security. Post-disaster temporary housing solutions are often developed in line with the priorities of rapid response, logistical speed, and cost-effectiveness; design-oriented parameters such as spatial quality, indoor comfort, and user experience remain secondary (Quarantelli, 1995; Johnson, 2007). However, this approach falls short both conceptually and practically in the face of the reality that temporary housing spaces effectively turn into long-term residences. Indeed, numerous empirical studies reveal that post-disaster housing units are used for months or even years, and during this period, they form the main spatial framework of the users' daily lives (Lizarralde et al., 2010; Félix et al., 2013).

The strong relationship between the built environment and the physical and psychological well-being of individuals has long been emphasized in the environmental psychology and architecture literature (Ulrich, 1984; Evans, 2003). In this context, indoor quality is not limited to measurable environmental parameters such as thermal, visual, and acoustic comfort, but also includes subjective dimensions such as spatial organization, ergonomics, privacy, sense of security, and

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belonging (Vischer, 2007; Bluyssen, 2015). It is argued that these dimensions play a determining role, especially in the post-disaster context, in terms of post-trauma recovery processes, the re-establishment of daily routines, and the nature of the relationship individuals establish with the space (Corsellis & Vitale, 2005; Sanderson, 2012).

A portion of the post-disaster housing literature addresses temporary housing units through engineering performance, structural safety, durability, speed, and cost-effectiveness; positioning indoor comfort and user-centered design principles as a secondary issue (Davis, 1978; Asfour, 2019; Kalkan, 2025). This approach leads to the inadequate visibility of the effects of temporary housing spaces on users' physical health, psychological well-being, and quality of life during long-term uses. However, the fact that post-disaster housing solutions are not merely "shelters" but indoor spaces where users continue their daily lives necessitates the evaluation of these structures within the framework of the interior architecture discipline.

In this context, the interior architecture discipline has the potential to address post-disaster temporary housing units from a human-centered perspective and to evaluate parameters such as indoor comfort, spatial adequacy, and ergonomic suitability in a holistic manner. Indoor comfort is not only about environmental conditions meeting certain standards but also the entirety of qualities that make users feel safe, comfortable, and a sense of belonging to the space (Vischer, 2008). Therefore, in terms of the sustainability and humane quality of post-disaster temporary housing solutions, indoor quality and user experience must be addressed as a central design criterion.

The starting point of this research is the spatial problems observed in container cities established in different regions of Turkey following the February 6, 2023 Kahramanmaraş earthquakes. Although container units were initially designed for short-term use, in practice they have transformed into long-term living spaces. During this process, serious problems have emerged in topics such as indoor comfort, ergonomics, privacy, and spatial adequacy. This situation clearly reveals that post-disaster temporary housing solutions need to be re-evaluated not only from an engineering and logistics perspective but also with a focus on interior architecture and user experience. This study aims to respond to this need for reevaluation by proposing a multi-parameter, user-centered interior comfort framework.

The aim of this research is to evaluate the indoor comfort of temporary housing units in container cities established after the February 6, 2023 Kahramanmaraş earthquakes based on user experiences; to reveal the main problem areas concerning thermal comfort, visual comfort and lighting, auditory (acoustic) comfort, indoor air quality, and ergonomics and spatial design parameters, and to develop improvement strategies in line with human-centered interior architecture approaches. In this respect, the study aims to contribute to the interior architecture literature by presenting a holistic evaluation and design framework that prioritizes indoor quality for post-disaster temporary housing units.

2. Literature Review

Post-disaster housing is defined in the literature as a time-spanning and multi-stage process that includes the transition from emergency shelter to permanent housing (Quarantelli, 1995). Although the temporary housing solutions developed in this process are mostly designed with the assumption of short-term use, in practice, a significant portion transforms into long-term living spaces (Johnson, 2007). This situation makes it necessary to approach temporary housing units not only on the axis of structural safety, speed, and cost-effectiveness but as qualified indoor spaces where users can maintain their daily life practices.

The post-disaster housing literature, especially since the 2000s, has begun to focus more on the social, spatial, and cultural dimensions of housing solutions. Indeed, Felix et al. (2013) emphasize that the time factor is ignored in most cases in post-disaster housing designs; structures defined as

"temporary" practically turn into permanent living spaces. Similarly, Lizarralde et al. (2010) reveal that the prioritization of speed and cost pressure in post-disaster projects pushes spatial quality, user requirements, and long-term habitability criteria to the background. This approach leads to temporary housing units being treated as short-term technical solutions; qualities such as indoor comfort and user experience are often evaluated in a limited manner.

A significant portion of temporary housing solutions are developed based on standardized typologies and generally show limited adaptation to different climatic, cultural, and socioeconomic contexts. Although the historical roots of this approach trace back to Davis's (1978) early critiques, recent reviews and meta-analyses show that this problem still maintains its relevance today (Bilau et al., 2015; Davidson et al., 2007; Opdyke et al., 2018). This situation makes it difficult for housing units to be adopted by users and used sustainably. Davis (1978) argues that ignoring user participation and cultural appropriateness in post-disaster housing projects is one of the main reasons for the failure of the spaces. Sanderson (2012) emphasizes that post-disaster housing spaces do not only serve a sheltering function; they also assume a symbolic and psychosocial role in identity, belonging, and social reconstruction processes. In this context, temporary housing is handled as a spatial and social component of the post-disaster recovery process, not just a physical one.

When Turkey-specific post-disaster housing research is examined, it is seen that the 1999 Marmara Earthquake constituted a radical breaking point in the literature and provided a rich empirical accumulation regarding the local context. The comprehensive literature analysis conducted by Baradan (2008) reveals that the architecture and design community in Turkey underwent a more "human-centered" shift in its approach to disaster housing after the 1999 earthquake. Building science studies empirically examining the post-occupancy processes, material vulnerabilities, and disassembly/reuse potentials of temporary prefabricated or container structures built during this period have found a wide place in the local literature (Arslan, 2007; Arslan & Coşgun, 2008). However, researchers such as Balamir (2001) and Dikmen (2005) have examined site selection policies, limits of spatial flexibility, and user satisfaction in post-disaster permanent and temporary housing applications in Turkey, emphasizing that ignoring local identity, traditional living practices, and socio-cultural needs directly and negatively affects the functional success of the spaces. Therefore, although housing production, disaster policies and spatial adaptation processes have been widely discussed historically in the local literature, the need to address interior comfort parameters based on user experience from a holistic interior architecture perspective remains current.

The indoor comfort literature reveals that the concept of comfort has a multidimensional structure and cannot be explained solely by measurable physical environmental parameters. Bluyssen (2015) defines indoor environmental quality (IEQ) through the components of thermal comfort, visual comfort, acoustic comfort, and indoor air quality; emphasizing the determining effects of these components on user health and satisfaction. Frontczak and Wargocki (2011) showed that IEQ parameters are directly effective on user satisfaction, space perception, and productivity; especially temperature, ventilation, and noise levels determine the perceived space quality.

From the perspective of the interior architecture discipline, comfort is handled as a holistic concept that is not limited to meeting environmental performance criteria but includes functional, psychological, and experiential dimensions. Vischer (2007, 2008) defines comfort as a multi-layered structure consisting of physical, functional, and psychological components; revealing that design decisions at the interior architecture scale, such as spatial organization, ergonomics, furniture layout, and privacy, play a determining role in the relationship users establish with the space. Altomonte et al. (2019) stated that user-perception-based IEQ evaluations in green-certified buildings are as important as analyses based on objective measurements and can provide direct input to design processes. These studies show that user experiences play a central role in assessing indoor comfort.

It is seen that studies focusing on indoor comfort and user experience in the post-disaster context are relatively limited. Corsellis and Vitale (2005) emphasize that qualities such as human dignity, privacy, and cultural appropriateness often remain secondary in post-disaster housing solutions. Furthermore, it is pointed out that the sustainability discourse in temporary housing projects is predominantly shaped by structural safety and environmental performance indicators; indoor quality and user satisfaction are not sufficiently considered (Gkoumas et al., 2025; Montalbano & Santi, 2023). This situation demonstrates that technical and engineering-focused approaches dominate the post-disaster shelter literature, while the interior design perspective is underrepresented.

The environmental psychology literature clearly demonstrates the effect of the physical environment on individuals' stress levels, mental health, and overall well-being. Ulrich (1984) showed that restorative environments reduce stress levels and support psychological recovery. Evans (2003) reveals that environmental stressors such as crowding, noise, spatial inadequacy, and lack of environmental control create negative effects on individuals' psychological health. These findings show that indoor air quality in temporary shelters after disasters is not limited to comfort levels; it is a matter directly related to psychosocial well-being and public health.

Despite this, empirical studies in the current literature addressing the indoor comfort of temporary housing units with a multi-parameter and user-centered approach are notably limited. Systematic reviews published especially in the last decade show that user experience, indoor environmental quality, and spatial design dimensions are mostly addressed at a secondary level in post-disaster housing research (Kim et al., 2025). Previous studies measured temporary housing as technical or structural "shells"; however, they largely ignored how these shells shape indoor quality in cases where they actually transform into long-term living spaces. Furthermore, there are very few studies that empirically address the relationship between user perception-based evaluations and spatial design decisions.

When the building science literature is examined, it is seen that there are various empirical studies investigating the indoor environmental quality (IEQ) in container or prefabricated temporary housing through objective measurements, simulations, and experimental methods. The material and shell vulnerabilities of these light steel or sandwich panel structures, which are deployed rapidly after disasters, have been documented through field measurements. For example, in their empirical research conducted in prefabricated temporary housing used after the Great East Japan Earthquake, Shinohara et al. (2014) determined that indoor temperatures in winter months remained well below acceptable comfort limits, and furthermore, indoor air pollutants such as acetaldehyde and NO_2 exceeded guideline values due to inadequate ventilation capacity and the heating practices of the users. Similarly, experimental and numerical simulation studies conducted by Tan and Tan (2021) confirmed with empirical data that the structural shell characteristics of temporary housing units fell short against climatic conditions; especially during hot periods, indoor temperatures and thermal dissatisfaction rates reached critical levels due to the limits of natural ventilation. Furthermore, Shinohara et al. (2018) empirically demonstrated that microclimatic insulation deficiencies and high humidity rates in prefabricated units led to intense mold and fungus formations that directly threaten indoor air quality and user health.

Although these studies in the building science literature profoundly document the material, shell, and engineering-oriented performance problems of temporary housing, there is a sharp methodological distinction in the post-disaster housing literature regarding what is measured and what is not. Existing empirical research has predominantly focused on measuring; (i) disaster policies at the macro scale, logistical speed, entitlement, and site selection decisions (Balamir, 2001; Lizarralde et al., 2010), or (ii) pure physical and quantitative parameters at the micro scale, such as the thermal conductivity of the building shell, moisture balance, and singular indoor air pollutants (Shinohara et al., 2014; Tan & Tan, 2021). In contrast, the fundamental area that previous empirical research has not holistically measured and left as a chronic gap in the literature is the collective

evaluation of the relationship between these physical/environmental parameters and interior architectural components such as the functional organization of the interior space, furniture layout, flexibility, ergonomics, and privacy, through user experience (Kim et al., 2025). Previous studies measured temporary housing merely as technical or structural "shells"; however, they largely ignored how these shells shape indoor quality in cases where they effectively transform into long-term living spaces.

In the context of Turkey, although there are important studies examining the performance and user satisfaction of temporary housing after the 1999 Marmara and Düzce earthquakes (Arslan, 2007; Dikmen, 2005), these researches have mostly remained focused on structural recycling, settlement decisions, or general spatial satisfaction. In the international literature, on the other hand, there are empirical studies (Shinohara et al., 2014; Tan & Tan, 2021) directly measuring indoor environmental quality (IEQ) in modular and temporary housing. However, the vast majority of these studies either focused solely on singular parameters such as thermal performance/air quality or were conducted in laboratory/simulation environments. Although the existing literature is successful in measuring the physical shell performance of container units; a holistic interior architectural perspective that evaluates IEQ parameters (acoustic, visual, thermal, air) together with user experience, spatial ergonomics, and privacy in post-disaster housing areas remains lacking. This study aims to fill this gap in the literature by analyzing these parameters, which previous studies left engineering-oriented or examined singularly, in the field with an empirical and multi-dimensional IEQ framework. Accordingly, within the scope of the study, answers to the following questions were sought:

Question 1: In the temporary housing units in the İslahiye Osmangazi Neighborhood container city; how are the thermal, visual, auditory, and indoor air quality perceptions of the users shaped within the framework of the existing structural shell and air conditioning characteristics?

Question 2: How do the indoor organization, furniture layout, storage capacity, and spatial flexibility limits of container units affect users' acoustic privacy and long-term habitability experiences?

Question 3: Which human-centered interior architecture strategies can the systematic problem areas identified based on user experience in these units provide input for in terms of institutional and design standards for future post-disaster temporary housing designs?

The literary gap emerging in this context necessitates the re-evaluation of post-disaster temporary housing units within the framework of the interior architecture discipline. Addressing the thermal, visual, auditory, and air quality dimensions of indoor comfort together with ergonomics and spatial design parameters is of critical importance in terms of revealing the suitability of these spaces for long-term living and their potential to support user satisfaction and well-being. This study aims to present a holistic framework that evaluates indoor comfort in post-disaster temporary housing units based on user experiences and to contribute to this area, which is limitedly represented in the interior architecture literature.

3. Material and Method

This study aims to evaluate the indoor comfort of temporary housing units based on user experience. The research was designed as a field-based, cross-sectional, and descriptive study. The research design relies on an evaluation approach based on user perceptions supported by quantitative data collection tools. The study is structured in line with a human-centered interior architecture approach and the indoor environmental quality (IEQ) framework (Figure 1).

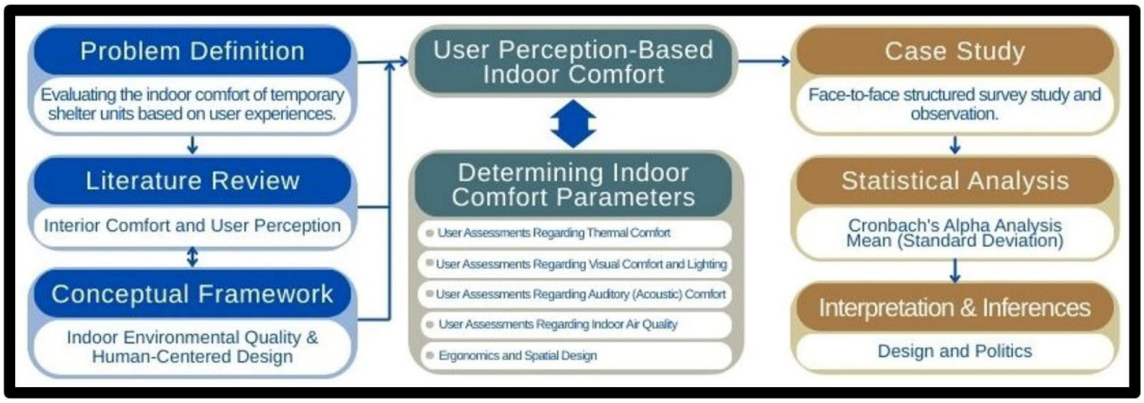

Figure 1 Conceptual and methodological workflow of the study

The research area is the Osmangazi Neighborhood Container City in the İslahiye district of Gaziantep province, established following the February 6, 2023 Kahramanmaraş earthquakes. There are 100 container structures in the settlement. This settlement is a planned temporary settlement area consisting of standard container units to respond to the need for rapid shelter after the disaster (Figure 2). The housing units in the settlement consist of single-story, modular, and prefabricated containers. Each unit contains a basic living area, a wet space, and limited storage space. Although the units were initially designed for short-term use, at the time of the fieldwork, they had effectively been converted into long-term living spaces. This situation makes the settlement a meaningful case for evaluating indoor comfort in the context of long-term use.

Figure 2 Research sample area

The sample of the research consists of 90 household representatives (users) who actively live in the Osmangazi Neighborhood Container City and voluntarily participated in the study. Considering that there are a total of 100 container units in the settlement, a "near-census" field survey approach supported by "convenience sampling", which is one of the non-probability sampling methods, was adopted as the sampling strategy in order to cover almost the entire population. During the field study process, all container doors in the settlement were knocked on one by one to reach the primary adult users of the units. The fact that 90 out of a total of 100 units were actually reached ensured that the sample represented the container city in general at a rate of ~90%. The participants have a diversity that fully reflects the general demographic structure and different usage models (large families, nuclear families, elderly users, etc.) of the existing settlement in terms of household sizes, age groups, and gender distributions.

A structured survey form was used as the data collection tool in the research. The survey form was developed based on the indoor environmental quality (IEQ) framework and ergonomics and spatial design parameters at the interior architecture scale. The content validity of the survey form was evaluated in line with the opinions of three academicians who are experts in the fields of

interior architecture and building physics. The experts contributed to its formation by evaluating each item in terms of its level of representing the relevant comfort parameter, its comprehensibility, and its suitability for the disaster context. As a result of this process, the content of the survey form was structured under five main parameters: (i) thermal comfort, (ii) visual comfort and lighting, (iii) auditory (acoustic) comfort, (iv) indoor air quality, and (v) ergonomics and spatial design.

The data collection process was carried out within the scope of the field study in the autumn period of 2023. The surveys were administered by the researcher using the face-to-face interview technique. A 5-point Likert-type scale was used to measure the participants' attitudes, perceptions, and opinions regarding specific statements. The scale was rated between 1 = Strongly Disagree and 5 = Strongly Agree. The internal consistency of the scale was evaluated using Cronbach's alpha coefficient. Reliability analyses were performed separately for both the entire scale and each comfort parameter sub-scale. It was observed that the obtained alpha coefficients were above the accepted threshold value of 0.70, and it was concluded that the internal consistency of the scale was sufficient.

The collected data were transferred to a digital environment and analyzed using appropriate software for statistical analysis. Mean values, standard deviations, and frequency distributions were calculated for each comfort parameter. Through these analyses, users' perceptions and satisfaction levels regarding different IEQ dimensions were revealed. In addition, the findings for each parameter were interpreted comparatively with the comfort ranges and design criteria recommended in the literature. This approach made it possible not only to describe the findings but also to generate design-oriented inferences.

The research aims to evaluate indoor comfort based on users' perceptions, experiences, and satisfaction levels rather than technical performance indicators. Indeed, the IEQ and environmental psychology literature shows that evaluations based on user perceptions are at least as meaningful as objective measurements in terms of revealing the effects of spatial quality in the context of daily use and have the quality of providing direct input for design processes (Al-Akhzami et al., 2024; Ruth et al., 2025; Schweiker et al., 2025).

The methodological framework of this study and the empirical findings obtained contain three main limitations that could serve as a reference for future research.

First, the data collection process (Autumn 2023 period) coincided with the initial phase when the container city was established immediately after the disaster. As seen in Table 1, all of the participants (100%) are early-stage users who have been residing in the respective units for 0-6 months. Although the fact that post-disaster temporary housing transforms into permanent spaces over time is theoretically emphasized in the literature, the findings of this research capture users' "early and medium-term" adaptation and transitional period comfort experiences. Therefore, the obtained data do not reflect the structural shell deteriorations, material wears, or chronic psychological habituation processes resulting from the long-term use of container structures.

The second and most important limitation is that the research methodologically relies entirely on subjective perception and satisfaction evaluations based on user experience (Post-Occupancy Evaluation); it does not include quantitative and objective environmental measurements (temperature data loggers, acoustic decibel levels, lighting lux values, or indoor air quality sensors) for indoor comfort parameters. Although subjective human perception is accepted as a legitimate and primary empirical data source in measuring spatial comfort and user well-being in the interior architecture literature, the fact that these data were not supported by physical measurement tools and not cross-checked (triangulation) limits the scope of the study. With this limitation, it is anticipated that the large user-oriented database presented by the study in its current form will constitute a foundational baseline and point of comparison for future longitudinal research with mixed methodologies that will blend subjective perception tests and objective device measurements together.

Finally, the ANOVA analyses regarding the effects of demographic variables on comfort perception were performed using the existing summary data, and it is recommended to collect larger and more detailed datasets in future studies to enable more comprehensive multivariate analyses (regression, etc.) based on individual participant data.

When the frequency tables presented in the findings section (especially Table 2, Table 4, and Table 5) are examined, a zero (0) frequency concentration can be observed in the "Agree" (4) and "Strongly Agree" (5) scores of some parameters. This situation, defined as the "floor effect" in statistics, is not a data anomaly or sampling error; it is the empirical result of the chronic physical inadequacies (lack of insulation, thermal comfort problems, odor and acoustic problems, etc.) harbored by the container city infrastructure in the early period of the disaster reflecting directly and homogeneously on the user experience.

4. Research Findings

This section presents the findings obtained from the survey study conducted with the users living in container units used for post-disaster temporary housing. The research findings begin with descriptive information regarding the demographic characteristics of the participants. Following this, the fundamental environmental and spatial comfort components that determine the living experiences of the users in the container units are addressed under the headings of thermal comfort, visual comfort and lighting, auditory (acoustic) comfort, indoor air quality, and ergonomics and spatial design. This structure allows user evaluations to be analyzed within a systematic and holistic framework.

4.1. Demographic Characteristics of the Participants

The distributions regarding the demographic characteristics of the users participating in the research are presented in Table 1. When the demographic data are examined, it is seen that the participants exhibit a relatively balanced distribution in terms of gender; the proportions of female and male participants are close to each other.

Table 1 Demographic Characteristics of Users

Variable	Category	n	%
Gender	Female	48	53.3
	Male	42	46.7
Nationality	Turkish citizen	90	100
	Other Nationalities	-	-
Age Group	15–25	13	14.4
	26–35	25	27.8
	36–45	28	31.1
	46–55	17	18.9
	56 and above	7	7.8
Household Size	1 person	-	-
	2–3 people	39	43.3
	4-5 people	37	41.1
	6-7 people	12	13.3
	8 and above	2	2.2
Education Level	Primary	29	32.2
	Secondary Education	47	52.2
	Higher Education	14	15.6
Time Spent in Containers Duration	0–6 months	90	100
	6–12 months	-	-
	12 months and older	-	-
Marital Status	Married	26	28.9
	Single	64	71.1

The fact that all participants are citizens of the Republic of Turkey indicates that the sample is compatible with the spatial and social context of the study. The distribution regarding age groups

reveals that the research sample is not concentrated in a single age range, and different age groups are represented in the study. This situation allows users' comfort perceptions to be evaluated without being reduced to a specific demographic profile, making it possible to interpret the comfort evaluations presented in the following subsections within a framework encompassing different user groups.

4.2. User Evaluations Regarding Thermal Comfort

When the user evaluations regarding thermal comfort are examined, it is seen that the temporary housing units fall far short of meeting user expectations in terms of both heating and cooling. The responses given to the thermal comfort scale consisting of five items reveal that the vast majority of the participants concentrated on negative evaluations (Table 2). The internal consistency of the scale regarding thermal comfort was tested with Cronbach's Alpha coefficient and calculated as $\alpha = 0.96$, and this value indicates that the scale has a high level of internal consistency.

Table 2 User Evaluations Related to Thermal Comfort

	1	2	3	4	5	Mean	SD
The interior of the container is sufficiently heated during the winter months.	20	40	30	-	-	2.11	0.73
The container interior can be kept cool during the summer months.	60	25	5	-	-	1.39	0.59
The temperature inside remains balanced throughout the day.	50	35	5	-	-	1.50	0.60
Heating/cooling systems are adequate for use.	55	25	10	-	-	1.56	0.69
The indoor temperature is generally comfortable.	60	25	5	-	-	1.39	0.59

[1] Strongly disagree [2] Disagree [3] Undecided [4] Agree [5] Strongly agree [M] Mean [SD] Standard deviation

The average of the responses given by the participants to the statement "The interior of the container is adequately heated in winter months" was calculated as Mean = 2.11 (SD = 0.73). This value indicates that the level of heating in winter conditions is generally perceived as inadequate by the users, but it is evaluated as a relatively less problematic area compared to other thermal comfort indicators. Evaluations regarding the summer months, on the other hand, are much more negative. The statement "The container interior can be kept cool in the summer months" stands out as the item with the lowest average with Mean = 1.39 (SD = 0.59). This finding shows that container units experience overheating problems, especially in hot climate conditions, and the current design approach falls short in terms of summer comfort.

Similarly, the statement regarding whether the indoor temperature is balanced throughout the day was evaluated with values of Mean = 1.50 (SD = 0.60), and the statement regarding the adequacy of heating/cooling systems with Mean = 1.56 (SD = 0.69). These results reveal that indoor temperature is perceived as unstable not only in extreme seasonal conditions but also during the daily usage process, and existing mechanical systems fall short in providing user comfort. The calculation of the statement "The indoor temperature is generally comfortable" as Mean = 1.39 (SD = 0.59) confirms that users' general thermal comfort perception is at a quite low level. The low standard deviation values indicate that participant opinions are largely homogeneous and that problems related to thermal comfort point to a widespread and systematic problem area rather than individual ones.

The complete absence of responses (0 frequency) in the 'Agree' and 'Strongly Agree' (4 and 5) options in the basic items regarding thermal comfort indicates that container units fall completely short in providing indoor temperature balance due to thin sandwich panel wall technology and inadequate insulation layers. This cumulative pattern confirms that the thermal comfort grievance experienced by users during seasonal transition periods (autumn/summer) points to a methodological floor effect originating from structural inadequacies and shared across the entire sample, rather than being individual/subjective exceptions.

Evaluated overall, it is understood that container units harbor serious thermal comfort problems, especially in the summer months in the context of long-term use; existing heating and cooling solutions are inadequate in meeting user needs. This situation reveals that in the design of post-disaster temporary housing units, thermal performance must be addressed not only as a technical adequacy but also as a critical design input in terms of user health and well-being.

4.3. User Evaluations Regarding Visual Comfort and Lighting

When user evaluations regarding visual comfort and lighting are examined, it is seen that visual comfort in temporary housing units is perceived relatively more positively compared to other environmental comfort components; however, user satisfaction remains limited in some sub-indicators. The responses given to the visual comfort and lighting scale consisting of five items reveal that participant evaluations concentrated at a moderate level (Table 3). The internal consistency of the scale regarding visual comfort and lighting was tested with Cronbach's Alpha coefficient and calculated as $\alpha = 0.91$, and this value indicates that the scale has a high level of internal consistency.

Table 3 User Evaluations Related to Visual Comfort and Lighting

	1	2	3	4	5	Mean	SD
Daylight enters the interior space at an adequate level.	20	4	15	45	6	3.14	1.30
Sufficient for use in artificially lit spaces.	30	14	3	33	10	2.77	1.50
The lighting level does not cause eye strain.	40	17	5	19	9	2.33	1.46
Window openings positively affect space utilization.	19	4	7	28	32	3.56	1.52
The interior is generally visually comfortable.	51	13	6	18	2	1.97	1.28

[1] Strongly disagree [2] Disagree [3] Undecided [4] Agree [5] Strongly agree [M] Mean [SD] Standard deviation

The average of the responses given by the participants to the statement "Daylight enters the interior space at an adequate level" was calculated as Mean = 3.14 (SD = 1.30). This value indicates that natural light generally reaches the interior space at an adequate level in container units and is perceived relatively positively by the users. This result regarding natural lighting stands out as one of the significant strong areas under the visual comfort heading.

Evaluations regarding artificial lighting, on the other hand, indicate a more limited level of satisfaction. The statement "Artificial lighting is adequate for using the space" was evaluated with Mean = 2.77 (SD = 1.50), suggesting that users find artificial lighting functionally acceptable, but do not consider it adequate in terms of visual comfort during long-term use. Similarly, the calculation of the statement "The lighting level does not cause eye strain" as Mean = 2.33 (SD = 1.46) reveals that the lighting quality in container interiors falls short in providing visual comfort.

In evaluations regarding the relationship of visual comfort with spatial openings, the statement "Window openings positively affect the use of space" stands out as the item with the highest average with Mean = 3.56 (SD = 1.52). This finding indicates that window openings offer a significant contribution not only in terms of natural lighting but also in terms of spatial perception and usage comfort. In contrast, the calculation of the statement "The interior space is generally visually comfortable" as Mean = 1.97 (SD = 1.28) confirms that users' general perception of visual comfort remains at a low level and that a holistic satisfaction is not achieved despite positive sub-indicators. The relatively high standard deviation values reveal that user perceptions regarding visual comfort and lighting are not homogeneous; natural and artificial lighting conditions can vary depending on the location and orientation of the containers, as well as individual usage habits.

Evaluated overall, it is seen that visual comfort and lighting in container units meet user expectations in some sub-indicators; in particular, natural light and window openings support the spatial use. However, the fact that artificial lighting quality and the general perception of visual comfort remain at a low level indicates that existing lighting solutions are inadequate in meeting user needs in the context of long-term living. This situation reveals that in the design of post-

disaster temporary housing units, visual comfort must be addressed holistically, not only through the illumination level but also in terms of eye health, spatial perception, and user satisfaction.

4.4. User Evaluations Regarding Auditory (Acoustic) Comfort

When user evaluations regarding acoustic comfort are examined, it is seen that the container units used for temporary housing fall far short of meeting user expectations in terms of sound insulation and interior silence. The responses given to the acoustic comfort scale consisting of five items reveal that the vast majority of the participants concentrated on negative evaluations (Table 4). The internal consistency of the scale was tested with Cronbach's Alpha coefficient and calculated as $\alpha = 0.97$, and this value indicates that the scale has a very high level of internal consistency.

Table 4 User Evaluations Related to Auditory (Acoustic) Comfort

	1	2	3	4	5	Mean	SD
Outdoor noise is not disturbing inside the container.	75	6	1	8	-	1.36	0.89
Noises from neighboring containers are not disturbing.	60	18	4	6	2	1.58	1.01
The interior is sufficiently quiet for relaxation and sleep.	65	17	3	3	2	1.44	0.89
The container's sound insulation is sufficient.	60	25	5	-	-	1.39	0.59
The interior is generally comfortable from an acoustic standpoint.	63	18	7	2	-	1.42	0.73

[1] Strongly disagree [2] Disagree [3] Undecided [4] Agree [5] Strongly agree [M] Mean [SD] Standard deviation

The average of the responses given by the participants to the statement "External noise is not disturbing inside the container" was calculated as Mean = 1.36 (SD = 0.89). This finding indicates that container units cannot provide adequate acoustic protection against noise originating from the external environment, and environmental sounds are distinctly felt indoors. Similarly, the evaluation of the statement "The interior space is quiet enough for rest and sleep" with Mean = 1.44 (SD = 0.89) reveals that containers fail to provide the quiet conditions necessary for rest and sleep, which is one of their basic usage scenarios.

Evaluations regarding sounds originating from neighboring units also point to a negative picture. Although the statement "Sounds coming from neighboring containers are not disturbing" seems to have a relatively higher average compared to other items with Mean = 1.58 (SD = 1.01), this value is still at a low level. This situation indicates that sound permeability between units is high in the container layout and that acoustic privacy is not adequately provided. The relatively high standard deviation value, on the other hand, suggests that the perception of noise coming from neighboring units may vary depending on the location of the containers and environmental conditions.

In evaluations directly related to the building shell, it is seen that the statement "The sound insulation of the container is adequate" has a low average with Mean = 1.39 (SD = 0.59). The complete absence of responses (0 frequency) at the 4 and 5 Likert points in the items related to the container's sound insulation and external noise methodologically confirms that all users statistically unite on a common ground of dissatisfaction (floor effect) in the face of the sound permeability of the sandwich panel shell technology. The low standard deviation value reveals that participant opinions are largely homogeneous specific to this item and that the inadequacy of sound insulation is perceived as a widespread and common problem area. Similarly, the calculation of the statement "The interior space is generally acoustically comfortable" as Mean = 1.42 (SD = 0.73) confirms that users' general acoustic comfort perception is at a quite low level.

When the low average and relatively low standard deviation values are evaluated together, it is seen that problems related to acoustic comfort point to a systematic problem area associated with the structural characteristics and layout of container units, rather than individual experiences. Evaluated overall, it is understood that temporary housing units exhibit inadequate acoustic performance against noise originating from both the external environment and neighboring units; and this situation creates negative effects on rest, sleep, and psychological well-being. These findings reveal that in the design of post-disaster temporary housing units, acoustic performance must be addressed not as a secondary comfort criterion, but as a fundamental design input in terms of user health and quality of life.

4.5. User Evaluations Regarding Indoor Air Quality

When user evaluations regarding indoor air quality are examined, it is seen that the container units used for temporary housing fall far short of meeting user expectations, especially in terms of odor formation and general air quality perception. The responses given to the indoor air quality scale consisting of five items reveal that a significant portion of the participants concentrated on negative evaluations (Table 5). The internal consistency of the scale was tested with Cronbach's Alpha coefficient and calculated as $\alpha = 0.91$. This value indicates that the scale has a high level of internal consistency and reliability.

Table 5 User Evaluations Regarding Indoor Air Quality

	1	2	3	4	5	Mean	SD
There is no unpleasant odor inside the room.	80	8	2	-	-	1.13	0.40
Ventilation is sufficient for the interior.	34	20	10	16	10	2.42	1.43
The indoor air provides a feeling of freshness.	36	18	7	17	12	2.46	1.50
The humidity level is comfortable.	40	15	3	22	10	2.41	1.52
Indoor air quality is generally adequate.	70	15	5	-	-	1.28	0.56

[1] Strongly disagree [2] Disagree [3] Undecided [4] Agree [5] Strongly agree [M] Mean [SD] Standard deviation

The average of the responses given by the participants to the statement "No disturbing odor occurs in the interior space" was calculated as Mean = 1.13 (SD = 0.40). The complete absence of responses (0 frequency) in the 'Agree' and 'Strongly Agree' options for the items regarding odor formation and general air quality adequacy demonstrates the sharp and unexceptional negative effect created in subjective perception by the septic, drainage, and ventilation deficiencies experienced in the first months the settlement was established. This quite low average value indicates that disturbing odors are widely felt in container interiors and that solutions related to odor control are perceived as inadequate by the users. The low standard deviation value reveals that this negative perception is largely shared among the participants.

Evaluations regarding ventilation, on the other hand, present a relatively more scattered picture. The statement "Ventilation is adequate for the interior space" was evaluated with Mean = 2.42 (SD = 1.43), showing that user perceptions differ significantly. Similarly, the calculation of the statement "The indoor air gives a feeling of freshness" as Mean = 2.46 (SD = 1.50) indicates that some users find the indoor air acceptable, but a significant portion experiences negative experiences in this regard. The relatively high standard deviation values suggest that ventilation performance can vary depending on the location of the containers, usage intensity, and environmental conditions. A similar situation applies to evaluations regarding humidity levels. The calculation of the statement "The humidity level is at a comfortable level" as Mean = 2.41 (SD = 1.52) reveals that indoor humidity conditions are perceived inconsistently and unpredictably by the users. This finding suggests that humidity control constitutes a significant problem area, especially in long-term use.

Looking at the general evaluation, it is seen that the statement "Indoor air quality is generally adequate" has a quite low average with Mean = 1.28 (SD = 0.56). This result confirms that problems in individual components (odor, ventilation, humidity) significantly negatively affect users' general perception of air quality. The low standard deviation value indicates that general air quality inadequacy is perceived as a widespread and systematic problem.

Evaluated overall, it is understood that indoor air quality in temporary housing units harbors serious problems in terms of user health and comfort; in particular, odor control and natural or mechanical ventilation performance remain inadequate. These findings reveal that in the design of post-disaster temporary housing units, indoor air quality must be addressed not only as a technical requirement but as a fundamental design input in terms of users' physical and psychological well-being.

4.6. User Evaluations Regarding Ergonomics and Spatial Design

When user evaluations regarding spatial comfort and ergonomics are examined, it is seen that the container units used for temporary housing fall short of meeting user expectations, especially in terms of storage capacity, spatial flexibility, and ergonomic adequacy. The responses given to the spatial comfort and ergonomics scale consisting of five items reveal that participant opinions generally concentrated on negative evaluations (Table 6). The internal consistency of the scale was tested with Cronbach's Alpha coefficient and calculated as $\alpha = 0.97$. This value indicates that the scale has a very high level of internal consistency and reliability.

Table 6 User Evaluations Regarding Ergonomics and Spatial Design

	1	2	3	4	5	Mean	SD
The spatial size of the container is sufficient for daily life.	30	15	8	29	8	2.67	1.45
Furniture placement facilitates space utilization.	40	22	4	14	10	2.24	1.44
Storage space is sufficient.	57	23	1	6	3	1.61	1.03
The space can be adapted to different needs.	45	28	7	8	2	1.82	1.06
The interior is generally ergonomic.	35	25	5	16	9	2.32	1.40

[1] Strongly disagree [2] Disagree [3] Undecided [4] Agree [5] Strongly agree [M] Mean [SD] Standard deviation

The average of the responses given by the participants to the statement "The spatial size of the container is adequate for daily life" was calculated as Mean = 2.67 (SD = 1.45). This value indicates that spatial size is perceived relatively more positively compared to other spatial comfort components, but it still does not fully meet user expectations. The relatively high standard deviation value suggests that the perception of spatial adequacy varies depending on the users' household size, usage habits, and layout.

In evaluations regarding the furniture layout, the calculation of the statement "Furniture layout facilitates the use of space" as Mean = 2.24 (SD = 1.44) reveals that the existing furniture layout remains limited in supporting the effective use of the space. Similarly, the evaluation of the statement "The interior space is generally ergonomic" with Mean = 2.32 (SD = 1.40) indicates that although ergonomic comfort is partially achieved, it is not perceived at an adequate level by the users. One of the areas where spatial comfort is perceived the weakest is storage facilities. The fact that the statement "Storage areas are adequate" has a quite low average with Mean = 1.61 (SD = 1.03) indicates that the inadequacy of storage areas in container units stands out as a widespread and prominent problem area (Figure 3). The low standard deviation value reveals that this negative perception is largely shared among the participants.

Figure 3 Examples of interior space usage and storage space needs

Similarly, the calculation of the statement "The space can adapt to different needs" as Mean = 1.82 (SD = 1.06) indicates that the capacity of container interiors to adapt to different user profiles and changing daily needs is limited. This finding reveals that the inadequacy of spatial flexibility is one of the fundamental factors negatively affecting spatial comfort in the context of long-term use.

Evaluated overall, the fact that the average values regarding spatial comfort and ergonomics remain below 3 in all items indicates that container units exhibit a limited performance in meeting

daily life requirements. The relatively high standard deviation values, on the other hand, suggest that spatial experiences can vary depending on user characteristics and usage patterns. These findings reveal that in the design of post-disaster temporary housing units, the issues of spatial adequacy, ergonomics, and flexibility must be addressed not only within the framework of minimum shelter requirements but within the scope of a holistic comfort approach that will support users' long-term living practices.

4.7. Differences in Comfort Perception According to Demographic Variables

A one-way analysis of variance (ANOVA) was conducted to examine the effect of demographic variables (age, household size, education level) on the perception of indoor comfort.

The Effect of Age Group

A statistically significant difference among age groups was detected only in the perception of acoustic comfort ($F(4,85) = 3.24$, $p = 0.015$). The post-hoc Tukey HSD test showed that the 56 and above age group (Mean = 1.62, SD = 0.58) evaluated acoustic comfort significantly better compared to the 26-35 age group (Mean = 1.35, SD = 0.49) ($p = 0.036$). No significant difference was found among age groups in other comfort parameters (thermal, visual, air quality, spatial) ($p > 0.05$).

The Effect of Household Size

The most prominent effect of household size on comfort perception was observed in the spatial comfort parameter ($F(3,86) = 10.89$, $p < 0.001$). The Tukey HSD test revealed that households of 2-3 people (Mean = 2.45, SD = 0.95) found spatial comfort significantly more adequate compared to households of 6-7 people (Mean = 1.62, SD = 0.65) ($p < 0.001$). Similarly, households of 4-5 people (Mean = 2.15, SD = 0.88) evaluated spatial comfort more positively than households of 6-7 people ($p = 0.002$). No significant effect of household size was found on other comfort parameters ($p > 0.05$).

The Effect of Education Level

The level of education created significant differences in the perception of visual comfort ($F(2,87) = 4.92$, $p = 0.009$) and indoor air quality ($F(2,87) = 3.45$, $p = 0.036$). In terms of visual comfort, higher education graduates (Mean = 3.02, SD = 1.12) reported higher satisfaction than primary education graduates (Mean = 2.55, SD = 0.92) ($p = 0.008$). In indoor air quality, higher education graduates (Mean = 2.18, SD = 0.75) have a more positive perception compared to secondary education graduates (Mean = 1.94, SD = 0.68) ($p = 0.034$). No significant effect of education level was detected on thermal and acoustic comfort, and spatial comfort.

5. Discussion

This study evaluated the environmental and spatial comfort perceptions of users in container units used for post-disaster temporary housing within a multi-dimensional framework. The findings show that user satisfaction remained at a limited level in all of the headings: thermal comfort, acoustic comfort, visual comfort and lighting, indoor air quality, and spatial comfort and ergonomics. When the average satisfaction scores presented in Table 7 are examined, it reveals that comfort problems emerged at different intensities among the headings, but generally, container units fall short in meeting long-term living requirements (Table 7).

Table 7 Users' Overall Satisfaction Level with the Interior

Basic Parameters	Average Satisfaction (Mean)	Average SD
Thermal Comfort	1.59	0.64
Acoustic Comfort	1.44	0.82
Visual Comfort and Lighting	2.75	1.41
Indoor Air Quality	1.94	1.08
Spatial Comfort and Ergonomics	2.13	1.28

The comparative evaluation shows that the lowest average satisfaction values are concentrated under the acoustic comfort (Mean = 1.44) and thermal comfort (Mean = 1.59) headings. This situation indicates that basic environmental comfort components, such as noise control and indoor temperature balance, negatively affect the user experience to a determining extent in container units. Especially, the overheating problems that become prominent in the summer period and the transmission of noise originating from the external environment and neighboring units to the interior space play a critical role in the decline of comfort perception. The literature also emphasizes that lightweight building shells and inadequate insulation solutions limit both thermal and acoustic performance in temporary and modular housing units; the user-based findings of this study support these assessments.

Although the indoor air quality heading (Mean = 1.94) presents a relatively higher average value compared to thermal and acoustic comfort, it is seen that the satisfaction level is still low. This result shows that components such as ventilation, odor formation, and humidity control are not perceived adequately by users. Furthermore, the relatively high standard deviation values under this heading indicate that the perception of indoor air quality can vary depending on the location of the containers, usage intensity, and environmental conditions. This situation suggests that indoor air quality is a comfort component sensitive not only to design but also to usage and operational practices.

The average satisfaction score (Mean = 2.13) obtained under the spatial comfort and ergonomics heading reveals that users found spatial size and general ergonomics partially acceptable; however, problems such as the inadequacy of storage areas and the inability of the space to adapt to different needs limited the comfort perception. This finding aligns with post-occupancy evaluation studies showing that the spatial organizations of container units, constructed at the "minimum shelter" scale, fall short in terms of long-term living practices.

In the summary table, the highest average satisfaction value was obtained under the visual comfort and lighting heading (Mean = 2.75). However, the fact that this value also remains below 3 indicates that natural and artificial lighting conditions are found adequate by users only to a limited extent. This situation suggests that daylight access, opening ratios, and indoor lighting arrangements in container units are decisive on spatial perception and the feeling of "freshness", but existing solutions do not fully meet this potential.

The ANOVA results show that comfort perception is not homogeneous and is significantly affected, especially by household size and education level. The most striking finding is that dissatisfaction with spatial comfort increases systematically as household size increases. The fact that the spatial comfort average is at an extremely low level, such as 1.62, in households of 6-7 people shows that standard container dimensions (approximately 20-25 m^2) are completely inadequate for large families. This finding directly overlaps with the concepts of 'crowding' and 'spatial inadequacy' defined as environmental stressors by Evans (2003).

It is noteworthy that the level of education affects the perception of visual comfort and indoor air quality. The more positive evaluation of these parameters by higher education graduates may be related to their environmental awareness and capacity to develop strategies for improving existing conditions (for example, using natural ventilation more effectively). This situation is consistent with the empirical findings of Frontczak and Wargocki (2011), indicating that individual background, expectations, and socio-demographic factors directly shape the perception of indoor environmental quality and comfort evaluations.

The difference observed only in acoustic comfort among age groups suggests that younger users are more sensitive to environmental noise. In the literature, it is stated that young individuals' need for private space and demand for a quiet environment is more prominent compared to older individuals (Ulrich, 1984; Vischer, 2007). This situation reveals that user profiles should be taken into account when designing solutions for noise control in container cities.

Evaluated overall, these findings, supported by the summary table, reveal that comfort problems in container units are multidimensional and interrelated to an extent that cannot be reduced to a single design parameter. Interactions between thermal, acoustic, visual, and spatial comfort components and indoor air quality show that inadequacy in one area can also negatively affect other comfort areas. In this context, it is understood that in the design of temporary housing units, comfort must be addressed not as a secondary criterion, but as a holistic design input that considers user health, quality of life, and long-term use requirements.

6. Conclusion

This study examined the indoor comfort performance of temporary housing units established in the Osmangazi Neighborhood Container City in the İslahiye district of Gaziantep province following the February 6, 2023 Kahramanmaraş earthquakes, with a holistic approach based on user experiences and empirical data. The findings obtained from the field research reveal that container units produced to rapidly meet the urgent shelter need after the disaster have effectively transformed into long-term living spaces, contrary to the assumption of "temporary" use. The survey study conducted with 90 users and on-site field observations prove that user satisfaction is at a critically low level in most of the thermal, auditory, indoor air quality, and ergonomics and spatial design parameters, and that it harbors a systematic inadequacy. This situation necessitates going beyond quantitative targets in the management and design of post-disaster housing areas and standardizing a multi-dimensional comfort optimization centered on user experience at the institutional level.

In this housing experience that lasts for months or years, structuring the units only within the limits of "minimum shelter areas" risks long-term user health and psychosocial well-being. Accordingly, national and international technical regulations and design guidelines need to be updated with a holistic approach. Modular ergonomics criteria, along with verifiable technical performance indicators such as the sound transmission loss (Rw) of the units, daylight factor, and indoor air quality (CO_2 and volatile organic compound levels), should be included in the relevant standards. Integrating interior architecture, environmental control, and building physics experts into planning and emergency logistics processes will be an institutional step that will directly increase the habitability of temporary settlements produced after a disaster.

Data and Climate-Oriented Design Strategies: The quantitative data obtained in the research present an evidence-based and prioritized hierarchy of design interventions, shaped depending on the intensity of user dissatisfaction (Mean) and its homogeneity aross the sample (SD):

First Priority Intervention Area (Acoustic and Thermal Comfort): According to the results of the comparative analysis, the parameters with the lowest and most homogeneous satisfaction levels across the sample are the acoustic comfort (Mean = 1.44, SD = 0.82) and thermal comfort (Mean = 1.59, SD = 0.64) areas. Considering the Mediterranean-Continental transitional climate of the İslahiye region, which is exposed to extreme heat exceeding 40°C and intense solar radiation in summer and is harsh in winter, the existing thin sandwich panel technology is completely inadequate in maintaining the indoor temperature balance. In the face of this specific climatic necessity, solar shading (reflective secondary roof) systems integrated onto the roofs of the units should be designed. This passive design strategy will reduce the radiation load on the unit while also physically damping the impact noise created by raindrops falling on the panel surface. At the settlement scale, acoustic absorbent landscape elements (dense leafy green bands) to be positioned between units will minimize neighborhood noise and privacy violations through spatial morphology.

Second Priority Intervention Area (Indoor Air Quality): Indoor air quality problems (Mean = 1.94), which rank second, are fueled especially by the chronic odor problem (Mean = 1.13) in the units. This problem deepens during periods in İslahiye's harsh winter months when windows cannot be opened due to climatic necessities. Inadequate air exchange leads to the accumulation of

moisture, mold, and carbon dioxide indoors. In order to resolve this situation, mechanical sealing apparatus with check valves should be used in the infrastructure and drainage lines of wet volumes; and decentralized heat recovery ventilation grilles with humidity sensors and carbon filters, operating independently of user control, should be integrated into the building shell.

Third Priority Intervention Area (Spatial Design and Ergonomics): The storage crisis (Mean = 1.61), which increases as household size increases, necessitates volumetric solutions instead of the limited 21 m² floor area. Although it is seen that users find spatial size and general ergonomics partially acceptable (Mean = 2.13), the lack of storage limits this perception. The standard 2.40 m ceiling height of container units should be carried to the vertical axis in modular interior design with drop-ceiling type lift storage units or hidden storage areas within a raised podium. Instead of being fixed elements, the furnishings used should be designed as folding work/dining tables integrated into container wall panels and railed/movable dividing wall panels that can flexibly divide the space according to day-night scenarios. Since daylight access to the interior space (Mean = 2.75) is relatively the most positively evaluated area by users in the summary data, flexible furniture layouts that will support this strength should be preferred.

The empirical and methodological limits of this study present a multidimensional scientific roadmap for future academic research:

Longitudinal Tracking: Monitoring user experiences longitudinally over broad timeframes such as the 1st, 3rd, and 5th years of the disaster will reveal how comfort conditions change over time depending on material wear and user adaptation.

Methodological Triangulation: Supporting the data obtained from the subjective survey study with objective indoor environmental quality data loggers such as thermal cameras, decibel meters, lux meters, and CO_2 sensors will clarify the correlations between the perceptual dimension and physical reality.

Multi-Site Comparative Studies: Comparing the original findings obtained from the İslahiye settlement with other container cities having different microclimatic characteristics (like the Hatay coastal region or Kahramanmaraş) and different settlement morphologies will contribute to the development of post-disaster housing standards in a flexible and context-sensitive manner.

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CRediT Authorship Contribution Statement

Esra Avlanmaz Bilecen: Writing – review & editing, Writing – original draft, Methodology, Investigation, Analysis, Data curation, Conceptualization, Buse Büyükkömürcü: Investigation, Analysis, Data curation, Conceptualization.

Declaration of Competing 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 paper.

Data Availability

Data will be made available on request.

Ethics Committee Approval

This study was approved by the Ethics Committee of Hasan Kalyoncu University (Protocol No: E-97105791-050.04-53568).

References

Al-Akhzami, F., Al-Khatri, H., Al-Saadi, S., Khan, H., & Etri, T. (2024). A comprehensive objective and subjective assessment survey of indoor environmental quality in higher education classrooms in a hot arid climate. *Building and Environment*, *263*, Article 111870. https://doi.org/10.1016/j.buildenv.2024.111870

Altomonte, S., Schiavon, S., Kent, M. G., & Brager, G. (2019). Indoor environmental quality and occupant satisfaction in green-certified buildings. *Building Research & Information*, *47*(3), 255-274. https://doi.org/10.1080/09613218.2018.1383715

Arslan, H. (2007). Re-design, re-use and recycle of temporary houses. *Building and Environment*, *42*(1), 400-406. https://doi.org/10.1016/j.buildenv.2005.07.031

Arslan, H., & Cosgun, N. (2008). Reuse and recycle potential of the temporary house after occupancy: Example of Duzce, Turkey. *Building and Environment*, *43*(5), 702_709. https://doi.org/10.1016/j.buildenv.2007.01.033

Asfour, O. S. (2019). Learning from the past: Temporary housing criteria in conflict areas with reference to thermal comfort. *International Journal of Disaster Risk Reduction*, *38*, Article 101206. https://doi.org/10.1016/j.ijdrr.2019.101206

Balamir, M. (2001). Depremzedelerin konutlandırılmasında sorunlar. *Planlama*, *4*, 4-10.

Baradan, B. (2008). Review of literature for the concept of post-disaster housing in Turkey. *Gazi University Journal of Science*, *21*(2), 43-49.

Bilau, A. A., Witt, E., & Lill, I. (2015). A framework for managing post-disaster housing reconstruction. *Procedia Economics and Finance*, *21*, 313-320. https://doi.org/10.1016/S2212-5671(15)00182-3

Bluyssen, P. M. (2015). *The indoor environment handbook: How to make buildings healthy and comfortable*. Earthscan.

Corsellis, T., & Vitale, A. (2005). *Transitional settlement: Displaced populations*. Oxfam GB in association with University of Cambridge shelterproject.

Davidson, C. H., Johnson, C., Lizarralde, G., Dikmen, N., & Sliwinski, A. (2007). Truths and myths about community participation in post-disaster housing projects. *Habitat International*, *31*(1), 100-115. https://doi.org/10.1016/j.habitatint.2006.08.003

Davis, I. (1978). *Shelter after disaster*. Oxford Polytechnic Press.

Dikmen, N. (2005). *Relocation or rebuilding in the same area: An important factor for decision making for post-disaster housing projects*. i-Rec International Conference, Montreal, Canada.

Evans, G. W. (2003). The built environment and mental health. *Journal of Urban Health: Bulletin of the New York Academy of Medicine*, *80*(4), 536-555. https://doi.org/10.1093/jurban/jtg063

Félix, D., Branco, J. M., & Feio, A. (2013). Temporary housing after disasters: A state of the art survey. *Habitat International*, *40*, 136-141. https://doi.org/10.1016/j.habitatint.2013.03.006

Frontczak, M., & Wargocki, P. (2011). Literature survey on how different factors influence human comfort in indoor environments. *Building and Environment*, *46*(4), 922_937. https://doi.org/10.1016/j.buildenv.2010.10.021

Gkoumas, I., Mavridou, T., Seymour, V., & Nanos, N. (2025). Post-disaster housing and social considerations. *International Journal of Disaster Risk Reduction*, *124*, Article 105537. https://doi.org/10.1016/j.ijdrr.2025.105537

Johnson, C. (2007). Strategic planning for post-disaster temporary housing. *Disasters*, *31*(4), 435-458. https://doi.org/10.1111/j.1467-7717.2007.01018.x

Kalkan, M. (2025). Evaluation of post-disaster temporary shelter quality criteria in the context of sustainability. *PLANARCH – Design and Planning Research*, *9*(2), 266_274. https://doi.org/10.54864/planarch.1672088

Kim, J., Lim, H., Nam, D., Sim, J., Lee, S., Kim, H., & Park, S. (2025). Enhancing temporary housing models for disaster resilience: Insights drawn from post-disaster experiences in Korea. *Sustainability*, *17*(20), Article 9225. https://doi.org/10.3390/su17209225

Lizarralde, G., Johnson, C., & Davidson, C. H. (Eds.). (2010). *Rebuilding after disasters: From emergency to sustainability*. Spon Press.

Montalbano, G., & Santi, G. (2023). Sustainability of temporary housing in post-disaster scenarios: A requirement_based design strategy. *Buildings*, *13*(12), Article 2952. https://doi.org/10.3390/buildings13122952

Opdyke, A., Javernick-Will, A., & Koschmann, M. (2018). A comparative analysis of coordination, participation, and training in post_disaster shelter projects. *Sustainability*, *10*(11), Article 4241. https://doi.org/10.3390/su10114241

Quarantelli, E. L. (1995). Patterns of sheltering and housing in US disasters. *Disaster Prevention and Management: An International Journal*, *4*(3), 43-53. https://doi.org/10.1108/09653569510088069

Ruth, O., Kuga, K., & Ito, K. (2025). Subjective and objective measurement of indoor environmental quality and occupant comfort in a multinational graduate student office. *Environments*, *12*(4), Article 117. https://doi.org/10.3390/environments12040117

Sanderson, D. (2012). Livelihood protection and support for disaster. In B. Wisner, J. C. Gaillard, & I. Kelman (Eds.), *Handbook of hazards and disaster risk reduction* (1st ed., pp. 697-710). Routledge. https://doi.org/10.4324/9780203844236-74

Schweiker, M., Andersen, R. K., Carlucci, S., Chinazzo, G., Hodder, S., Mahdavi, A., Palella, B. I., Pisello, A. L., d'Ambrosio Alfano, F. R., & Vellei, M. (2025). Ten questions concerning the usage of subjective assessment scales in research on indoor environmental quality. *Building and Environment*, *283*, Article 113393. https://doi.org/10.1016/j.buildenv.2025.113393

Shinohara, N., Tokumura, M., Kazama, M., Yonemoto, Y., Yoshioka, M., & Kagi, N. (2014). Indoor air quality and thermal comfort in temporary houses occupied after the Great East Japan Earthquake. *Indoor Air*, *24*(4), 425-437. https://doi.org/10.1111/ina.12082

Shinohara, N., Tokumura, M., & Yanagi, U. (2018). Indoor fungal levels in temporary houses occupied following the Great East Japan Earthquake of 2011. *Building and Environment*, *129*, 26-34. https://doi.org/10.1016/j.buildenv.2017.11.042

Tan, A. Y. K., & Tan, C.-K. (2021). Thermal comfort performances of temporary shelters using experimental and computational assessments. *Buildings*, *11*(12), Article 655. https://doi.org/10.3390/buildings11120655

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science*, *224*(4647), 420-421. https://doi.org/10.1126/science.6143402

Vischer, J. C. (2007). The effects of the physical environment on job performance: Towards a theoretical model of workspace stress. *Stress and Health*, *23*(3), 175-184. https://doi.org/10.1002/smi.1134

Vischer, J. C. (2008). Towards an environmental psychology of workspace: How people are affected by environments for work. *Architectural Science Review*, *51*(2), 97_108. https://doi.org/10.3763/asre.2008.5114

Resume

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Green building certification systems: An assessment of the city of Izmir

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Abstract

This study examines the sustainability performance of LEED and BREEAM-certified green buildings in Izmir, province of Türkiye, in terms of certification levels, assessment categories, building types and the environmental strategies implemented. Guided by a conceptual framework based on sustainability, sustainability in architecture, urban sustainability, the green building approach and international certification systems, the research aims to provide a comparative assessment at a local-scale. A qualitative research approach was adopted in the study; document analysis was used as the data collection technique. Data obtained from ÇEDBİK, USGBC, BREEAM and relevant project sources were classified according to certification type, certification level, total score, credit categories, building function and sustainability strategies; and interpreted using descriptive statistics and comparative content analysis. In this respect, the study distinguishes itself from research focusing on a single building type or a single certification category by developing a multi-typology evaluation framework based on the example of Izmir province. The findings show that there are 32 LEED-certified projects in Izmir and four BREEAM certification records associated with three separate buildings or projects. It was determined that performance in LEED-certified buildings is concentrated in the categories of energy and atmosphere, water efficiency, indoor environmental quality, location and transport, and sustainable sites; however, the materials and resources category is under-represented. BREEAM projects, on the other hand, are characterised by the operational performance of existing buildings, environmental management, energy and water conservation, waste control, user comfort and safety measures. Furthermore, it has been observed that sustainability priorities vary according to building function; different strategies are prominent in office, industrial, commercial, residential and transport buildings. The study reveals that green building practices in Izmir are spreading across different building functions; however, the publicly available records examined are insufficient to directly assess the spatial and socio-economic dimensions of this spread. Based on the findings, it is recommended that the strong practices observed in energy and water efficiency be maintained; while sustainability strategies relating to materials and resource management, the operational performance of existing buildings, and building functionality should be developed through local policies and incentives.

Keywords: green building, Izmir, LEED and BREEAM certifications, sustainability

1. Introduction

Industrialisation, rapid urbanisation, population growth and the intensive consumption of natural resources are placing multidimensional pressures on the ecological balance, giving rise to environmental, economic and social consequences (Mebratu, 1998; Bozlağan, 2010). These developments have highlighted the inadequacy of explaining the concept of development solely in terms of economic growth; they have brought to the fore a sustainability approach that addresses environmental limits, social welfare and intergenerational justice collectively (WCED, 1987; Purvis et al., 2019). As the impacts of the built environment on the natural environment have become increasingly apparent, the concept of sustainability has also found its way into the fields of architecture and building construction. Within this framework, buildings' energy and water

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consumption, material use, waste generation and carbon emissions have become key performance areas that require systematic assessment (Hill & Bowen, 1997; McLennan, 2004; Zuo & Zhao, 2014; Allen et al., 2015; Kibert, 2022; Karimi et al., 2023).

During transformation processes, the green building approach and certification systems have been among the key tools enabling sustainability to become measurable, verifiable and comparable at the building level (Doan et al., 2017; Shan & Hwang, 2018). Systems such as LEED, BREEAM, DGNB, EDGE, Green Star and B.E.S.T. assess building performance against specific criteria in areas such as energy, water, materials, indoor environmental quality, transport and land use, but differ in terms of their scoring methods and the performance areas they prioritise (Ebert et al., 2012; Feijão et al., 2024). Among these systems, LEED stands out on an international scale due to its adaptability to different building types, as well as new and existing buildings. LEED- and BREEAM-certified buildings, meanwhile, present an important area of research for examining the practical implications of the sustainability approach in building construction (Zuo & Zhao, 2014; Shan & Hwang, 2018; Akşit & Baştanoğlu, 2021; Kibert, 2022; Akşar, 2025).

Research on green building certification systems in Türkiye has largely focused on theoretical comparisons of the systems, the nationwide distribution of certified buildings, or the examination of a specific building type (Uruk & Külünkoğlu-İslamoğlu, 2019; Deligöz et al., 2020; Akşar, 2025). Furthermore, there are few studies that jointly evaluate LEED- and BREEAM-certified buildings with different functions within the same urban context in terms of certification levels, credit categories and the sustainability strategies applied (Çillioğlu-Karademir & Dağ, 2021; Büyükünsal & Alıcı, 2023; Hashi & Kasapoğlu, 2023). This study compares different building types in Izmir, province of Türkiye, within a common analytical framework, revealing the areas of assessment in which the performance of certified buildings is concentrated and how sustainability strategies differ according to building function. Within this framework, it contributes a local-scale, comparative and multi-typology assessment to the literature.

2. Conceptual Framework

2.1. Sustainability

The concept of sustainability has gained prominence with the rise of industrialisation, rapid population growth, the over-exploitation of natural resources and the increasing visibility of environmental degradation; it has evolved into a fundamental approach demonstrating that development cannot be explained solely in terms of economic growth (Mebratu, 1998; Bozlağan, 2010). The most widely accepted definition of the concept was provided in the World Commission on Environment and Development's report entitled 'Our Common Future'; sustainable development is described as a form of development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). This definition positions sustainability not merely as an approach seeking solutions to environmental problems, but as a principle linked to intergenerational justice, the continuity of resources, and the ethical boundaries of development (WCED, 1987; Du-Pisani, 2006). However, the literature indicates that sustainability does not have a single, fixed definition, but is addressed with different priorities by various disciplines (Lélé, 1991; Gedik, 2020). According to Lélé (1991), although the concept is widely accepted, the tension between the environment and development is often not sufficiently clearly defined. Mebratu (1998), on the other hand, emphasises that the concept of sustainability has a multi-layered structure shaped at the intersection of environmental concerns, economic expectations and social needs.

Sustainability in Architecture: It is a holistic approach that requires consideration not only of a building's energy performance during its operational phase, but also of site selection, design, material selection, construction, use, maintenance and the post-life cycle (Hill & Bowen, 1997; Kibert, 2022). This approach redefines architecture as a discipline that, in addition to being a field of aesthetic and functional production, bears the responsibility of reducing environmental impacts, balancing resource consumption and enhancing user well-being (Sev, 2009; Korur, 2024). Akadiri et

al. (2012) evaluate the fundamental components of sustainable architecture under the headings of resource conservation, cost-effectiveness and adaptation to human needs. Within this framework, sustainable architecture requires the integration of passive and active strategies, such as the use of high-energy-efficiency technical systems, climate-responsive design decisions, the utilisation of natural light, natural ventilation, water efficiency, and appropriate material selection (Sassi, 2006; Ateş-Can & Özipek, 2019).

Urban Sustainability: It is a multidimensional approach that requires urban development to be assessed not solely in terms of economic growth, but in conjunction with the objectives of environmental protection, social justice and liveability (Campbell, 1996; Jenks & Jones, 2010; Dilfiruz & Sevinç, 2025). This approach has evolved into a planning and management framework aimed at reducing the pressures generated by cities through their consumption of natural resources, land use, transport systems, infrastructure burden and social inequalities (Keleş, 1990; Newman & Kenworthy, 1999; Cohen, 2017). Consequently, a sustainable city is understood not only as a physical settlement that causes less harm to the environment, but also as an urban system in which access to services, the quality of public spaces, transport equity and social welfare are organised in a balanced manner (Campbell, 1996; Jenks & Jones, 2010; Kaya & Taylan-Susan, 2020).

2.2. Green Building

Green building is a comprehensive approach to sustainable construction that includes design, construction, operation, maintenance, and the end of the life cycle, even if it is a technical solution meant to lower energy consumption throughout the operational phase (McLennan, 2004; Kubba, 2017; Kibert, 2022). This approach aims to ensure the efficient use of energy, water and materials; to reduce waste and emissions; to consider the environmental impacts of land use; and to establish a balanced relationship between the building and its natural environment (Edwards, 2010; Zuo & Zhao, 2014; Kibert, 2022). Consequently, green building represents a multidimensional performance concept that requires the joint assessment of numerous criteria, including energy efficiency, indoor environmental quality, water management, material selection, waste management, resilience and life-cycle performance (McLennan, 2004; Kubba, 2017; Belek & Yamaçlı, 2023).

The literature makes clear that research into green buildings initially focused on environmental performance, energy efficiency and certification systems; over time, however, social, economic and user-centred dimensions have also come to the fore (Zuo & Zhao, 2014; Darko & Chan, 2016; Khan et al., 2019). Recent studies indicate that green buildings can make positive contributions to user health through indoor air quality, daylight, thermal comfort and general indoor environmental conditions (Allen et al., 2015; Wei et al., 2015; Karimi et al., 2023). However, economic feasibility, integrated design, managerial capacity and stakeholder collaboration are among the key factors influencing the widespread adoption of green building practices (Yudelson, 2009; Darko & Chan, 2017). The literature identifies the perception of high initial investment, lack of information, insufficient incentives, low market demand and regulatory gaps as the main barriers to green building practices (Dwaikat & Ali, 2016; Darko & Chan, 2017). In the Turkish literature, green building is defined as a multi-criteria building approach that considers both the environment and human health, and which must be addressed using sustainable criteria throughout the design, construction, use and demolition processes (Erdede & Bektaş, 2014; Bayat & Küçükali, 2022; Belek & Yamaçlı, 2023).

2.2.1. Green Building Certification Systems (LEED, BREEAM, EDGE, DGNB, Green Star, B.E.S.T.)

Green building certification systems are tools that assess the environmental performance, resource efficiency, occupant health and sustainability levels of buildings against specific criteria, making these aspects comparable and verifiable (Doan et al., 2017; Shan & Hwang, 2018). Although these systems provide a common framework for integrating sustainability principles into design, construction and operation processes, they differ in terms of their scoring methods, the

performance areas they prioritise and their regional adaptations (Ebert et al., 2012; Feijão et al., 2024).

LEED is one of the most widely used systems internationally and assesses building performance across categories such as energy, water, materials, indoor environmental quality, transport and regional priorities (Shan & Hwang, 2018; Uruk & Külünkoğlu-Islamoğlu, 2019). BREEAM, as one of the oldest certification systems, assesses categories such as management, health and comfort, energy, transport, water, materials, waste, land use, ecology and pollution; it stands out for its weighting structure, which can vary depending on the building type and context (Doan et al., 2017). Comparisons within the Turkish context demonstrate that LEED and BREEAM assign different weights to energy, water and materials criteria; consequently, the same building may exhibit different strengths and weaknesses across the two systems (Deligöz et al., 2020).

Other systems, meanwhile, are distinguished by different sustainability priorities. The DGNB assesses economic, socio-cultural, functional, technical and process quality alongside ecological performance using a life-cycle approach (Ebert et al., 2012; Geçimli, 2021). EDGE focuses on energy, water and material-related embodied energy savings by offering a more accessible model, particularly for developing countries (Isimbi & Park, 2022). Green Star has evolved as an Australia-based assessment system covering the categories of management, indoor environmental quality, energy, transport, water, materials, land use and emissions (Doan et al., 2017; Dharmarathna et al., 2025). B.E.S.T., developed in Türkiye, is a system that takes into account local climate, legislation and implementation conditions; it provides a national assessment framework based on categories such as energy, water, materials, health and comfort, and living in the home (Deligöz et al., 2020; Geçimli, 2021). While these certification systems are united by the same sustainability objective, each reflects the priorities of its own geographical, economic and institutional context. Therefore, the choice of system should be made by taking into account the building type, project objective, cost expectations, local conditions and the performance areas to be assessed (Shan & Hwang, 2018; Feijão et al., 2024).

Table 1 shows the EDGE certification levels, Table 2 shows DGNB ratings scores, Table 3 shows the LEED Certification ratings, Table 4 shows the BREEAM certification ratings, Table 5 shows the Green Star ratings, and Table 6 shows the B.E.S.T. certification ratings.

Table 1 EDGE Certification Levels

EDGE Certified	EDGE Advanced	Zero Carbon
Over 20% savings on energy, water and materials	Over 40% energy savings	100% energy savings (carbon neutral)

Source: Adapted from the official EDGE certification criteria (EDGE, 2026)

Table 2 DGNB Rating Table

VALID	BRONZE	SILVER	PLATINUM
38,5 points or more	55 points or more	71,5 points or above	88 points or more

Source: Adapted from the official DGNB rating criteria (DGNB, 2026)

Table 3 LEED Certification Rating Table

Platinum 80+ Points	Gold 60-79 Points	Silver 50-59 Points	Certified 40-49 Points

Source: Adapted from the LEED rating system (USGBC, 2026)

Table 4 BREEAM Certification Rating Table

BREEAM Pass	BREEAM Good	BREEAM Very Good	BREEAM Excellent	BREEAM Outstanding
1 Star	**2 Star**	**3 Star**	**4 Star**	**5 Star**
>=30	>=45	>=55	>=70	>=85

Source: Adapted from the official BREEAM rating benchmarks (BREEAM, 2026)

Table 5 Green Star Rating Table

1 Star	2 Star	3 Star	4 Star	5 Star	6 Star
10 – 19 points	20 – 29 points	30 – 44 points	45 – 59 points	60 – 74 points	75 points and above

Source: Adapted from the official Green Star rating criteria (USGBC, 2026)

Table 6 B.E.S.T. Certification Rating Table

Approved	Good	Very good	Perfect
46 – 64 points	65 – 79 points	80 – 99 points	100 – 110 points

Source: Adapted from the B.E.S.T. certification criteria (ÇEDBİK, 2026)

3. Literature Review

In the international literature, green building certification systems have largely been examined comparatively in terms of assessment methods, credit categories and sustainability dimensions. These studies demonstrate that systems such as LEED, BREEAM, CASBEE and Green Star assign different weights to categories such as energy, water, materials, indoor environmental quality, transport and management; furthermore, they share a common objective of making the sustainability performance of buildings measurable and comparable (Doan et al., 2017; Shan & Hwang, 2018). A study conducted within the European context, meanwhile, reveals that certification systems not only serve as technical assessment tools but also provide multi-criteria decision-making frameworks in which environmental, economic and managerial priorities vary according to regional conditions (Sánchez-Cordero et al., 2020). In this respect, certification systems are regarded as important tools that guide decision-making processes in the sustainable architecture and construction sector (Shan & Hwang, 2018; Sánchez-Cordero et al., 2020).

Some of the studies conducted in Türkiye on green buildings and certification systems examine the prevalence of international systems—particularly LEED—across the country, their distribution by building type, and trends in their implementation (Çillioğlu-Karademir & Dağ, 2021; Akşar, 2025). Other studies, meanwhile, compare certification systems such as BREEAM, LEED and B.E.S.T. in terms of their energy, water and material criteria, as well as the weightings assigned to these criteria (Uruk & Külünkoğlu-Islamoğlu, 2019; Deligöz et al., 2020; Akşar, 2025). Within this framework, it is evident that the Turkish literature has largely focused on the theoretical comparison of certification systems and the determination of the general distribution of certified buildings; however, it has devoted limited attention to the joint evaluation of certified projects with different functions implemented at a local-scale.

The literature also includes studies focusing on specific building types or credit categories. Hashi and Kasapoğlu (2023), who assessed LEED-certified office buildings in Türkiye in terms of sustainable material and resource use, found that even in projects with high certification levels, performance in certain credit categories could be limited. Karaer and Kömürlü (2025), who examined LEED Gold-certified hotel buildings, sought to identify building-type-specific patterns by comparing scores obtained by category and common sustainability features. By examining the certification process through the lens of implementation experience, Büyükünsal and Alıcı (2023) demonstrate that these systems should be evaluated not merely as scoring tools, but as processes related to knowledge levels, stakeholder awareness and implementation capacity. Similarly, Darko and Chan (2017) note that knowledge gaps, costs, insufficient incentives, low demand and regulatory gaps are the main factors limiting the widespread adoption of green building practices.

It is evident that studies in the literature have primarily focused on the theoretical comparison of certification systems, determining the nationwide distribution of certifications in Türkiye, and examining a single building type or credit category (Deligöz et al., 2020; Akşar, 2025; Karaer & Kömürlü, 2025). Furthermore, there are few studies that jointly evaluate certified buildings with different functions within a specific city in terms of their certification levels, credit categories and sustainability strategies. The scarcity of research comparing different typologies—such as

residential, office, hotel, commercial, industrial, data centre and transport buildings—within the same urban context is striking (Deligöz et al., 2020; Çillioğlu-Karademir & Dağ, 2021; Hashi & Kasapoğlu, 2023). Building on this gap, this study evaluates LEED- and BREEAM-certified buildings in Izmir using a multi-typology sample; it examines not only the numerical distribution of certified buildings but also the credit categories where sustainability performance is concentrated, as well as the strategies that vary according to building function.

4. Materials and Methods

Examining the sustainability performance of green-certified buildings in Izmir province in terms of their certification levels, assessment criteria/credit categories, and environmental initiatives put in place is the goal of the current study. To this end, a qualitative research approach was adopted and document analysis was used as the data collection technique. According to Yıldırım and Şimşek (2021), document analysis is considered a method that enables the systematic collection, examination, classification and interpretation of written and visual materials related to the research topic. Existing documents pertaining to green building-certified projects in Izmir were also screened, assembled, and brought together for comparative analysis in this study. The certification records and publicly available project documents used in the research were last checked on 23 May 2026, and the data collection process was completed on that date. By examining the green building database of the Çevre Dostu Yeşil Binalar Derneği (ÇEDBİK, 2026), information on LEED, BREEAM, EDGE and DGNB certified buildings was obtained. Within this framework, the study also includes information on the current distribution of LEED and BREEAM certifications in Türkiye.

ÇEDBİK (2026) report was examined, and research based on the database revealed that there are n=675 LEED-certified buildings, n=83 with BREEAM certification, and n=3 with EDGE certification in Türkiye. However, following the investigations, it was determined that only LEED and BREEAM certification records exist in the city of Izmir. Buildings with EDGE and DGNB certification, however, are not present in the city of Izmir (EDGE, 2026). The U.S. Green Building Council's (2026) LEED Project Directory database lists 32 completed LEED-certified projects in Izmir. The BREEAM (2026) Explore database, meanwhile, contains a total of four certification records associated with three separate projects or physical structures, two of which relate to different sections of the same building. In this context, the research data consists of compiled project information relating to LEED-certified projects in Izmir and BREEAM certification records. For LEED projects, scorecards, certification levels, total scores, credit categories, building functions and the sustainability strategies outlined in the project descriptions were examined. Under the BREEAM framework, the assessment scheme, rating, certificate code, assessor details, project or section description and available operational performance statements were compiled The projects covered by the study encompass a range of functions, including offices, residential buildings, shopping centres, industrial buildings, data centres, retail outlets, petrol stations, campus buildings and airport terminals. For LEED projects, scores relating to the categories of Location and Transportation, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation and Regional Priority were recorded; information contained in the project descriptions—such as energy and water savings, material usage, indoor air quality and renewable energy applications—was also included in the dataset. In the case of BREEAM records, however, due to the more limited availability of publicly accessible data, the analysis was restricted to existing ratings, certificates and project descriptions.

Four stages were included in the data gathering method for this study, which was based on document review. In the first stage, the conceptual and theoretical framework of the study was established by reviewing the literature on sustainability, sustainability in architecture and urban planning, the concept of green buildings, and green building certification systems, particularly LEED and BREEAM. In the second stage, project documents, scorecards, project descriptions, certification codes, assessment systems and plan information relating to LEED and BREEAM-certified projects in Izmir were compiled. In the third stage, the data obtained was classified based on project name,

building type, certification level, total score, credit categories and assessment criteria. In the fourth stage, the classified data was analysed comparatively to determine in which credit categories LEED and BREEAM certification records in Izmir are concentrated, which sustainability strategies are prominent in which building types, and how the distribution varies according to certification levels. This phased approach aligns with the steps in the document review process outlined by Sığrı (2021)—namely, accessing materials, classifying materials, preparing data for analysis, and ensuring its suitability for use in the research report—as well as with the explanatory and methodological framework. This contributes to the diversity of data in the research. To enable the systematic interpretation of data obtained through document analysis and to test the study's objectives more clearly, the following research questions have been formulated:

1) Which green building certification schemes are represented in Izmir, and what is the breakdown of LEED-certified projects and BREEAM certification records in terms of their number and certification outcome?
2) What are the certification levels of LEED-certified buildings in Izmir, the distribution of points across credit categories, and the key sustainability strategies?
3) What are the ratings of the BREEAM certification records in Izmir, the project or section characteristics, and the key sustainability and operational strategies?
4) What similarities and differences are evident between LEED-certified projects in Izmir and BREEAM certification records in terms of assessment areas, key performance patterns and sustainability strategies that vary according to building function?
5) Based on the findings, what recommendations can be made for the development of green building practices in Izmir?

The sample for the study was determined using a criterion-based purposive sampling approach. According to Creswell and Poth (2024), purposive sampling enables the deliberate selection of cases that are directly relevant to the research objectives and rich in information. Projects were included in the study provided they met the following criteria:

- They must be situated within the geographical boundaries of Izmir,
- They must have a completed and verifiable LEED or BREEAM certification record in the relevant official certification database as at 23 May 2026
- Publicly available project information must be available that allows the project name, location, certification system or level, and the building's function to be identified.

Projects located outside Izmir, applications without a completed and verifiable certification record, and records that did not contain the minimum information required for classification at project level were excluded from the study. EDGE and DGNB-certified projects were also screened; however, as no verifiable completed project records for these systems could be identified in Izmir as of the final data collection date, they were not included in the analysis dataset. As a result of these criteria, the research dataset was composed of LEED-certified projects with different functions and BREEAM certification records. The basic unit of analysis for the study is a project or project section represented by a separate record in the official certification databases. Under the LEED framework, each certified project was treated as a separate unit of analysis. Under BREEAM, each certification record listed separately in the database was accepted as an analysis unit, and certification records relating to different sections of the same physical structure were examined as separate records. However, when interpreting the findings, the distinction between the certification record and the independent physical structure was maintained.

In the analysis of the data, a descriptive statistical analysis method was employed first. Healey (2014) defines descriptive statistics as the process of interpreting data using tools such as frequency, ratios, percentages and measures of central tendency, with the aim of identifying the fundamental characteristics of a dataset. According to Büyüköztürk et al. (2020), this method plays

a fundamental role, particularly in simplifying and making large-scale datasets more interpretable. Within this framework, as part of the descriptive statistical analysis, the types of certificates, certificate levels, score ranges and building types for the projects were organised into tables and the current situation was presented. The second method used in the research is comparative content analysis. According to Krippendorff (2018), content analysis is defined as a research technique aimed at making valid and repeatable inferences from texts. Within this scope, the comparative content analysis utilised in this study identified prominent trends between credit categories and assessment headings; project patterns were evaluated under headings such as energy and atmosphere, water efficiency, materials and resources, indoor environmental quality, and location/transport. In this context, the sustainability performance of buildings with different functions located in the same city was examined under common headings, and the similarities and differences between building types were interpreted. Assessment data from LEED scorecards and BREEAM projects formed the basis of this comparative analysis. The combined use of two analytical methods in the study contributes to validity and reliability. Furthermore, to enhance validity and reliability, data sources were diversified as much as possible, and scores, certification levels and sustainability strategies relating to the same project were compared across different documents. In addition, project data were reorganised under common headings for analysis. As the dataset contains projects certified under different LEED versions, assessment schemes and building functions, the projects' absolute total scores have not been compared directly as equivalent performance indicators. The total scores have been used to describe each project's position within its own certification level and the relevant assessment system. Comparisons between projects were primarily conducted on the basis of performance distributions across credit categories, prominent sustainability strategies, and common or differing patterns observed across building functions. However, no one-to-one score mapping was carried out between the LEED and BREEAM systems; the comparison was conducted on the basis of common performance areas and sustainability practices defined in the certification schemes.

5. Findings

5.1. General Characteristics of the Sample According to Its Structural Functions

It can be seen that the LEED-certified projects and BREEAM certification records examined as part of the research are distributed across different building functions. The sample covers a range of different uses, including office buildings, petrol stations, industrial facilities, shops, shopping centres, data centres, residential projects, campus buildings and airport terminals. This diversity demonstrates that green building practices in Izmir are not limited to a single building type but are spread across building functions of varying scales.

5.2. Breakdown of LEED-Certified Projects by Year and Certification Level

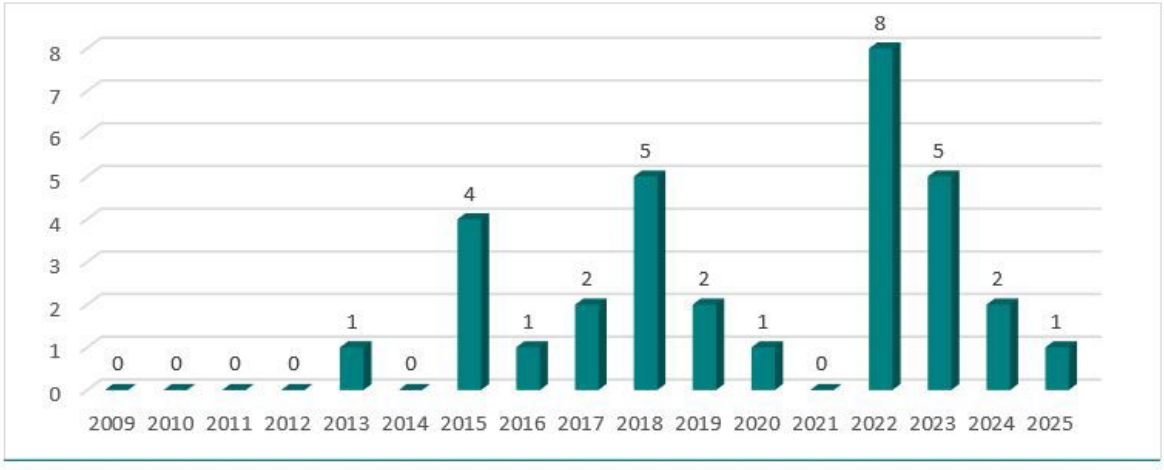


Figure 1 Distribution of LEED-certified projects in Izmir by certification year

Source: Prepared by the authors based on data obtained from the LEED Project Directory (USGBC, 2026)

Figure 1 shows the distribution of LEED-certified projects in Izmir by year of certification. It can be seen that the highest number of LEED certifications took place in 2022 (n=8). This year is followed by 2018 (n=5) and 2023 (n=5). The distribution by year does not show a regular and continuous upward trend; the number of certifications fluctuates between periods. The dataset examined contains a total of 32 completed LEED-certified projects.

Table 7 Distribution of LEED-Certified Projects by Year and Certification Level

Years	Certified	Silver	Gold	Platinum	Total
2009	-	-	-	-	-
2010	-	-	-	-	-
2011	-	-	-	-	-
2012	-	-	-	-	-
2013	-	-	1	-	1
2014	-	-	-	-	-
2015	-	2	2	-	4
2016	-	1	-	-	1
2017	-	-	2	-	2
2018	-	-	5	-	5
2019	-	-	2	-	2
2020	-	-	1	-	1
2021	-	-	-	-	-
2022	1	2	3	2	8
2023	-	2	2	1	5
2024	-	-	2	-	2
2025	-	-	1	-	1
Total	1	7	21	3	32

Source: Prepared by the authors based on the LEED Project Directory (USGBC, 2026)

Table 7 shows the distribution of LEED-certified buildings in the city of Izmir by year and certification level. According to this, there are a total of 32 LEED-certified buildings in Izmir. Among the certification levels, Gold-certified projects account for the largest share (n=21). The Gold certification level is followed by Silver (n=7) and Platinum (n=3), while only one project is at the Certified level. This distribution shows that the majority of LEED projects in the sample under review exceed the minimum certification level, and that the Gold level is the predominant category.

Table 8 presents information on LEED-certified projects in Izmir, including the approval date, project name, certification level, assessment system, project size and total score. The projects listed in the table encompass a range of different functions, such as offices, residential buildings, industrial facilities, commercial buildings, data centres, retail premises and transport buildings. This diversity demonstrates that LEED certification in Izmir is not limited to a specific building type but is applicable across different scales and usage areas. Furthermore, the inclusion of LEED applications not only for newly constructed projects but also for the operation and use of existing buildings highlights that the sustainability approach in the city is developing through both new construction and the performance of existing buildings.

Table 8 Data on LEED-Certified Projects in Izmir

Project Approval Date	Project	Certificate Level	Assessment System	Project Size	Points
14.10.2025	Cetas Izmir Plaza	Gold	LEED O+M: Existing Buildings . v4.1 - LEED v4.1	15.100 m²	68
22.04.2024	ING Bank Turkey, Izmir Regional Office	Gold	LEED O+M: Existing Buildings . v4.1 - LEED v4.1	28.497 ft²	67
12.09.2024	DB Agricultural Energy Office Building	Gold	LEED BD+C: New Build . v4 - LEED v4	955 m²	68
24.01.2023	Opet Petrol Station – Foça West Station	Gold	LEED O+M: Existing Buildings . v4.1 - LEED v4.1	411 m²	71
24.01.2023	Opet Petrol Station – Foça East Station	Gold	LEED O+M: Existing Buildings . v4.1 - LEED v4.1	411 m²	72
3.10.2023	Camyapi Factory	Silver	LEED BD+C: New Build . v4 - LEED v4	22.026 m²	52
30.10.2023	Pinar Et Administration Building	Platinum	LEED O+M: Existing Buildings . v4.1 - LEED v4.1	886 m²	80
29.10.2023	Packaging Factory	Silver	LEED BD+C: New Build . v4 - LEED v4	18.575 m²	54
17.01.2022	Puratos – Efes	Silver	LEED BD+C: New Build . v4 - LEED v4	9.188 m²	52
21.01.2022	Izmirgaz Head Office Building	Silver	LEED BD+C: New Build . v4 - LEED v4	79.201 m²	55
30.03.2022	Arçelik Sustainable Store	Platinum	LEED ID+C: Retail . v4 - LEED v4	860 m²	84
04.04.2022	JTI Minced Meat Packaging Plant	Gold	LEED BD+C: New Build . v4 - LEED v4	782 m²	61
29.04.2022	Lansinoh Izmir Factory	Gold	LEED O+M: Existing Buildings . v4 - LEED v4	8.198 m²	67
2.08.2022	Ck Design Studio	Platinum	LEED BD+C: New Build . v4 - LEED v4	440 m²	80
4.10.2022	Kocaer Çelik A.Ş. Galvanising Plant	Gold	LEED BD+C: New Build . v4 - LEED v4	6.810 m²	63
26.10.2022	UPS Izmir Distribution Centre	Certified	LEED BD+C: New Build . v3 - LEED 2009	6.237 m²	45
19.05.2020	Izmir Karşıyaka Shopping Centre	Gold	LEED BD+C: Kernel and Shell. v3 - LEED 2009	102.258 m²	60
9.01.2019	Turkcell Izmir Data Centre	Gold	LEED BD+C: New Build . v3 - LEED 2009	11.412 m²	70
7.08.2019	Mistral Towers Residences	Gold	LEED BD+C: Kernel and Shell . v3 - LEED 2009	299.552 ft²	67
10.02.2018	Park Yaşam Ataşehir – Block A	Gold	LEED BD+C: New Build . v3 - LEED 2009	53.333 ft²	61
10.02.2018	Park Yaşam Ataşehir – Block B	Gold	LEED BD+C: New Build . v3 - LEED 2009	71.059 ft²	62
10.04.2018	Izmir Chamber of Commerce	Gold	LEED BD+C: New Build . v3 - LEED 2009	13.029 m²	70
26.04.2018	Allianz Izmir Operations Centre	Gold	LEED BD+C: New Build . v3 - LEED 2009	16.496 m²	68
11.09.2018	Mistral Towers Offices	Gold	LEED BD+C: Kernel and Shell . v3 - LEED 2009	434.255 ft²	71
17.01.2017	Hilton Garden Inn Izmir Bayraklı	Gold	LEED BD+C: New Build . v3 - LEED 2009	117.492 ft²	67
16.10.2017	T. Garanti Bank Karşıyaka Office Building	Gold	LEED BD+C: New Build . v3 - LEED 2009	8.619 ft²	75
17.02.2016	Soyak Siesta Blue	Silver	LEED BD+C: New Build . v3 - LEED 2009	227.606 ft²	53
26.02.2015	Soyak Mavişehir Optimus First	Gold	LEED BD+C: New Build . v3 - LEED 2009	714.210 ft²	64
30.03.2015	Soyak Mavisehir Optimus Gold	Gold	LEED BD+C: New Build . v3 - LEED 2009	372.303 ft²	63
18.08.2015	Ever Ramada Encore Hotel	Silver	LEED BD+C: New Build . v3 - LEED 2009	120.638 ft²	53
24.12.2015	Izmir Adnan Menderes Airport Terminal	Silver	LEED BD+C: New Build . v3 - LEED 2009	2.071.837 ft²	56
15.04.2013	Alaçatı Macrocenter	Gold	LEED O+M: Existing Buildings . v3 - LEED 2009	14.646 ft²	65

Source: Compiled by the authors from the LEED Project Directory (USGBC, 2026)

Table 9 Comparison of LEED-Certified Projects by Credit Category

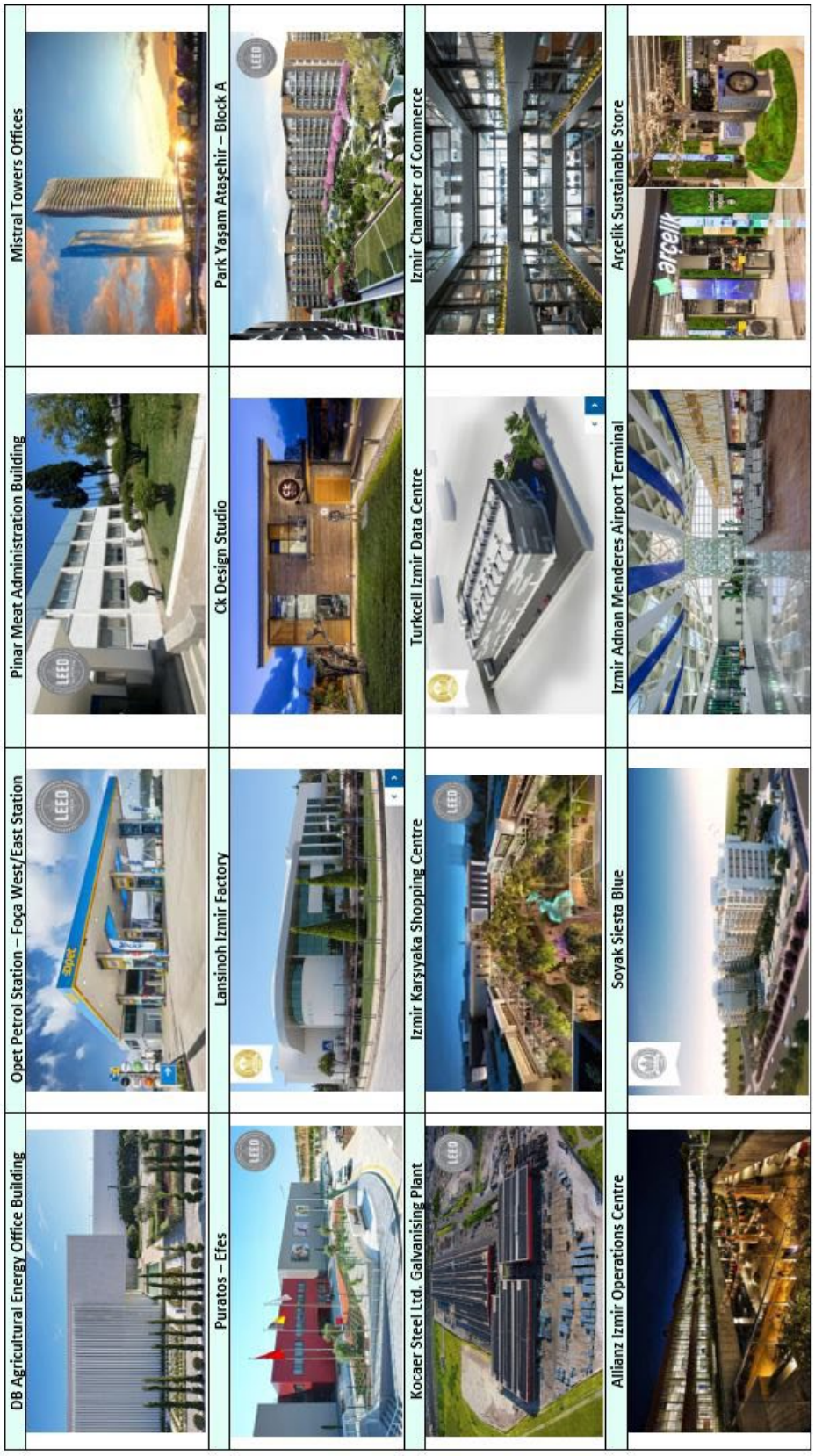
LEED Scorecard Table										
Project Name	Integrative Process Credits	Location and Transport	Sustainable Areas	Water Efficiency	Energy and the Atmosphere	Materials and Resources	Indoor Environmental Quality	Regional Priority Loans	Innovation	Point
Cetas Izmir Plaza		12/14	1/4	6 / 15	23 / 35	7 / 9	19 / 22		0 / 1	Gold 68/100
ING Bank Turkey, Izmir Regional Office		13 / 14	0 / 4	10 / 15	22 / 35	7 / 9	14 / 22		1 / 1	Gold 67/100
DB Agricultural Energy Office Building	1 / 1	3 / 20	10/10	9 / 11	27 / 89	3 / 13	6 / 16	4 / 4	5 / 6	Gold 68/ 100
Opet Petrol Station – Foça West Station		13/14	2/4	6/15	27/35	3/9	21/22		0/1	Gold 72/100
Opet Petrol Station – Foça East Station		13/14	2/4	6/15	26/35	3/9	21/22		0/1	Gold 71/100
Camyapi Factory	0 / 1	4 / 20	7 / 10	9 / 11	15 / 89	3 / 13	5 / 16	4 / 4	5 / 6	Silver 52/110
Pinar Meat Administration Building		11/14	2/4	11/15	30/35	7/9	18/22		1/1	Platinum 80/100
Packaging Factory	1 / 1	3 / 20	5 / 10	9 / 11	23 / 89	2 / 13	2 / 16	4 / 4	5 / 6	Silver 54/110
Puratos – Efes	1 / 1	2 / 20	1 / 10	8 / 11	24 / 89	2 / 13	5 / 16	4 / 4	5 / 6	Silver 52/110
Izmirgaz Head Office Building	1 / 1	10 / 20	5 / 10	10 / 11	12 / 89	3 / 13	6 / 16	3 / 4	5 / 6	Silver 55/110
Arçelik Sustainable Store	2/2	18/20		8/12	28/81	8/14	11/16	4/4	5/6	Platinum 84/110
JTI Minced Meat Packaging Plant	1 / 1	3 / 20	5 / 10	10 / 11	22 / 89	3 / 13	8 / 16	3 / 4	6 / 6	Gold 61/110
Lansinoh Izmir Factory		15/20	9/10	9/12	17/56	5/8	5/17	4/4	3/6	Gold 67/110
Ck Design Studio	1/1	8/20	7/10	9/11	26/89	8/13	11/16	4/4	6/6	Platinum 80/110
Kocaer Steel Ltd. Galvanising Plant	0/1	8/20	4/10	8/11	25/89	3/13	6/16	5/6	4/4	Gold 63/110
UPS Izmir Distribution Centre			15/26	10/10	6/53	4/14	3/15	3/4	4/6	Certified 45/110
Izmir Karşıyaka Shopping Centre			21/28	8/10	12/55	6/13	6/12	3/4	4/6	Gold 60/110

Project Name	Integrative Process Credits	Location and Transport	Sustainable Areas	Water Efficiency	Energy and the Atmosphere	Materials and Resources	Indoor Environmental Quality	Regional Priority Loans	Innovation	Point
Turkcell Izmir Data Centre			16/26	10/10	22/53	6/14	9/15	4/4	3/6	Gold 70/110
Mistral Towers Residences			25/28	10/10	15/55	6/13	7/12	4/4	5/6	Gold 71/110
Park Yaşam Ataşehir – Block A			21/26	8/10	10/53	6/14	8/15	3/4	5/6	Gold 61/110
Park Yaşam Ataşehir – Block B			23/26	8/10	9/53	6/14	8/15	3/4	5/6	Gold 62/110
Izmir Chamber of Commerce			19/26	8/10	22/53	7/14	8/15		6/6	Gold 70/110
Allianz Izmir Operations Centre			21/26	8/10	15/53	5/14	10/15	4/4	5/6	Gold 68/110
Mistral Towers Offices			25/28	10/10	14/55	6/13	7/12	4/4	5/6	Gold 71/110
Hilton Garden Inn Izmir Bayraklı			21/26	10/10	18/53	4/14	5/15	3/4	6/6	Gold 67/110
Garanti Bank Karşıyaka Office Building			20/26	6/10	24/53	5/14	12/15	4/4	4/6	Gold 75/110
Soyak Siesta Blue			19 / 26	4 / 10	12 / 53	5 / 14	7 / 15	2 / 4	4 / 6	Silver 53/110
Soyak Mavişehir Optimus First			20/26	6/10	14/53	6/14	8/15	4/4	6/6	Gold 64/110
Soyak Mavısehır Optimus Gold			20/26	6/10	13/53	6/14	8/15	4/4	6/6	Gold 63/110
Ever Ramada Encore Hotel			22 / 26	8 / 10	7 / 53	6 / 14	5 / 15	2 / 4	3 / 6	Silver 53/110
Izmir Adnan Menderes Airport Terminal			20 / 26	8 / 10	7 / 53	8 / 14	5 / 15	2 / 4	6 / 6	Silver 56/110
Alaçatı Macrocenter	0/2		17/26	5/14	27/35	5/10	2/15	3/4	4/6	Gold 63/110

Source: Compiled by the authors from the project scorecards available in the LEED Project Directory (USGBC, 2026)

Table 9 presents a comparison of LEED-certified buildings in the city of Izmir by scorecard and credit category. Table 10 shows examples of images from LEED-certified buildings located in the city of Izmir. The examples include images of the exterior architectural design for some projects and the interior architectural design for others.

Table 10 Examples of LEED-Certified Projects in Izmir



5.2.1. LEED Credit Categories and Sustainability Strategies Based on Building Functions

When LEED-certified buildings in Izmir are assessed by credit category, it is evident that sustainability performance is concentrated particularly in the areas of energy and water efficiency, indoor environmental quality, site and transportation, and sustainable sites. In contrast, the materials and resources category is represented to a more limited extent in many projects. This distribution indicates that, within the Izmir sample, LEED success has strengthened in certain performance areas, whilst developing in a more selective manner in other categories.

Energy and Water Performance: The areas of strongest performance in LEED-certified buildings in Izmir are energy and water efficiency. The Pınar Et Administrative Building, the DB Agricultural Energy Office Building, the OPET Foça East and West Stations, the Turkcell Izmir Data Centre and certain large-scale commercial buildings stand out in these categories. The recurrence of strategies such as the use of renewable energy, energy modelling, efficient mechanical systems, low-consumption lighting fixtures, rainwater harvesting and greywater reuse in project descriptions demonstrates that LEED performance in the Izmir sample has largely become visible through measurable energy and water savings.

Indoor Environmental Quality, Location, Transport and Sustainable Sites: The categories of indoor environmental quality, location, transport and sustainable sites are key themes in LEED projects in Izmir, both from a user-centred perspective and at an urban scale. In projects such as the OPET Foça stations, the Arçelik Sustainable Store, the Izmir Chamber of Commerce, the Allianz Izmir Operations Centre and the Hilltown Karşıyaka Shopping Centre, indoor air quality, thermal comfort, use of natural light, user control, access to public transport, cycling facilities and alternative transport solutions are all notable features. These findings demonstrate that LEED applications focus not only on environmental performance but also on user health, comfort, accessibility and the urban context.

The Relatively Limited Representation of the Materials and Resources Category: While the materials and resources category is not entirely excluded from LEED projects in Izmir, it appears to be a more limited area of performance compared to the energy and water categories. The Arçelik Sustainable Store, CK Design House, the Izmir Chamber of Commerce and some residential projects highlight the use of recycled materials, the preference for local materials, repurposing and waste management practices. However, the fact that this category is represented by lower scores across most projects on the scorecard indicates that the 'Materials and Resources' category does not translate into the main category determining certification success in every project.

Sustainability Strategies Varying by Building Type: LEED-certified buildings in Izmir differ in terms of their sustainability strategies depending on the type of building. While energy efficiency, user comfort, indoor environmental quality and urban accessibility are prioritised in office and administrative buildings; in industrial buildings, energy management, water efficiency, waste control, sub-metering and operational efficiency are key. In commercial buildings and retail premises, user access, visible environmental initiatives and indoor environment quality are prioritised; whereas in residential projects, quality of life, natural lighting, water conservation, the use of low-emission materials and a healthy indoor environment take centre stage. In specialised structures such as data centres and airport terminals, sustainability is linked to large-scale energy, water and waste management, technical reliability and operational continuity. Consequently, in the Izmir sample, LEED applications do not produce a uniform sustainability model; instead, they are shaped around different priorities depending on the building's function.

The findings from the analyses in this section show that the sustainability performance of LEED-certified buildings in Izmir is concentrated particularly in the areas of energy and water efficiency, indoor environmental quality, and location and transport. Furthermore, it is evident that sustainability strategies vary according to building type, with different priorities emerging in office, industrial, commercial and residential buildings.

5.3. Findings Regarding BREEAM Certification Records in Izmir

Table 11 BREEAM Certification Details for the Karşıyaka Hiltown Shopping Centre

Karşıyaka Hilltown Shopping Centre (2024)	
Certificate	BIU00020995-1.0
Assessment	Superior %85.1
Plan	In Use: International Trade V6
	- Year of Completion: October 2019 - Location: Izmir, Turkey - Number of shops: 220 - Area/Capacity: 64,000 m² - Selected as the world's best project at the ICSC 2021 Global Design and Development Awards. - BREEAM In-Use 'Outstanding Achievement Award' – Commercial 6 Version, 2024

Source: Compiled by the authors from the official Hilltown Karşıyaka project documentation (Hiltown Karşıyaka, 2026)

Table 11 provides details of the BREEAM certification for the Karşıyaka Hiltown shopping centre.

Table 12 BREEAM Certification Details for the Izmir Optimum Shopping Centre

Izmir Optimum Shopping Centre	
Evaluator	Turkeco Consultancy
Certificate	BIU00003568-2.0
Assessment	Superior %86.0
Plan	In Use: International Trade V6
	- Following the update of the existing BREEAM In-Use Certificate to Commercial Version 6, İzmir Optimum Shopping Centre has been recognised as the first building in Turkey to hold this certificate. - The implementation of the ISO 14001 Environmental Management System ensures that the building's environmental performance is improved and that its environmental impact is reduced. - Annual improvement and development targets are set to achieve energy and water savings and reduce waste generation. Sustainable procurement is ensured through the environmental/sustainable procurement policy in place. - As part of new energy-saving strategies for outdoor lighting, energy consumption is reduced by ensuring that specific areas are lit only when necessary. - As part of occupational health and safety measures, accredited third-party organisations carry out annual measurements of indoor and outdoor lighting, thermal comfort, ambient noise and CO (carbon monoxide) levels, thereby creating healthy and comfortable indoor environments. Within this framework, visitors are provided with a better and healthier environment in which to spend their time.

Source: Compiled by the authors from the official project documentation of Rönesans Holding (2024)

Table 12 shows the BREEAM certification details for the Izmir Optimum shopping centre.

Table 13 Certification Details for the BREEAM Certificates Held by the Building

Altensis Construction and Energy Ltd.		
	Chapter 1	Chapter 2
Evaluator	Altensis Construction and Energy Ltd.	Altensis Construction and Energy Ltd.
Certificate	BIU00022847-1.0	BIU00022847-1.0
Assessment	Good %45.0	Good %53.3
Plan	In Use: International Trade V6	In Use: International Trade V6
	- Floor Area: 8,216 m² Accessibility, indoor comfort and user safety conditions within the building have been assessed in detail. Accordingly, existing facilities—such as changing rooms, showers, lockers, access provisions for disabled users and pedestrian safety measures—have been carefully examined, and improvements have been meticulously implemented where deemed necessary. - As part of the project, the building management's waste management and recycling policies, as well as its procurement processes for environmentally friendly materials and products, have been reviewed in detail. - Monthly and annual electricity and water consumption data for the building were analysed to identify potential areas for improvement aimed at enhancing energy and resource efficiency. - This comprehensive assessment aims to minimize the building's environmental impact whilst enhancing the comfort of its occupants.	

Source: Compiled by the authors from Altensis project documentation and the BREEAM Explore database (Altensis, 2026)

Table 13 presents details of the BREEAM certificates held for the Altensis Construction Energy Ltd. building. Two separate sections of the Altensis Construction Energy Ltd. building have been awarded BREEAM certificates. Information regarding the BREEAM certificates for Sections 1 and 2 is provided.

5.3.1. An Assessment of BREEAM Ratings and Operational Sustainability Strategies

As part of the research, 32 completed LEED-certified projects in Izmir and four BREEAM certification records associated with three separate projects or physical structures were identified. As two of the BREEAM records relate to different sections of the same building, this figure is not interpreted as representing four independent physical buildings. The official records examined indicate that LEED is a more widespread certification scheme in Izmir compared to BREEAM. This distribution indicates that LEED has a more widespread application in green building certification in Izmir, while BREEAM offers a stronger presence in specific projects, albeit on a more limited scale. BREEAM projects particularly stand out in areas such as the operational performance of existing buildings, environmental management, energy and water conservation, waste reduction, sustainable procurement, user comfort and safety.

The fact that Izmir Optimum Shopping Centre has been rated 'Excellent' demonstrates that it has delivered a strong performance under the BREEAM In-Use framework, through its operational processes, ISO 14001 environmental management, energy and water saving targets, outdoor lighting strategies and measurements of indoor environmental quality. In the case of Altensis/CEVA Logistics in Izmir, the "Good" rating highlights practices such as accessibility, indoor comfort, user safety, waste management, environmentally friendly procurement processes, and the monitoring of electricity and water consumption. However, data on BREEAM certification data are more limited and general in nature compared to LEED projects. While detailed point distributions by credit category are available for LEED projects, assessments of BREEAM projects are typically based on the assessment level, certification code, plan information and project descriptions. Consequently, in the Izmir sample, BREEAM findings are evaluated primarily in terms of operational performance, environmental management practices and user-focused improvement strategies, rather than detailed credit scores.

5.4. A Comparison of LEED and BREEAM-Certified Green Buildings in the City of Izmir

When green building examples in Izmir are evaluated together, it is evident that there are significantly more LEED-certified buildings than BREEAM-certified ones. Within the scope of this study, 32 LEED-certified buildings were identified in Izmir, compared to 4 BREEAM certification records. This distribution indicates that LEED has a more widespread application in the Izmir sample. This finding is consistent with LEED's international visibility and prevalence in Türkiye (Doan et al., 2017; Shan & Hwang, 2018; Deligöz et al., 2020; Akşar, 2025).

One of the key differences between LEED and BREEAM is the level of data available. While BREEAM projects usually only provide the overall assessment level, certification code, assessment plan, and project descriptions, LEED projects offer comprehensive data, including certification level, assessment system, project size, total score, and the distribution of points across credit categories. Consequently, while LEED projects can be compared in greater detail based on credit categories, BREEAM projects are assessed primarily through operational processes, overall performance levels, and sustainability practices highlighted in the project descriptions.

In terms of performance areas, LEED projects tend to focus on energy and atmosphere, water efficiency, indoor environmental quality, location and transport, and sustainable sites, while the materials and resources category is relatively under-represented. In BREEAM projects, however, sustainability is more evident through existing building performance, environmental management, energy and water conservation, waste control, user comfort, safety and sustainable operational practices. From this perspective, while LEED offers a broader distribution across new building construction and different building typologies in the Izmir sample, BREEAM creates a more limited

yet complementary assessment area, focusing particularly on the operational performance and management processes of existing commercial buildings.

6. Discussion

The findings of this study indicate that sustainability practices in LEED- and BREEAM certification records in Izmir are not limited to isolated and exceptional examples, but rather exhibit a pattern that extends across different building types and has reached a certain level of maturity. This result is consistent with studies (Çillioğlu-Karademir & Dağ, 2021; Akşar, 2025) that demonstrate the increasing prevalence of LEED-certified projects in Türkiye over time and their emergence across different building types. The predominance of the Gold certification level in the Izmir case study indicates that the sustainability approach is being addressed not only in terms of minimum compliance but also with higher performance targets.

One of the most striking aspects of the findings is that the categories of energy, atmosphere and water efficiency emerged as the areas of strongest performance in the projects. This aligns with the studies by Doan et al. (2017) and Shan and Hwang (2018), which emphasise that green building certification systems employ an evaluation logic that makes measurable environmental outcomes—particularly regarding energy and resource consumption—visible. Furthermore, green building research indicates that energy efficiency, water conservation and operational performance are among the most visible and widespread dimensions of the sustainable building discourse (Zuo & Zhao, 2014; Li et al., 2021; Kibert, 2022). In the case of Izmir, the prominence of strategies such as mechanical systems that reduce energy consumption, the use of renewable energy, water-saving fixtures, and rainwater and greywater applications reveals that sustainability performance is largely expressed through quantifiable environmental gains. This finding suggests that future policies and incentives should safeguard existing energy and water efficiency practices, whilst also supporting the transfer of this performance to less well-represented areas of sustainability. Consequently, material selection, recycled content, environmental product declarations, construction waste management and the life-cycle approach are addressed as priority areas for development in the policy recommendations.

One of the study's other notable findings is that the 'materials and resources' category is not represented as strongly as energy and water in many projects. This finding is consistent with the studies by Deligöz et al. (2020) and Hashi and Kasapoğlu (2023), which indicate that material-focused credits are often a more selective, documentation-based field that is more closely linked to the supply chain. However, the implementation of topics such as recycled content, local materials, environmental product declarations and waste management is directly linked not only to design decisions but also to production, procurement, certification and implementation capacity (Kubba, 2017). Consequently, the relatively limited performance in the 'materials and resources' category is interpreted as a reflection not only of design preferences but also of the structural challenges encountered during implementation processes.

Another key finding of the study is that the categories of indoor environmental quality and location-transport sustainability also emerged as significant factors. This finding is consistent with studies (Allen et al., 2015; Wei et al., 2015; Karimi et al., 2023) demonstrating that green buildings encompass not only energy-saving technical aspects but also human-centred dimensions such as user health, comfort, accessibility and quality of life. Furthermore, the need to evaluate sustainable buildings not only at the building scale but also within the urban context, in terms of public transport access and alternative transport options, is emphasised in both sustainable urban planning and certification literature (Campbell, 1996; Jenks & Jones, 2010; Doan et al., 2017). In the Izmir case study, the prominence of factors such as proximity to public transport, cycling facilities, low-emission vehicle zones, use of natural light, indoor air quality and thermal comfort demonstrates that sustainability is addressed within an integrated framework that balances technical efficiency with user experience. This finding demonstrates that sustainable building

policies should be based not only on energy and water savings, but also on user health, accessibility, public transport links and alternative transport options.

The differences emerging based on building types are an important finding that warrants discussion. Office and administrative buildings focus on energy efficiency, user comfort and urban accessibility. Industrial buildings, meanwhile, emphasise measurable environmental performance, process-based resource management and waste control. In commercial buildings, user access and visible environmental practices are prioritised; in residential projects, quality of life and a healthy indoor environment are key; while in infrastructure and specialised-use buildings, operational continuity and large-scale system performance take precedence. This aligns with studies (Doan et al., 2017; Shan & Hwang, 2018; Deligöz et al., 2020) which indicate that while green building certification systems provide a common framework for all buildings, implementation priorities vary according to building type, usage scenarios and functional requirements. In this context, the example of Izmir demonstrates that sustainability does not offer a one-size-fits-all design model; rather, it is addressed through different strategic priorities across various building types. In this context, rather than applying the incentives, guidelines and performance criteria to be drawn up at city level in the same way to all building types, it would be more appropriate to take into account the specific priorities of office, industrial, commercial, residential and special-purpose buildings.

The findings of this study demonstrate that green building certification processes transform the built environment through both architectural design strategies and urban planning decisions. The performance patterns of the buildings examined across the city of Izmir reveal how sustainability objectives are reflected at the plot-scale level and highlight the constraints at the urban scale. The high scores achieved by certified buildings in Izmir, particularly in the 'Location and Transport' and 'Sustainable Spaces' categories, indicate that these projects align strongly with trends towards public transport integration, pedestrian and cycle accessibility, and transit-oriented development. This relationship between the success of individual buildings and the city's existing infrastructure and transport network aligns perfectly with the vision of the Izmir Green City Action Plan (YŞEP; Izmir Metropolitan Municipality, 2020a) to improve the quality of urban life and reduce transport-related emissions. The fact that a significant proportion of the projects examined consist of large-scale commercial, industrial and corporate investments indicates that certification practices have become more prominent in projects with high investment capacity. However, as the study did not directly analyse rent levels, land values or spatial clustering within cities, it is not possible to draw a definitive conclusion regarding the socio-economic reasons behind this distribution. Furthermore, the preference for the BREEAM In-Use system in large-scale existing buildings, such as shopping centres, demonstrates that the green transition is not limited to new construction processes alone, but is also a powerful tool in terms of operational performance improvements for the existing building stock and the city's energy efficiency policies.

The high performance demonstrated in the 'Energy and Atmosphere' and 'Water Efficiency' categories at the architectural and building scale is in line with the commitment made under the Izmir Sustainable Energy and Climate Action Plan (SECAP; Izmir Metropolitan Municipality, 2020b). Project descriptions highlight efficient mechanical systems, low-energy-consumption equipment, renewable energy applications and water-saving technical solutions. However, as the level of detail regarding passive design decisions in publicly available documents varies from project to project, it is not possible to make a clear distinction as to whether high performance stems from technical systems or from passive spatial solutions. Furthermore, the fact that the 'Materials and Resources' category is represented to a lesser extent than the 'Energy' and 'Water' categories indicates that there is scope for improvement in terms of the circular economy, the use of low-carbon materials and resource efficiency. The limited visibility of local and recycled materials may be linked to various factors such as the supply chain, cost, certification or implementation capacity. However, as these factors were not directly examined in the study, it is not possible to attribute the low performance to a specific cause.

The stringent geometric and spatial requirements of current zoning plans frequently clash with the goal of green building certification processes (like LEED and BREEAM) to maximize environmental performance from the design stage onward. Fundamental planning parameters, such as building layout and number of storeys, as defined by implementation plans, can limit a building's potential for passive climate control, energy efficiency and indoor environmental quality. For example, the fact that building layout in zoning plans is generally defined along the road frontage line, and that mandatory setback areas do not permit ideal orientation along the north-south axis, makes it impossible to optimise the building mass in relation to the sun. This situation diverts buildings away from passive design strategies in the 'Energy and Atmosphere' categories of LEED and BREEAM, rendering them dependent on mechanical climate control systems.

Similarly, building layouts characterised by adjacent and block-style arrangements that obstruct airflow block the prevailing wind corridors, thereby eliminating the potential for cooling through natural ventilation. Furthermore, the building layout and number of storeys specified in the implementation master plans, along with the associated floor area ratios (FAR), do not allow for flexibility in massing or surface-to-volume ratios. Compact or stepped mass designs, which are ideal from a climatic perspective, become unfeasible when constrained by floor-count limits and setback distances; the resulting expansion of the thermal envelope inevitably increases heat loss and gain. These standard planning decisions, taken without regard for the 'right to sunlight' between plots, increase the shading effect of neighbouring buildings, thereby reducing the efficiency of photovoltaic (PV) panels and making it difficult to score points for natural daylight and views. Furthermore, floor area ratio (FAR) regulations hinder ecological infrastructure schemes—such as rainwater harvesting and the reduction of surface water runoff—by limiting the amount of open green spaces and permeable surfaces within a plot. Consequently, this situation necessitates the development of new urban policies that will free the environmental performance targets offered by green building certifications from the restrictive impact of traditional planning tools, shift sustainability from being a plot-based architectural endeavour to one integrated with macro-climate objectives of Izmir, and extend the green transition across the entire city.

This current study distinguishes itself from three key trends identified in the literature. Existing research (Darko & Chan, 2017; Doan et al., 2017; Deligöz et al., 2020; Büyükünsal & Alıcı, 2023; Hashi & Kasapoğlu, 2023; Akşar, 2025) compare certification systems at a theoretical level, examine their general distribution at the national level in Türkiye, or focus on a single building type. This study examines LEED and BREEAM certification records with different functions located in a specific city, discussing the relationship between credit categories and building types through a multi-typology sample. In this respect, the study contributes to filling a gap in the literature by revealing how sustainability performance is shaped at the local level. However, the research also has certain limitations. As the study was conducted using a document analysis method, the assessments were limited to the available project data, scorecards and project descriptions. Furthermore, the fact that the projects were assessed according to different LEED types and versions makes it somewhat difficult to compare the total scores directly. Consequently, the findings have not been presented in terms of absolute score superiority but have been structured around category concentrations and the nature of sustainability strategies. In this regard, the research not only highlights the distribution of LEED and BREEAM certification records in Izmir, their performance areas, and the sustainability strategies that vary by building type; it also offers a comprehensive analytical framework by linking these findings to urban planning tools to develop policy recommendations at a macro level using the Izmir case study.

7. Conclusions and Policy Recommendations

This current study has demonstrated that LEED and BREEAM certification records in Izmir are not limited to a single type of building; rather, they have gained typological diversity by extending across different building types such as offices, industrial, educational and residential. However, while this sectoral diversity is evident at the functional level, it has not been achieved at the spatial

and socio-economic levels. The findings indicate that green building practices do not exhibit a homogeneous distribution across the city; rather, they are concentrated primarily in projects with high investment capacity—such as large-scale commercial buildings, industrial facilities and branded residential developments—even when these projects have different usage scenarios.

When considering macro-level objectives such as mitigating the urban heat island effect or ensuring urban water management, it is clear that these isolated successes—which remain the sole initiative of specific capital groups—will prove insufficient in improving the city's overall ecological performance and climate resilience. This situation necessitates that practices enhancing environmental performance be moved beyond the realm of luxury and exceptional projects, and instead be disseminated through planning policies to standard building production and the city as a whole. In order for Izmir to establish an integrated climate-resilient city model aligned with its SECAP (Sustainable Energy and Climate Action Plan) and YŞEP (Green City Action Plan) targets, fundamental policy changes are required both in local authorities' urban planning processes and in architectural design strategies. The policy recommendations developed in this context are presented below.

Performance-Based Urban Planning and Incentive Mechanisms: Current urban planning parameters largely treat the built environment through a two-dimensional framework of regulation and plot division. However, green building performance requires three-dimensional interactions between building masses and climatic data such as solar paths and prevailing winds, as well as volumetric assessments such as shadow analysis. In order for buildings to generate flexible design solutions that integrate with topography and climate, traditional planning tools must be adapted and reinterpreted through the concept of 'Performance-Based Planning'. Building regulations and conditions, such as building layout and number of storeys, must be updated in a way that does not restrict a building's potential for passive climate control and natural ventilation, while safeguarding the right to sunlight for neighbouring plots.

On the other hand, in order for Izmir Metropolitan Municipality to achieve its 40% emissions reduction target for 2030, green building certification should not be left solely to the initiative of the private sector. In implementation master plans, incentives should be defined for projects that meet a specific green building standard (e.g. LEED Gold/BREEAM Excellent) or commit to complying with SECAP's water and energy conservation targets. Planning notes should be developed that include reductions in urban infrastructure contribution shares, exemptions from planning permit fees, or additional floor area rights designed within limits that do not disrupt the urban fabric. Furthermore, to ensure that projects' achievements in the 'Location and Transport' category translate into spatial policy, mixed-use decisions should be promoted; residential, commercial and amenity areas should be integrated in a way that reduces car-dependent mobility, thereby strengthening sustainable urban transport networks.

Integration of Urban Green Infrastructure and Water Management: Although the study shows that projects perform strongly in the area of 'water efficiency', from an urban planning perspective, it is insufficient for these buildings to remain as sustainable 'islands' within their own property boundaries. Confining rainwater harvesting and treated greywater solely to the mechanical volumes of the relevant plot or using it only to irrigate its own landscaping limits the vision of urban resilience. In Izmir, which is vulnerable to the effects of the climate crisis such as extreme heat and drought, the significant surplus water generated by large-scale commercial buildings and industrial facilities in particular must be channelled into the city's blue-green infrastructure system. This water should be designed as an ecological infrastructure component that nourishes urban agricultural areas, parks and tree-lined walkways, and ecological corridors should be established between plots.

Resilient Transformation of the Existing Building Stock and Public Leadership: The adoption of the BREEAM In-Use system in existing commercial buildings, such as shopping centres, demonstrates that sustainability holds significant potential not only in new building processes but

also in improving the operational performance of the existing building stock. In line with the objective of developing safe and secure residential areas outlined in Izmir's strategic documents, urban regeneration processes should not be conducted solely with a focus on earthquake resilience. Improving the energy and water efficiency of the existing building stock should be made a legal requirement and treated as a mandatory parameter in urban regeneration strategies.

Public buildings must play a leading role in this building-scale transformation. The use of water-efficient fittings should be made mandatory in new buildings owned by Izmir Metropolitan Municipality; initiatives such as 'workshop roofs fitted with solar panels', as outlined in the SECAP, should be rolled out across educational and healthcare facilities. Requiring public projects to meet at least the 'Certified' level of green building criteria will act as a driving force in the implementation of the city's climate action plans.

Urban and Legal Policies for Sustainable Architectural Practices: Sustainability at the architectural scale must go beyond being a 'voluntary certification label' that adds value to a project after a building has been constructed, and instead become a fundamental prerequisite for building permit processes. Parcel-based architectural designs that prioritise local climate data, topography and passive climate control should not be left solely to the designer's initiative; these principles must be enshrined in a legal framework through context-specific 'Urban Design Guidelines' prepared by local authorities.

To improve the performance of materials that receive the lowest scores in green building assessments, the principles of urban metabolism and the circular economy should be adopted. Under current market conditions, where access to local and environmentally friendly materials is limited, imposing legal requirements could stifle the sector. Therefore, public procurement should be used as a transformative tool for the market. By introducing 'green public procurement' criteria in urban regeneration projects and public tenders, building material manufacturers should be steered towards low-carbon production. Concurrently, a secondary materials market where construction and demolition waste is re-evaluated should be established by local authorities. Ultimately, institutionalising this environmental sensitivity—which manifests at the plot level—by integrating it into planning legislation and urban policies will ensure that Izmir becomes not merely a city housing green-labelled buildings, but a city that is itself "climate-resilient and sustainable".

CRediT Authorship Contribution Statement

Duygu Gökce: Conceptualization, Investigation, Validation, Writing – original draft, Writing – review & editing. Onur Tos: Conceptualization, Methodology, Investigation, Data curation, Validation, Writing – original draft, Writing – review & editing. Harika Tos: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Validation, Visualization, Writing – original draft.

Declaration of Competing 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 paper.

Data Availability

Data will be made available on request.

Ethics Committee Approval

Ethics committee permission is not required.

References

Akadiri, P. O., Chinyio, E. A., & Olomolaiye, P. O. (2012). The design of a sustainable building: A conceptual framework for implementing sustainability in the construction sector. *Buildings, 2*(2), 126-152. https://doi.org/10.3390/buildings2020126

Akşar, S. (2025). Green building certification in Turkey: An evaluation based on LEED data. *Journal of Sustainable Engineering Applications and Technological Developments, 8*(1), 45_60. https://doi.org/10.51764/smutgd.1668796

Akşit, Ş. F., & Baştanoğlu, E. (2021). An overview of LEED green building certification systems in Europe and Turkey. *A|Z ITU Faculty of Architecture Journal, 18*(1), 115_126. https://doi.org/10.5505/itujfa.2021.72473

Allen, J. G., MacNaughton, P., Laurent, J. G. C., Flanigan, S. S., Eitland, E. S., & Spengler, J. D. (2015). Green buildings and health. *Current Environmental Health Reports, 2*(3), 250_258. https://doi.org/10.1007/s40572-015-0063-y

Altensis. (2026). *CEVA Lojistik İzmir.* Retrieved May 23, 2026, from https://www.altensis.com/proje/ceva-lojistik-izmir/

Ateş-Can, S., & Özipek, B. (2019). Sürdürülebilirlik kavramı ve mekânda biçimlenişi [The concept of sustainability and its formation in space]. *Yalvaç Akademi Dergisi, 4*(1), 41-55.

Bayat, F., & Küçükali, U. F. (2022). Sürdürülebilirlik bağlamında yeşil binaların ulusal ve uluslararası örnekler üzerinden incelenmesi. *Anadolu Bil Meslek Yüksekokulu Dergisi, 16*(64), 321-347.

Belek, A. N., & Yamaçlı, R. (2023). Ekolojik binaların sürdürülebilir tasarım kriterleri ve değerlendirme süreci. *Mimarlık ve Yaşam, 8*(2), 529-550. https://doi.org/10.26835/my.1219441

Bozlağan, R. (2010). Sürdürülebilir gelişme düşüncesinin tarihsel arka planı. *Sosyal Siyaset Konferansları Dergisi, 50*, 1011-1028.

BREEAM. (2026). *Explore BREEAM: Maps* [Database]. Retrieved April 23, 2026, from https://tools.breeam.com/projects/explore/map.jsp?sectionid=0&projectType=&rating=&certNo=&buildingName=&client=&developer=&certBody=&assessor=&addressPostcode=&countryId=7&partid=10023&Submit=Search

Büyüköztürk, Ş., Kılıç Çakmak, E., Akgün, Ö. E., Karadeniz, Ş., & Demirel, F. (2020). *Bilimsel araştırma yöntemleri* [Scientific research methods]. Pegem Akademi.

Büyükünsal, A., & Alıcı, O. (2023). Türkiye'deki yeşil bina sertifikasyon süreci ve anket uygulaması. *Uluslararası Sürdürülebilir Mühendislik ve Teknoloji Dergisi, 7*(2), 177-187.

Campbell, S. (1996). Green cities, growing cities, just cities? Urban planning and the contradictions of sustainable development. *Journal of the American Planning Association, 62*(3), 296_312. https://doi.org/10.1080/01944369608975696

Cohen, M. (2017). A systematic review of urban sustainability assessment literature. *Sustainability, 9*(11), Article 2048. https://doi.org/10.3390/su9112048

Creswell, J. W., & Poth, C. N. (2024). *Qualitative inquiry and research design: Choosing among five approaches* (5th ed.). Sage Publications.

Çevre Dostu Yeşil Binalar Derneği. (2026). *Yeşil bina veri tabanı: Sertifikalı binalar* [Database]. Retrieved April 23, 2026, from https://www.cedbik.org/items

Çillioğlu-Karademir, A., & Dağ, A. (2021). Sürdürülebilirlik uygulaması olarak yeşil bina ve LEED sertifikasyonu üzerine Türkiye'de inşaat sektöründe bir çalışma. *Akademia Doğa ve İnsan Bilimleri Dergisi, 7*(1), 63-83.

Darko, A., & Chan, A. P. C. (2016). A critical analysis of green building research trends in construction journals. *Habitat International, 57*, 53-63. https://doi.org/10.1016/j.habitatint.2016.07.001

Darko, A., & Chan, A. P. C. (2017). Review of barriers to green building adoption. *Sustainable Development, 25*(3), 167-179. https://doi.org/10.1002/sd.1651

Deligöz, D., Kabak, S., & Sağlam, A. İ. (2020). Türkiye'de konut yapılarında kullanılmakta olan sertifika sistemlerinin kaynakların korunumu bağlamında incelenmesi. *GRID - Mimarlık Planlama ve Tasarım Dergisi, 3*(2), 222-245. https://doi.org/10.37246/grid.743045

Deutsche Gesellschaft für Nachhaltiges Bauen. (2026). DGNB building project directory [Database]. April 23, 2026, from https://www.dgnb.de/en

Dharmarathna, D., Graham, P., & Bunster, V. (2025). Unpacking the evolution of Green Star rating tools and their certification trends in Australian building projects. *Journal of Building Engineering, 111*, Article 113328. https://doi.org/10.1016/j.jobe.2025.113328

Dilfiruz, B., & Sevinç, İ. (2025). Sürdürülebilirliği anlamak ve kentlerle bağını kurmak. *Çağdaş Yerel Yönetimler, 34*(2), 147-180.

Doan, D. T., Ghaffarianhoseini, A., Naismith, N., Zhang, T., Ghaffarianhoseini, A., & Tookey, J. (2017). A critical comparison of green building rating systems. *Building and Environment, 123*, 243_260. https://doi.org/10.1016/j.buildenv.2017.07.007

Du-Pisani, J. A. (2006). Sustainable development: Historical roots of the concept. *Environmental Sciences, 3*(2), 83-96. https://doi.org/10.1080/15693430600688831

Dwaikat, L. N., & Ali, K. N. (2016). Green buildings cost premium: A review of empirical evidence. *Energy and Buildings, 110*, 396-403. https://doi.org/10.1016/j.enbuild.2015.11.021

Ebert, T., Eßig, N., & Hauser, G. (2012). *Green building certification systems: Assessing sustainability – International system comparison – Economic impact of certifications.* DETAIL Green Books.

Edwards, B. (2010). *Rough guide to sustainability: A design primer* (3rd ed.). RIBA Publishing.

Erdede, S. B., & Bektaş, S. (2014). Ekolojik açıdan sürdürülebilir taşınmaz geliştirme ve yeşil bina sertifika sistemleri. *Harita Teknolojileri Elektronik Dergisi, 6*(1), 1-12.

Excellence in Design for Greater Efficiencies. (2026). *EDGE building project directory* [Database]. April 23, 2026, from https://edgebuildings.com/project-studies/greenox-residence/

Feijão, D., Reis, C., & Marques, M. C. (2024). Comparative analysis of sustainable building certification processes. *Journal of Building Engineering, 96*, Article 110401. https://doi.org/10.1016/j.jobe.2024.110401

Geçimli, M. (2021). Sürdürülebilir tasarımda yeşil bina sertifikasyon sistemlerinin karşılaştırmalı analizi: BEST-DGNB. *Online Journal of Art and Design, 9*(4), 28-37.

Gedik, Y. (2020). Sosyal, ekonomik ve çevresel boyutlarla sürdürülebilirlik ve sürdürülebilir kalkınma. *Uluslararası Ekonomi Siyaset İnsan ve Toplum Bilimleri Dergisi, 3*(3), 196-215.

Hashi, M. N., & Kasapoğlu, E. (2023). Türkiye'de LEED belgesi almış büro binalarının sürdürülebilir malzeme ve kaynak kullanımı bağlamında değerlendirilmesi. *Eksen Dokuz Eylül Üniversitesi Mimarlık Fakültesi Dergisi, 4*(1), 170-188. https://doi.org/10.58317/eksen.1161249

Healey, J. (2014). *Statistics: A tool for social research.* Cengage Learning.

Hill, R. C., & Bowen, P. A. (1997). Sustainable construction: Principles and a framework for attainment. *Construction Management and Economics, 15*(3), 223-239. https://doi.org/10.1080/014461997372971

Hiltown Karşıyaka. (2026). *BREEAM Certificate*. April 28, 2026, https://hilltownkarsiyaka.com/tr/hakkimizda

Isimbi, D., & Park, J. (2022). The analysis of the EDGE certification system on residential complexes to improve sustainabilit and affordability. *Buildings, 12*(10), Article 1729. https://doi.org/10.3390/buildings12101729

Izmir Metropolitan Municipality. (2020a). *Izmir green city action plan* (GCAP).

Izmir Metropolitan Municipality. (2020b). *Izmir sustainable energy and climate action plan* (SECAP).

Jenks, M., & Jones, C. (Eds.). (2010). *Dimensions of the sustainable city.* Springer.

Karaer, R., & Kömürlü, R. (2025). Türkiye'deki LEED Gold sertifikası almış otel yapılarının karşılaştırılmalı analizi. *Kent Akademisi, 18*(6), 3592-3611. https://doi.org/10.35674/kent.1667648

Karimi, H., Adibhesami, M. A., Bazazzadeh, H., & Movafagh, S. (2023). Green buildings: Human-centred and energy efficiency optimisation strategies. *Energies, 16*(9), Article 3681. https://doi.org/10.3390/en16093681

Kaya, H. E., & Taylan-Susan, A. (2020). Sürdürülebilir bir kentleşme yaklaşımı olarak, ekolojik planlama ve eko-kentler. *İDEALKENT, 11*(30), 909-937. https://doi.org/10.31198/idealkent.533730

Keleş, R. (1990). *Kentleşme politikası* [Urbanisation policy]. İmge Kitabevi.

Khan, J. S., Zakaria, R., Shamsudin, S. M., Abidin, N. I. A., Sahamir, S. R., Abbas, D. N., & Aminudin, E. (2019). Evolution to emergence of green buildings: A review. *Administrative Sciences, 9*(1), Article 6. https://doi.org/10.3390/admsci9010006

Kibert, C. J. (2022). *Sustainable construction: Green building design and delivery* (5th ed.). John Wiley & Sons.

Korur, Z. N. (2024). Mimarlıkta sürdürülebilirliğin öneminin yeniden yorumlanması. *Kent Akademisi, 17*(5), 2081-2102. https://doi.org/10.35674/kent.1434768

Krippendorff, K. (2018). *Content analysis: An introduction to its methodology* (4th ed.). Sage Publications.

Kubba, S. (2017). *Handbook of green building design and construction: LEED, BREEAM, and Green Globes* (2nd ed.). Butterworth-Heinemann.

Lélé, S. M. (1991). Sustainable development: A critical review. *World Development, 19*(6), 607-621. https://doi.org/10.1016/0305-750X(91)90197-P

Li, Y., Rong, Y., Ahmad, U. M., Wang, X., Zuo, J., & Mao, G. (2021). A comprehensive review on green buildings research: Bibliometric analysis during 1998–2018. *Environmental Science and Pollution Research, 28*, 46196-46214. https://doi.org/10.1007/s11356-021-12739-7

McLennan, J. F. (2004). *The philosophy of sustainable design: The future of architecture.* Ecotone.

Mebratu, D. (1998). Sustainability and sustainable development: Historical and conceptual review. *Environmental Impact Assessment Review, 18*(6), 493-520. https://doi.org/10.1016/S0195-9255(98)00019-5

Newman, P., & Kenworthy, J. (1999). *Sustainability and cities: Overcoming automobile dependence.* Island Press.

Purvis, B., Mao, Y., & Robinson, D. (2019). Three pillars of sustainability: In search of conceptual origins. *Sustainability Science, 14*(3), 681-695. https://doi.org/10.1007/s11625-018-0627-5

Rönesans Holding. (2024, July 29). *BREEAM In_Use Certificate.* https://ronesans.com/haberler/izmir_optimum-breeam-in-use-sertifikasi-ni-olaganustu-duzeyde-kazandi

Sánchez-Cordero, A., Gómez Melgar, S., & Andújar-Márquez, J. M. (2020). Green building rating systems and the new framework Level(s): A critical review of sustainability certification within Europe. *Energies, 13*(1), Article 66. https://doi.org/10.3390/en13010066

Sassi, P. (2006). *Strategies for sustainable architecture.* Taylor & Francis.
Sev, A. (2009). *Sürdürülebilir mimarlık* [Sustainable architecture]. YEM Yayın.
Shan, M., & Hwang, B.-G. (2018). Green building rating systems: Global reviews of practices and research efforts. *Sustainable Cities and Society, 39*, 172-180. https://doi.org/10.1016/j.scs.2018.02.034
Sığrı, Ü. (2021). *Nitel araştırma yöntemleri* [Qualitative research methods]. Beta Basım Yayım Dağıtım.
Uruk, Z. F., & Külünkoğlu-Islamoğlu, A. K. (2019). BREEAM, LEED ve DGNB yeşil bina sertifikasyon sistemlerinin standart bir konutta karşılaştırılması. *Avrupa Bilim ve Teknoloji Dergisi, 15*, 143_154. https://doi.org/10.31590/ejosat.512291
U.S. Green Building Council. (2026). *LEED project directory* [Database]. Retrieved April 23, 2026, from https://www.usgbc.org/projects
Wei, W., Ramalho, O., & Mandin, C. (2015). Indoor air quality requirements in green building certifications. *Building and Environment, 92*, 10-19. https://doi.org/10.1016/j.buildenv.2015.03.035
World Commission on Environment and Development. (1987). *Our common future.* Oxford University Press.
Yıldırım, A., & Şimşek, H. (2021). *Sosyal bilimlerde nitel araştırma yöntemleri* (12. baskı). Seçkin Yayıncılık.
Yudelson, J. (2009). *Green building through integrated design.* McGraw-Hill.
Zuo, J., & Zhao, Z.-Y. (2014). Green building research – Current status and future agenda: A review. *Renewable and Sustainable Energy Reviews, 30*, 271-281. https://doi.org/10.1016/j.rser.2013.10.021

Resume

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Onur Tos, who graduated first in his class from the Department of Public Relations and Advertising at the Faculty of Communication at Ege University in 2015, earned his master's degree from the Institute of Social Sciences at Uşak University in 2018 with a thesis titled "The Perceived Image of Political Party Leaders in the Grand National Assembly of Turkey: A Study Focusing on State Universities in Izmir." Tos completed his doctoral studies in the Communication Research Program within the Department of Public Relations and Advertising at the Institute of Social Sciences, Ege University, between 2019 and 2023. On March 5, 2020, at the 6th Gender Justice Congress organized by KADEM and hosted by Istanbul University, she was awarded the prize for the third-best paper presented at the congress for her paper titled "Generations X and Z's Perception of Parenting Based on Cultural Change." On December 22, 2020, she began working as an Instructor in the Department of Marketing and Advertising at the Tarsus University Vocational School. In February 2021, she was appointed Chair of the Department of Marketing and Advertising, a position she continues to hold. Tos continues her work in the field of communication and her interdisciplinary research.

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Contemporary practices and policies for the conservation and presentation of antique ruins in multi-layered cities: Insights from İzmir

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Abstract

Historic urban landscapes often embody a multi-layered city structure, where successive phases of urbanization, transformation, and cultural accumulation coexist within the same physical and symbolic landscape. However, despite continuing conservation initiatives, persistent problems remain: a lack of accessibility in physical, visual, and intellectual terms limits public engagement with the city's archaeological layers, while a lack of integration, both physical and societal, prevents these invisible periodic layers from being incorporated into contemporary urban planning and public narratives. In response to these challenges, the aim of this study is to analyze current policies and practices for conserving and presenting urban heritage embedded within complex historic fabrics, and its objective is to trace the chronological evolution of İzmir's urban base to reveal how successive transformations have preserved, obscured, transformed or reinterpreted heritage layers. The research adopts a case study approach focusing on the Kadifekale city walls in İzmir. Its methodology integrates a literature review using historical maps, memoirs, and publications for understanding the case, comparative studies, and international documents regarding effective heritage conservation with fieldwork and evaluative analysis to elucidate on-site conditions and policy contexts. Ultimately, the study proposes an integrated, participatory, and sustainable framework for managing and presenting multi-layered urban heritage within historic cities.

Keywords: city wall, heritage management, historic urban landscape, invisible periodic layers, multi-layered urban heritage

1. Introduction

The physical, social, and intellectual accessibility and visibility of archaeological sites (AS), particularly those embedded in multi-layered urban landscapes (MUL), is often constrained by contemporary urban conditions and related management (Ali & Abouelfadl, 2022; Bonadei et al., 2017; Diceglie, 2023; Ebejer et al., 2023; Łakomy, 2021; Moreno et al., 2023; Serrano-Chacón et al., 2025; Şahin Körmeçli, 2024; Wang et al., 2019). Dense urban development and vandalism (UNESCO, 2019), the limited public understanding (Ali & Abouelfadl, 2022), imbalance between well-defined intrinsic values and the insufficiently explored extrinsic values of heritage (Ebejer et al., 2023), poverty (Ripp & Rodwell, 2015), migration (Ababneh et al., 2016; Dines, 2002), and/or gentrification (Ripp & Rodwell, 2015; Ababneh, et al., 2016) hinder the accessibility of mentioned sites, turning them into hidden remains that pose significant challenges for heritage management (Ababneh et al., 2016; Ali & Abouelfadl, 2022; Dines, 2002; Ebejer et al., 2023; Ripp & Rodwell, 2015; UNESCO, 2019). There are also intrinsic qualities of heritage that diminish its accessibility and visibility, such as complicated interactions between natural settings and built heritage (Pardela et al., 2022). Another challenge threatening AS in MUL is their vulnerability to natural risks, e.g., earthquakes (Diceglie, 2023). Furthermore, case studies from diverse geographies demonstrate that archaeological and architectural remains are subject to multiple forms of vulnerability, from seismic risk and moisture-driven physical deterioration (Moreno et al., 2023) to the challenges of ensuring

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the visibility of military heritage landscapes and managing the complicated interactions between natural settings and built heritage (Pardela et al., 2022). Similarly, cases such as the merging into the background of traditional urban culture during China's modernization process (Wang et al., 2019) or the constraints of Poland's monument protection system (Łakomy, 2021) reveal the mechanisms through which ideological and administrative frameworks influence the invisibility of urban heritage layers. In historical settlements such as Amasra, the difficulty in identifying architectural anchors that mediate social interaction networks (Şahin Körmeçli, 2024) represents yet another factor limiting the visibility of complex urban layers. These studies demonstrate that the periodic layers of urban archaeological heritage become invisible not only due to physical, socio-cultural, and intellectual fragilities but also because of planning-related barriers (Ali & Abouelfadl, 2022; Bonadei et al., 2017; Diceglie, 2023; Ebejer et al., 2023; Łakomy, 2021; Moreno et al., 2023; Pardela et al., 2022; Serrano-Chacón et al., 2025; Şahin Körmeçli, 2024; Wang et al., 2019).

Recent conservation studies emphasize that addressing the challenges of conserving and presenting antique ruins requires integrated approaches that extend beyond mere physical preservation (Ali & Abouelfadl, 2022; Bonadei et al., 2017; Diceglie, 2023; Ebejer et al., 2023; Łakomy, 2021; Moreno et al., 2023; Pardela et al., 2022; Serrano-Chacón et al., 2025; Şahin Körmeçli, 2024; Wang et al., 2019). Majority of the practices include only physical conservation (Ali & Abouelfadl, 2022; Bonadei et al., 2017; Diceglie, 2023; Ebejer et al., 2023; Łakomy, 2021; Moreno et al., 2023; Pardela et al., 2022; Wang et al., 2019) while limited studies integrate physical conservation with public engagement (Bonadei et al., 2017), adaptive reuse (Ebejer et al., 2023; Wang et al., 2019) or long-term sustainability (Ali & Abouelfadl, 2022; Diceglie, 2023; Łakomy, 2021; Moreno et al., 2023; Pardela et al., 2022; Serrano-Chacón et al., 2025; Wang et al., 2019). In this context, conservation practices intersect with broader objectives such as education (Bonadei et al., 2017; Ebejer et al., 2023), the reinforcement of cultural identity, and the development of heritage-based tourism (Ali & Abouelfadl, 2022; Bonadei et al., 2017; Ebejer et al., 2023; Łakomy, 2021; Moreno et al., 2023; Wang et al., 2019), underscoring the close relationship between preservation strategies and public engagement. These interconnections highlight the necessity of reconsidering both heritage theory and practice through more holistic, participatory, and value-orientated frameworks capable of responding to the complex demands of contemporary heritage management.

The existing literature on Kadifekale predominantly examines urban regeneration in landslide areas, often framed through discussions of gentrification and its socio-spatial impacts (Demirtas-Milz, 2013; Mutlu Kılıç, 2025; Mutlu Kılıç & Göksu, 2018; Saraçoğlu & Demirtaş-Milz, 2014; Yılmaz & Zafer Kurt, 2022). These studies indicate that formal planning strategies frequently overlook the needs of the disadvantaged and vulnerable groups mentioned. Complementary sociological studies have examined refugee populations and the physical condition of 19th- and 20th-century housing stock (Oner et al., 2020). Despite extensive research on urban management, a significant gap remains in understanding how administrative and planning frameworks, when combined with informal settlements, infrastructure investments, and urban transformation processes, contribute to the loss of archaeological data and the trivialization of local public perspectives in MULs. The insufficient application of the Historic Urban Landscape (HUL) approach in small-scale, participatory conservation practices (Bonadei et al., 2017) exacerbates this gap. In the Kadifekale case, these dynamics have led to the progressive loss of archaeological data and the physical, social, and intellectual invisibility of the city walls.

Early international conservation charters initially limited their scope to the protection of individual monuments and ensembles (International Museums Office, 1931). From the mid-20th century onwards, however, a significant approach shift occurred, prioritising the in-situ conservation and presentation of AS within their historic urban sites (ICOMOS, 1964; ICOMOS, 1994). This shift was accompanied by a growing consensus on the need to integrate archaeological heritage into contemporary urban life through interdisciplinary approaches and participatory interpretation strategies (ICOMOS, 1987; ICOMOS, 1994; UNESCO, 1976). Toward the end of the

20th century, doctrinal texts increasingly addressed the challenges of managing tourism at places of heritage significance and the protection of archaeological heritage in historic cities (Council of Europe, 1992; ICAHM, 1990; ICOMOS, 1999). The UNESCO Recommendation on the Historic Urban Landscape (2011) represents a critical milestone by internationalizing conservation theory and practice beyond its predominantly European focus and framing archaeological heritage as an integral component of broader urban systems. Over the past two decades, international charters have further emphasized sustainable urban development, landscape-based approaches, and the public presentation of archaeological sites as living parts of the city (ICOMOS, 2008; ICOMOS, 2011; ICOMOS, 2017; ICOMOS & IFLA, 2017; UNESCO, 2011). Despite this evolution, a coherent theoretical framework capable of guiding conservation and presentation practices across diverse HULs remains insufficiently articulated.

This study contributes to the literature by conceptualizing AS not only as isolated heritage assets but also as functions that both physically and metaphorically serve as urban bases that continue to structure contemporary socio-spatial relations within MULs. Using Kadifekale as a case study, the research extends current HUL-based discussions by examining how invisible periodic layers become physically, socially, and intellectually inaccessible under conditions of uncontrolled urbanization, migration dynamics, and irregular urban transformations. In doing so, it proposes an integrated framework linking accessibility, public engagement, and heritage interpretation to the conservation and presentation of archaeological urban bases in non-European historic urban contexts.

This study aims to clarify how MULs can be effectively conserved and communicated within rapidly transforming urban contexts. It focuses on the conservation and presentation of historic urban layers that have become periodically invisible due to successive urban interventions, with particular attention to the Kadifekale city walls. The research analyses current policies and practices to assess the conservation, obfuscation, transformation, or representation of heritage layers over time. It aims to formulate policies and strategies that enhance the integration of historic sites with adjacent urban renewal areas within the HUL framework.

Methodologically, the study traces the chronological evolution of İzmir's urban base to contextualize Kadifekale within the city's broader MUL. When considering the architectural, natural, cultural, and socioeconomic characteristics of the case study, its values, potential, and problems are analyzed and evaluated; as a result, proposals are created that will enhance the integrity of the concepts related to both the historical site and the urban renewal area.

This research employed both qualitative methods, which include the literature review and a comparative study of similar cases, and quantitative research methods, such as fieldwork and on-site visual observation[1]. The study is primarily grounded in qualitative analysis, supported by a clearly defined quantitative component. The quantitative dimension is operationalized through the numerical evaluation of socio-spatial data derived from fieldwork, which includes measurable indicators related to social patterns and spatial conditions. This approach clarifies both the scope and the analytical role of quantitative methods within the comprehensive research framework. A systematic literature review was conducted in WoS with the identification of related thematic keywords (Table 1). As a result, twenty-two (22) publications were retrieved from the Web of Science Core Collection, from which ten (10) open-access English-language articles were selected for detailed examination.

[1] *The data used in this study were generated within the scope of the graduate-level course titled "RES511 Preservation and Development Methods of Historic Environment", conducted during the 2021–2022 fall semester at the Department of Conservation and Restoration of Cultural Heritage, Faculty of Architecture, İzmir Institute of Technology. The dataset is unpublished and is stored in the university archive. The authors are members of the research team that contributed to the creation of the dataset. The dataset is not available online but may be accessed on site upon reasonable request."*

Table 1 Literature Search Keywords Strategy

	PROBLEM DEFINITION				CONTEXT		CASE						RESULT
	Urbanisation Pressure	OR	Migration	AND	Multi-Layered Cities	AND	Kadifekale	OR	İzmir City walls	OR	City Wall	AND	Heritage Management
KEYWORDS	urban* OR urbanisation* OR press* OR pressure* OR urbanisation pressure*	OR	migrate* OR migration* OR demograph* OR chang* OR demograph* chang*	AND	Multi-layer* OR cit* OR Multi-Layer* Cit* OR historic*city OR historic urban landscape OR historic urban site OR antique ruin*	AND	Kadifekale*	OR	İzmir* OR fortficat* OR city wall*	OR	cit* OR cit* wall*	AND	law* OR legal* OR legis* OR regulat* OR polic* OR heritage* OR manag* OR heritage management * OR heritage conservation * OR heritage preservation
Selected Keywords					historic urban landscape OR "Multi-Layer* Cit*" OR historic urban site				city wall*		city wall*		heritage conservation OR heritage preservation

2. Case Study: Kadifekale and the Urban Base of İzmir

The study area is in the centre of İzmir, a major city in the Aegean Region situated at the interface of Asia and Europe. It is bordered by the historic districts of Kemeraltı and the Agora to the west, the Roman-built Smyrna Theatre to the southeast, and the Basmane district to the north. The case study area lies within the boundaries of the Kemeraltı Historical Urban Site and is near both the Geologically Objectionable Area and the Ballıkuyu Urban Transformation Zone (Figure 1), placing it at the intersection of heritage conservation and ongoing irregular urban transformation processes due to the dense uncontrolled international immigration and rural depopulation (Ertan & Eğercioglu, 2016; Mutlu Kılıç, 2025; Yetiskul & Kul, 2023).

Situated on a hill on the northern slopes of Mount Pagos at an elevation of 186 m, overlooking the İzmir Gulf, the city walls of Kadifekale were first constructed in 334 BC at the request of Alexander the Great following the liberation of Anatolia from Persian rule (Kütükoğlu, 2001). Owing to its strategic topography, Mount Pagos provided control over both the İzmir Gulf and the path extending toward the Yeşildere Valley and the Bornova Plain. Military threats repeatedly plagued. Smyrna throughout history, necessitating the construction of an extensive defensive system (Ersoy et al., 2015).

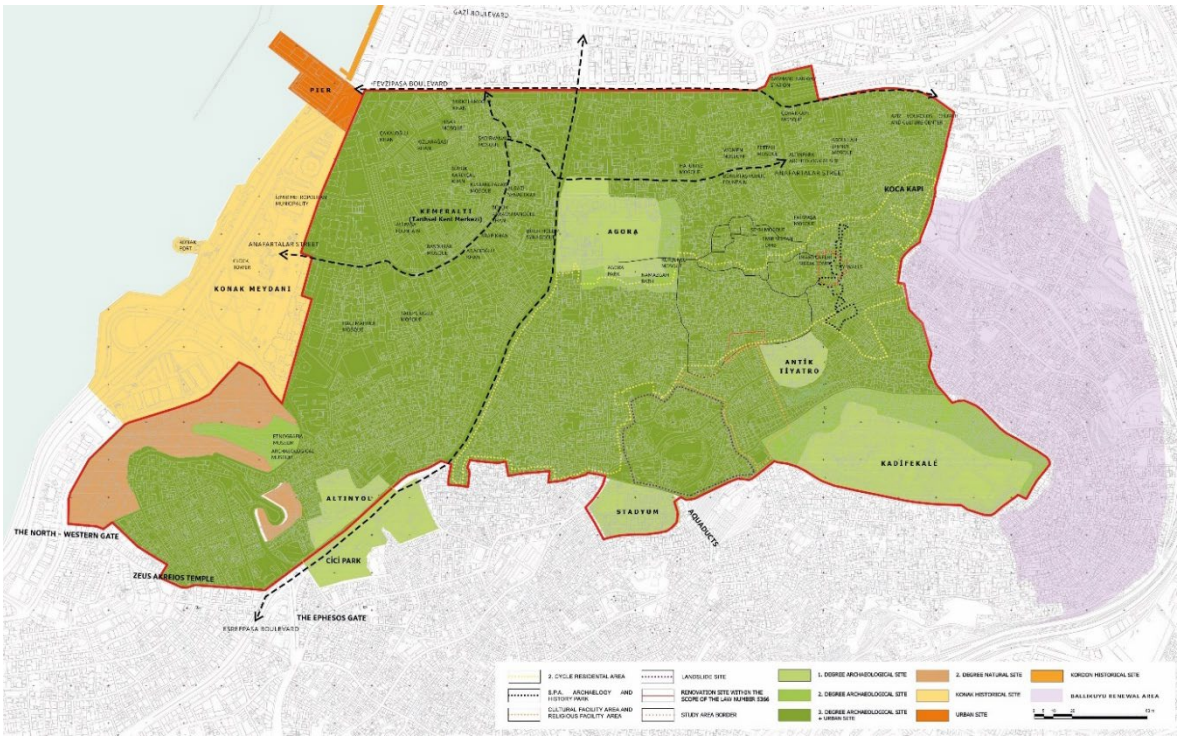

Figure 1 Environmental analysis of the HUL (Revised from the unpublished RES511 course dataset, 2021–2022)

Archaeological evidence indicates the presence of two principal city wall lines extending from the acropolis toward the ancient Sardis Road in present-day Basmane and from the Ephesus Road in Eşrefpaşa down to the coastline (Figure 2).

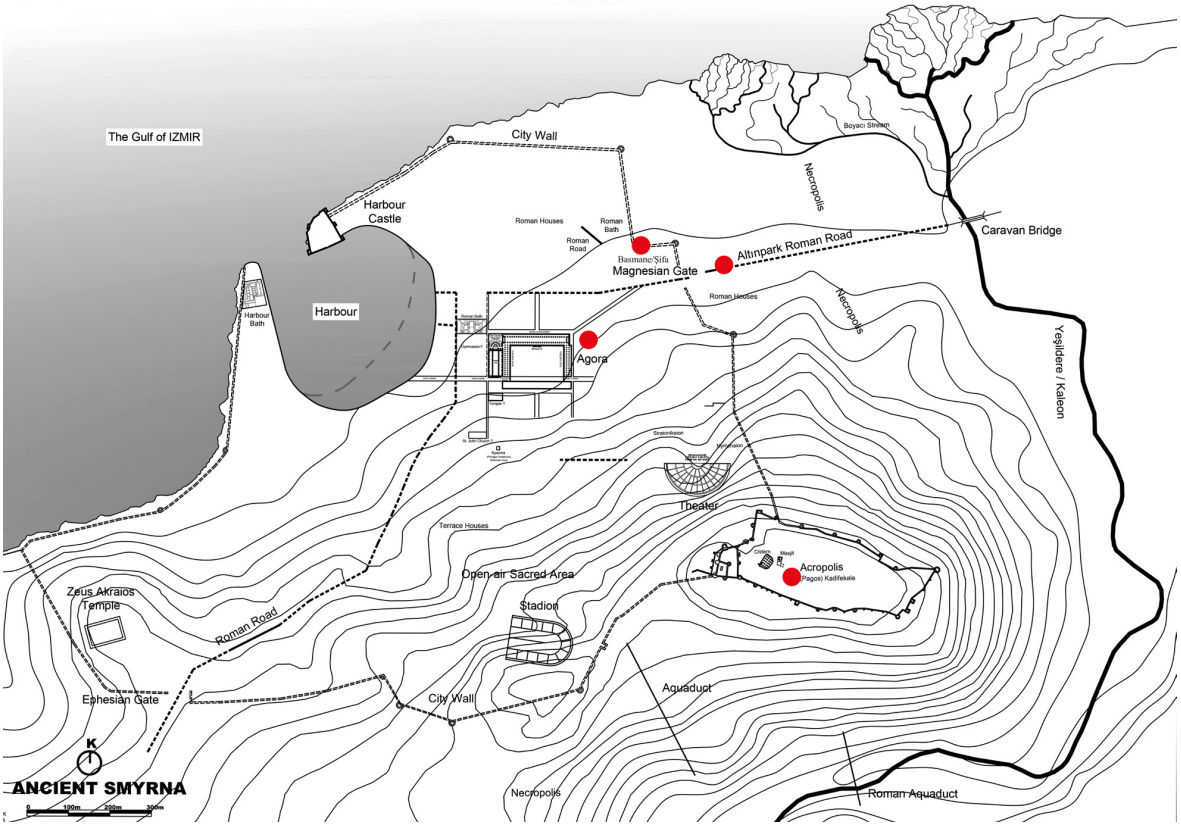

Figure 2 Smyrna city plan (Reproduced from Ersoy & Çakmak, 2025, p. 20)

The city walls suffered major destruction during the mediaeval period, following Timur's campaign in 1402 and the subsequent earthquake of 1668 (Kütükoğlu, 2001). Consequently, the

surviving remains predominantly date to the Middle Ages; however, investigations beneath these structures reveal earlier Hellenistic masonry system (Ersoy et al., 2015). The walls were constructed using rubble stone, ashlar blocks, and brick, reflecting successive building phases. Parts of the city walls were deliberately dismantled during the reign of Çelebi Mehmet (Kütükoğlu, 2001). The most reliable documentation of the urban wall alignments is Storari's 1856 map, which already depicts the eastern and northern walls as fragmented system (Ersoy et al., 2015). Today, apart from the acropolis city walls, the city walls of ancient Smyrna have largely disappeared under modern urban pressure, with only limited traces of the eastern wall surviving between contemporary residential buildings system (Ersoy et al., 2015).

Although the city walls of Kadifekale played a defining role in the defensive structure of ancient Smyrna, they have progressively lost their visibility within the MUL. While the Acropolis wall remains the most legible component, the continuity of the southern, eastern, and northern city walls has been disrupted by successive destruction and irregular urbanization. The city walls have functioned both physically and metaphorically as an urban base for the contemporary city, starting from their Hellenistic foundations and continuing through Roman, Byzantine, mediaeval, and Late Ottoman residential overlays. Today, this urban base is perceived not as an integrated MUL but as fragmented remains, further obscured by limited accessibility and inadequate urbanization.

3. Findings

The Kadifekale city walls, within their MUL, are under intense urbanization pressure as a result of continuous migrations and informal growth (Ertan & Egercioglu, 2016; Mutlu Kılıç, 2025; Yetiskul & Kul, 2023). Solid–void analysis indicates a high degree of building density; particularly the case study area exhibits a lower solid ratio of around 52%, largely due to recent expropriations aimed at exposing the city walls, which have resulted in fragmented voids, including vacant lots, gardens, and residential courtyards.

Storey analyses further demonstrate a clear divergence from the area's original low-rise morphology. While the historic fabric was predominantly composed of one- to two-storey buildings, contemporary pressures have resulted in widespread vertical extensions and new constructions. In the area, three- and four-storey buildings now constitute approximately 36% of the building stock (Figure 3). Chronologically, the area retains older heritage elements, including city wall remains dating to the Hellenistic Period and an Ottoman-era tomb; however, these layers have been substantially obscured by later constructions, some of which are directly superimposed on archaeological remains, transforming the city wall into both a physical infrastructural element and a metaphorical urban base upon which subsequent urban layers have accumulated.

Figure 3 Overlapped analysis period of buildings and number of story (Revised from the unpublished RES511 course dataset, 2021–2022)

Social survey findings further reveal security problems (3/12), infrastructural deficiencies (3/12), and environmental neglect (2/4), which collectively diminish everyday accessibility and reinforce the physical, social, and intellectual invisibility of the city walls. These findings underscore the impact of unregulated densification and socio-spatial pressures on the diminishing visibility of multi-layered urban heritage contexts, where archaeological layers persist yet remain predominantly inaccessible within the MUL.

Figure 4 The inaccessible Kadifekale city walls as an urban base of İzmir (Authors, 2021)

The findings indicate that the Kadifekale city walls represent a significant component of İzmir's HUL, embodying intertwined historical, architectural, environmental, urban, and socio-cultural values. As part of the city's long-term development, the continuity of the urban base, the persistence of traditional street patterns, and the presence of archaeological deposits reinforce the area's urban hub role within a MUL. The fortifications, originating in the Hellenistic period and subsequently transformed, maintain both architectural authenticity, collective memory and socio-

cultural relevance with potential of their integration into everyday urban life. Despite this significance, the AS remains largely inaccessible and poorly visible within contemporary urban context (Figure 4). Dense and unregulated construction, combined with limited public space, constrains physical access to the walls. At the same time, the absence of coherent interpretive and public-orientated presentation strategies weakens intellectual accessibility, limiting public awareness and engagement. This condition results in the reduced visibility of archaeological layers, highlighting a critical disjunction between heritage value and its effective integration into contemporary urban life.

The Kadifekale city walls are part of a complex whole characterized by pronounced topographic variation and significant geological risks. The area's elevation differs from approximately 10 to 180 meters above sea level, resulting in steep gradients that vary across neighborhoods. For example, the Smyrna Theatre zone exhibits an average slope of 2.6%, and the Kubilay Neighborhood presents comparatively gentler inclines below 1% (Figure 5).

Figure 5 The view from the Smyrna Acropolis shows elevation differences and the landslide-evacuated area around the Smyrna Theatre (Authors, 2025)

These topographical conditions, combined with the site's location within lower Miocene volcanic formations, increase susceptibility to landslides, particularly as the study area lies adjacent to zones previously evacuated due to active landslide risk (Figure 5). The Kandilli Observatory's historical seismic records indicate that earthquakes have happened many times since the 17th century (Kütükoğlu, 2001). Destructive events, documented since antiquity, have repeatedly threatened the structural integrity of the built environment (Kütükoğlu, 2001). Together, seismic vulnerability, landslide exposure, and steep terrain constitute critical environmental pressures that affect both the preservation of the archaeological layers of Kadifekale and their visibility within the contemporary MUL.

An environmental-scale survey along the route connecting the Smyrna Agora and the Roman Theatre indicates a high concentration of religious, cultural, educational, public, residential, and commercial uses, while health-related facilities remain limited (Figure 6). The site's physical accessibility makes the spatial conflicts between pedestrian and vehicle movement even more clear, especially along Tarık Sarı Street, where the lack of or obstruction of pavement forces narrow roadways to be shared. Informal parking practices, dead-end streets resulting from organic urban morphology, and one-way traffic imposed by limited street widths intensify accessibility and safety problems, especially near schools and public gathering areas. Visual and perceptual assessments identify both positive and negative contributors to urban quality: while landmarks such as the castle, mosque, bazaar square, and sports field function as focal points of social interaction, inappropriate building heights, irregular parking, and poorly positioned urban services disrupt visual coherence. Traditional architectural elements like projections, fountains, chamfers, alms stones, and horse blocks are still important ways to remember the past, but unregulated development makes them less visible. The conflict between officially listed buildings and the

presence of unregistered high-quality structures indicate gaps in heritage recognition, reinforcing the partial social and intellectual invisibility of the city walls. Within the HUL framework, these findings demonstrate that, limited interpretive integration constrain its capacity to function as a visible and inclusive layer of the MUL.

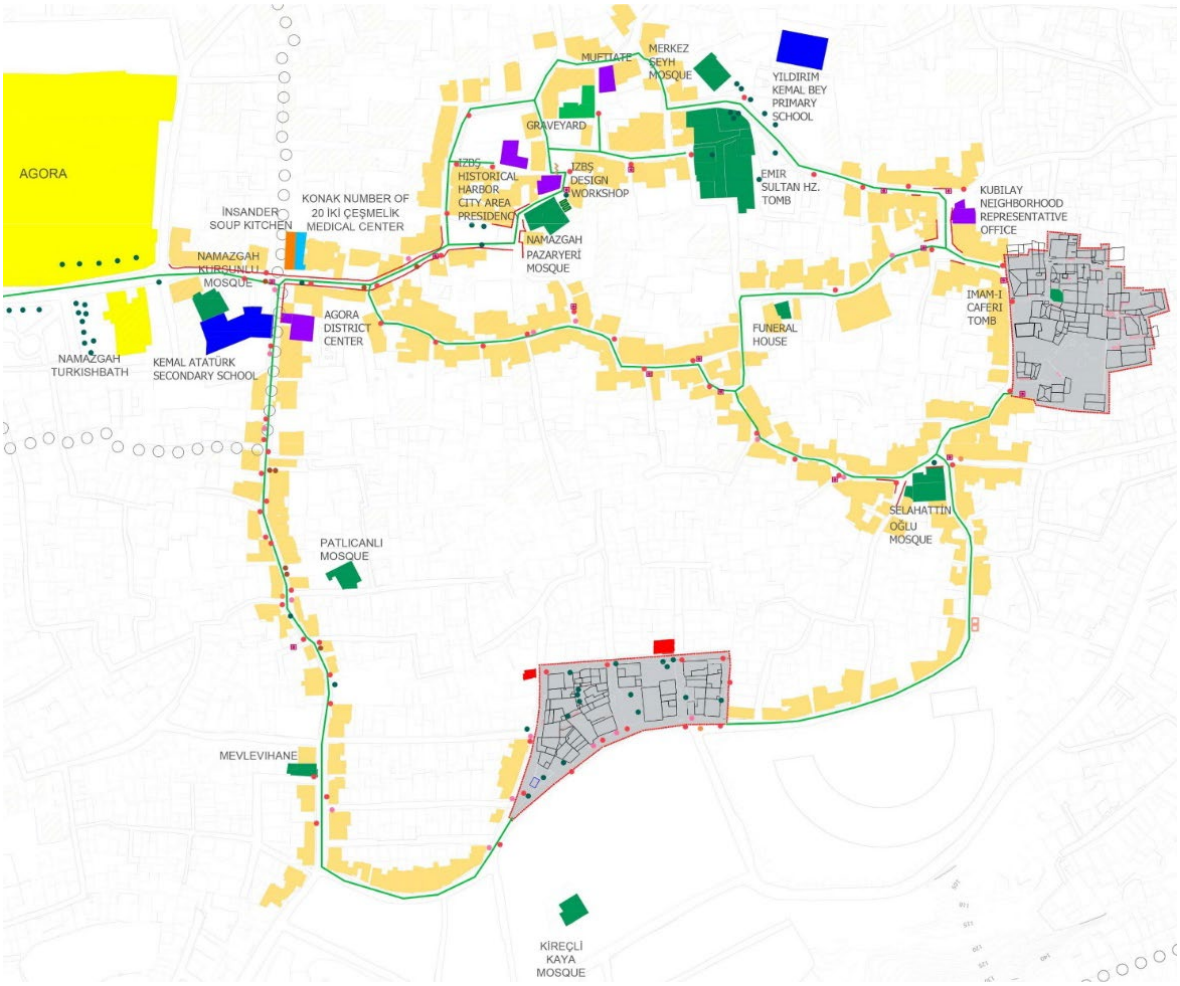

Figure 6 Land use analysis of urban space (Revised from the unpublished RES511 course dataset, 2021–2022)

While residents are generally aware of the significance of nearby excavation areas, this awareness does not extend to city walls; it remains embedded within the foundations and lower floors of their dwellings, where the city wall segments remain physically present but cognitively unrecognized. Types of roads overlapped analyses such as land use and number of storeys, and condition and maintenance state further demonstrate that dense residential development and limited visual visibility constrain the perception of the city walls as a coherent heritage entity (Figure 7). Visitors' access routes primarily follow the main circulation axes that bypass interior neighborhoods, limiting experiential engagement with invisible periodic layers and weakening spatial continuity between archaeological remains. Consequently, the area's significant potential for public use and heritage-based tourism remains largely unused. The lack of interpretive infrastructure, clear signboards, and integrated presentation strategies prevents the transformation of everyday urban spaces into learning environments capable of communicating the MUL. Within the HUL framework, these findings underline that the invisibility of archaeological layers is not solely a matter of physical invisibility but also of limiting both public perception and the broader socio-cultural value of the city walls.

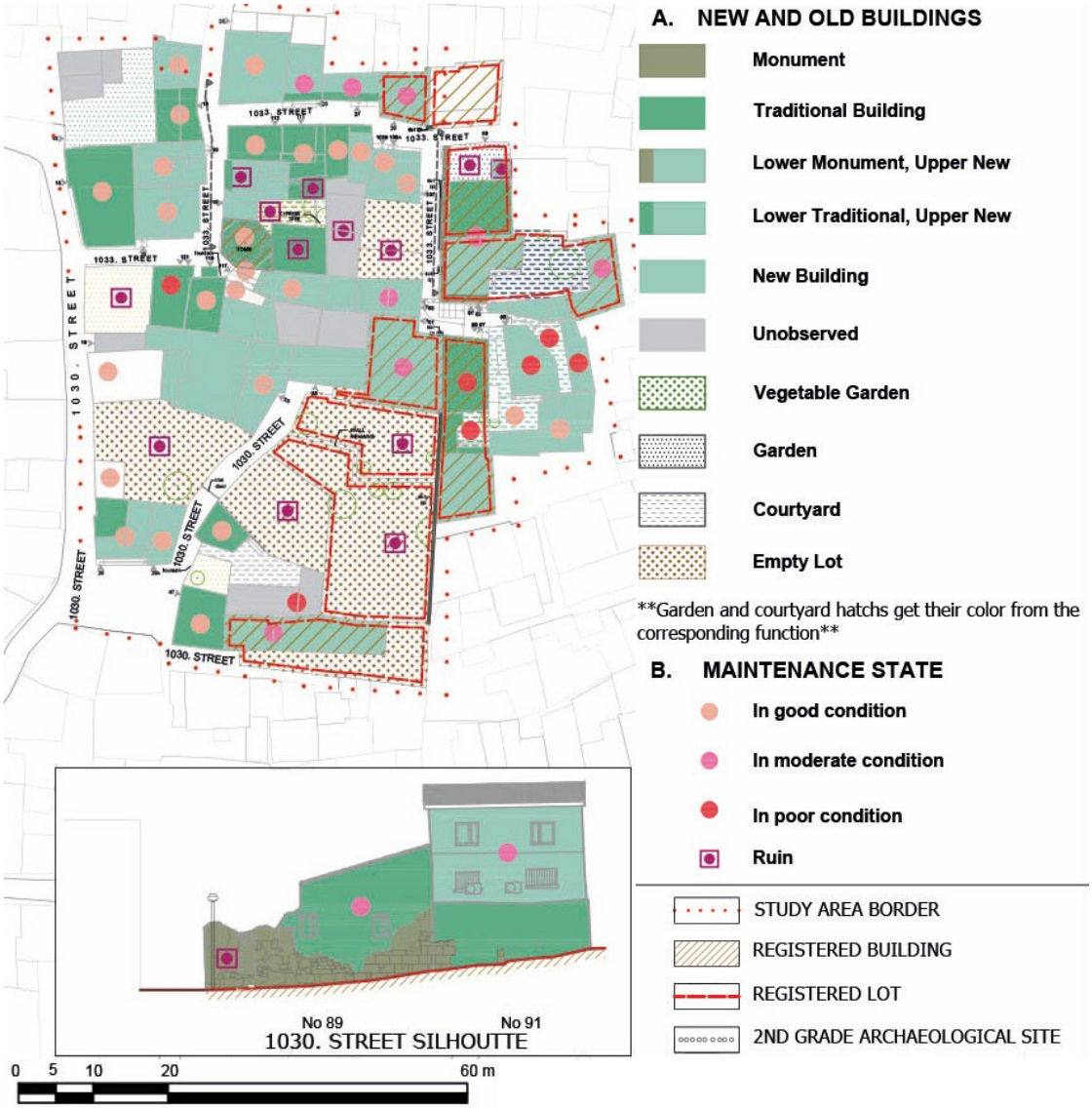

Figure 7 Overlapped analyses new-old buildings and maintenance state (Revised from the unpublished RES511 course dataset, 2021–2022)

Conservation and presentation practices in the Kadifekale area reveal a gradual policy shift from neglect toward integrated heritage planning. In the early Republican period, archaeological remains were largely ignored, and rapid urbanisation after the 1950s led to the occupation and spatial fragmentation of the Roman Theatre and the Kadifekale city wall system, rendering them almost entirely invisible within the urban fabric. Early statutory plans, including the 1955 İzmir City Plan (1/2000) and the 1984 Kemeraltı Protected Area Development Plan (1/1000), defined archaeological boundaries only in limited and schematic terms, failing to establish physical or visual connections with surrounding neighbourhoods. Although the rediscovery of the Roman Theatre in 2008 and the 2013 revision of the 1/1000 Kadifekale Theatre and Its Surroundings Conservation Plan Revision marked a significant conceptual shift, introducing 1st and 2nd degree archaeological site designations and proposing an “Archaeology and History Park” to enhance public participation, implementation has remained constrained (Figure 8).

Figure 8 Archaeology and History Park Project (Revised from Municipality of Konak, Department of Conservation of Cultural Heritage, n.d.)

As a result, despite their formal recognition within conservation policy, the archaeological layers of Kadifekale remain physically inaccessible and perceptually disconnected from daily urban life, reinforcing their continued invisibility within the HUL.

4. Discussions

The preservation of antique city walls that are now situated within the HULs of European cities is evaluated in several studies (Table 2). The European researchers emphasize that the physical and social accessibility to the antique city walls in historic urban centers are achieved to a great extend in European cities, but there are still challenges related to the insufficiency of their intellectual accessibility (Ali & Abouelfadl, 2022; Ebejer et al., 2023). By contrast, researchers working on Asian historic cities tend to focus on mitigating the consequences of limited physical and social accessibility, and place greater emphasis on necessity of improvement of perception, public engagement, and interpretive integration. Positioned at the intersection of these contexts, the Kadifekale city walls offer a critical case for examining the interaction between historic defensive structures and contemporary urban life, particularly in partially renewed and fragmented settings where research remains limited (Şahin Körmeçli, 2024; Wang et al., 2019). Despite their significance as an archaeological layer embedded in İzmir's urban fabric, the walls remain physically, socially, and intellectually inaccessible due to deterioration, security concerns, and insufficient conservation and presentation strategies. This condition highlights the necessity for integrated and participatory approaches that reconnect heritage with everyday urban life. Accordingly, a coordinated framework combining conservation, spatial planning, and heritage-led interventions is proposed to restore the citizens' right to the city and enhance accessibility and visibility. (Figure 9).

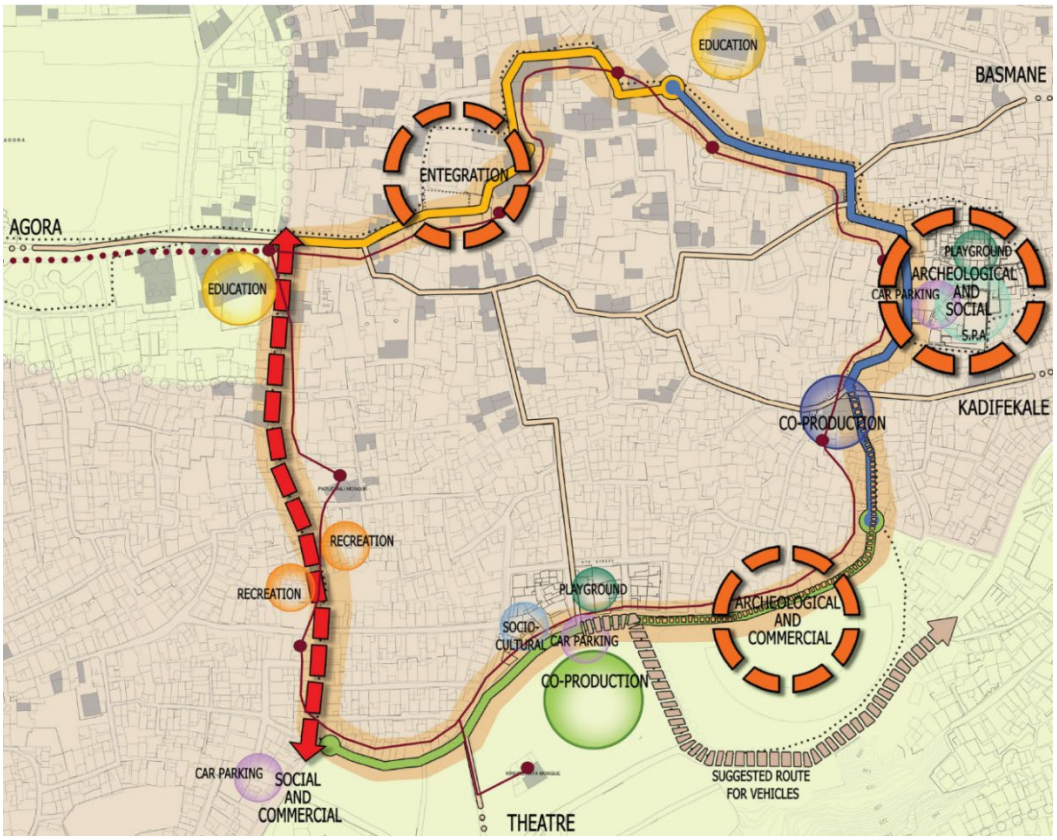

Figure 9 Proposed concept plan (Revised from the unpublished RES511 course dataset, 2021–2022)

Table 2 Comparative Cases of City Walls in Urban Landscapes

ARTICLE	IDENTIFICATION					PROBLEM DEFINITON	AIM	METHOD	INTERPRETATION APPROACH	ACCESSIBILITY	CONSERVATION	PRESENTATION	POLICY AND PRACTICE
	CASE	HERITAGE TYPE	CONTEXT	CULTURAL	THREAT								
Ali, & Abouelfadl, 2022	Alexandria	Ancient City Wall and	HUL	Heritage Landscape, Cultural	Inaccessible, Unrecognisable	Archaeological remains lack perceived significance within contemporary public contexts.	Integrate MUL and traditional practices to promote sustainable urban conservation.	Literature Review, Case Study Approach, Empirical Study	Mixture of top-down and bottom-up approach	Physical	Regular Monitoring Structural Care and Maintenance	A Culture-Led Touristic Path Archaeological Park	Renovation and Management Plan
Bonadei, et. al., 2017	Bergamo	Ancient City Wall	HUL	Cultural Landmark	-	The effectiveness of the HUL approach in small-scale participatory conservation remains insufficiently examined.	To reassess the significance of ancient city walls in Bergamo.	Literature Review, Case Study Approach, Empirical Study	The HUL Approach, Mixture of top-down and bottom-up approach	Physical Social Intellectual	Public Dissemination Communication Activities	Museumification New Gaze and Rejuvenation	Guidebook Short Animated Film
Diceglie, 2023	Monopoli in Puglia	A House within the	HUL	Historical and Cultural	Natural Disasters	The seismic vulnerability of heritage artefacts is still inadequately addressed.	To provide a method for conserving and protecting historic buildings in connection with ancient city walls.	Field Research Practice, Documentary-Based Historical Studies, Case Study Approach	Morpho-Typological and Stratigraphic Analysis	Physical Social Intellectual	Reconstruction	Cultural Documents of The City	Management Plan

Ebejer, et. al., 2023	Poland, Malta	Ancient Fortress	HUL	Intrinsic, Extrinsic	Nature, Excessive	While intrinsic heritage values are well-defined, extrinsic heritage values are less studied.	To define a conceptual framework of values relevant to fortified heritage.	Literature Review, Case Study Approach	Discussion of The Values	Physical Social	Adaptive Reuse Rehabilitation	Museum	General Framework for Fortified Heritage Referring to Values Set
Łakomy, 2021	Opole Silesia	Post-City wall Area	HUL	Natural, Historical	Biotic Factors, Air Pollution,	The Polish monument protection system presents unresolved methodological limitations.	To assess how the historical city's founding decisions influence current functioning and development within a sustainable framework.	Formal Analysis, Field Analyses, Skyline Legibility Analyses, Case Study Approach, Comparative Study	Multidimensional Comparative Analysis	Social	Urban Greenery System Consisting of Investigation, Design, Maintenance	Combining Residential Park and Cemeteries with Natural Greenery (riverbeds, wetlands)	General Guidelines of for Post-City wall Areas Sustainable Tourism Strategy
Moreno, et. al, 2023	Seville and Niebla	Medieval City wall Walls and	HUL	Historical, Architectural	Humidity Changes, Increasing	Green areas are viewed as a threat to heritage structures due to humidity changes that accelerate decay.	To evaluate how sustainable green-city strategies are applied in historic cities and their compatibility with heritage conservation.	Remote Sensing, Test The Statistical Use of Landsat Image, The Analysis of The NDWI Levels, Case Study Approach	Statistical Analysis of Historical Series of Satellite Images	n/a	Regular Monitoring Maintenance	Public Gardens Public Park	Vegetation Monitoring Plan to Implement Sustainable Urban and Heritage Management Policies
Pardela, et. al, 2022	France, Germany, Poland	Historic City walls	HULs	Historical, Cultural,	Vegetation, Invasive Plant	The strategies for shaping MHLs to ensure their legibility and optimal naturalness are currently unclear.	To identify the relationship between the legibility and naturalness of MHLs and social preference, considering mediating effects.	Questionnaire Survey, The Units of Analysis, Case Study Approach, An Interdisciplinary and Holistic Approach	Sampling Size and Sampling Method	Social	Maintenance	Green Areas	Nature-Based Solutions and Planning for Different Zones of Greenery Within MHLs
Serrano-Chacón, et. al, 2025	Seville	The Medieval City Wall	HUL	Historical, Cultural, Architectural	Weather-Related Erosion, Capillary Rise,	The mediaeval wall on rammed earth in Seville highlights specific vulnerability, degradation and erosion factors requiring NDT methods.	To explore the dynamics of characterizing historic rammed-earth structures in urban settings by recording ambient vibrations.	Literature Review, Case Study Approach, The Enhanced Frequency Domain Decomposition, Ambient Vibration Test, The Stochastic Subspace Identification-Unweighted, Operational Modal Analysis, Principal Components-Merged Test Setups	Non-Destructive Techniques (NDT)	n/a	Monitoring	n/a	Proposed Protocol for The Global Structural Diagnosis of The City Wall
Şahin Körmeçli, 2024	Amasra	Ancient Fortress and City Walls	HUL	Historical, Social, Architectural,	Unhealthy and Uncontrolled	The identification of architectural structures affecting social interaction clusters in Amasra remains an unresolved heritage issue.	To present an analysis model that uses visual methods to map the network that shapes the historic centre's urban image.	Literature Review, Empirical Study, Case Study Approach, Integrating Network Analysis and Mental Mapping	The Graph Commons Platform Study	Social Intellectual	n/a	n/a	n/a
Wang, et al, 2019	Xi' an	Ancient City Wall	HUL	Historical, Cultural	_	China's modernisation led to the neglect of traditional urban culture, resulting in demolition of city walls.	To support the sustainable conservation and development of historic Chinese city walls.	Literature Review, Case Study Approach, Empirical Study, HUL	The Dynamic Integration of Heritage Protection and Social Development	Physical Social Intellectual	Adaptive Reuse	Greenbelt Park Residential Recreation Space Modern Public Transport Station Residential Leisure Square	Sustainable Development Plan

Environmental threats, such as weather-related erosion, capillary rise, and humidity fluctuations (Moreno et al., 2023), as well as natural disasters (Diceglie, 2023), earthquakes, landslides, floods,

and fires (Serrano-Chacón et al., 2025), and excessive vegetation growth, invasive plant species, biotic factors, and allergenic pollen, further obscure archaeological features (Ebejer et al., 2023; Pardela et al., 2022). These are intensified by pollution (Łakomy, 2021), urban pressures, including uncontrolled development, and rapid urbanization (Moreno et al., 2023; Serrano-Chacón et al., 2025; Şahin Körmeçli, 2024). Complex topography and seismic vulnerability in Kadifekale compound these risks, limiting documentation, monitoring, and integration into conservation frameworks. Such an issue highlights the necessity of risk-based heritage management strategies that integrate preventive conservation measures, hazard assessment, and adaptive management strategies within the HUL approach. In this phase of the conservation strategy, the Smyrna Theatre excavation area, adjacent to a disaster-risk zone, is proposed to function as an archaeological node with controlled public access. Pedestrianisation of the surrounding streets and the redirection of vehicular traffic would integrate the site into the pedestrian ring, enhancing accessibility and visibility while supporting risk-sensitive heritage management within the HUL.

Comparative studies highlight that socio-cultural integration within HULs depends on the coordinated provision of physical, social, and intellectual accessibility (Ali & Abouelfadl, 2022; Bonadei et al., 2017; Diceglie, 2023; Ebejer et al., 2023; Łakomy, 2021; Moreno et al., 2023; Pardela et al., 2022; Serrano-Chacón et al., 2025; Şahin Körmeçli, 2024; Wang et al., 2019). The case exemplifies how the absence of such coordination contributes to the progressive inaccessibility of heritage in the MUL (Ali & Abouelfadl, 2022). The area's use as a temporary accommodation for migrants attempting to reach Europe (Oner et al., 2020) generates significant security concerns (Yıldız, & Uzgören, 2016). This neglect and lack of maintenance expose the surrounding examples of high-quality civil architecture to physical deterioration, as well as intellectual invisibility and inaccessibility. As in the conservation process, a pedestrian ring is proposed to connect the three key focus points of the case study area and improve physical accessibility within the multi-layered heritage context. The ring integrates designated co-production and educational spaces, including a craft-orientated production area located within the case study site, to support heritage-based skills development and public engagement. This intervention makes periodical layers more visible and useful in everyday life, while also showing the continuity between cultural heritage, social use, and contemporary urban life within the HUL framework.

The studies emphasize the challenging possibility of linking multi-layered urban heritage sites with traditional practices as a catalyst for sustainable urban conservation (Ali & Abouelfadl, 2022), in accordance with the HUL framework. Research on fortified urban fabrics, including the reassessment of the cultural significance of the Bergamo city wall (Bonadei et al., 2017), the formulation of methodological guidelines for conserving buildings associated with defensive structures (Diceglie, 2023), and value-based frameworks for fortified heritage (Ebejer et al., 2023), demonstrates the continued relevance of city walls in shaping urban identity (Wang et al., 2019). Parallel studies investigate the impact of foundational decisions in early urban formations on contemporary development potential (Łakomy, 2021) and the implementation of green-city strategies within historical contexts, scrutinizing their alignment with cultural heritage preservation (Moreno et al., 2023). Additional contributions examine the interplay between visibility, naturalness, and social preference in military heritage landscapes (Pardela et al., 2022); evaluate ambient vibration techniques for characterizing historic rammed earth structures (Serrano-Chacón et al., 2025); and suggest visual network-based models for analyzing urban image formation in historic centres, such as Amasra (Şahin Körmeçli, 2024). Research on the sustainable development of historic Chinese city walls reinforces these themes (Wang et al., 2019), collectively illustrating an expanding body of knowledge dedicated to enhancing the visibility, interpretation, and conservation of layered urban environments (Ali & Abouelfadl, 2022). Based on the objectives articulated in comparable studies, this research aims to clarify how multi-layered urban heritage can be conserved and communicated within rapidly transforming urban contexts. By analysing the architectural, natural, cultural, and socio-economic attributes of the case area, the study evaluates its heritage values, opportunities, and threats, ultimately formulating strategies that reinforce coherence between the historic site and the surrounding urban renewal zone.

The literature also indicates that methodological approaches to MULs rely on a fundamental methodological cluster that includes case study approaches and empirical studies, which together form the dominant analytical basis in contemporary heritage management science (Ali & Abouelfadl, 2022; Bonadei et al., 2017; Ebejer et al., 2023; Wang et al., 2019). A secondary group of methods combines field analysis, formal architectural assessment, skyline and visibility studies, and documentary historical research to interpret the spatial logic of historic environments, particularly those shaped by defensive structures such as the city wall (Diceglie, 2023; Ebejer et al., 2023; Moreno et al., 2023). Increasingly technical approaches make use of remote sensing, Landsat-based statistical testing, and NDWI analysis to evaluate environmental impacts on heritage sites (Moreno et al., 2023). Interdisciplinary studies further incorporate questionnaire surveys and unit-based spatial analyses, often framed within the HUL approach to examine social perception and public engagement (Pardela et al., 2022; Wang et al., 2019). At the advanced diagnostic level, methods such as ambient vibration testing, operational modal analysis, and related frequency-domain and subspace identification techniques are employed to assess the structural behaviour of vulnerable historic fabrics (Serrano-Chacón et al., 2025). Complementary cognitive spatial tools, including mental mapping and network analysis, offer an explanation of how historic centres are perceived and navigated, despite the partial invisibility of their archaeological layers (Şahin Körmeçli, 2024). Together, these methodological approaches illustrate a consolidated yet diversified set of tools for enhancing the visibility, interpretation, and sustainable management of layered urban environments. In the case study, the methodological framework combines qualitative approaches widely adopted in comparative studies, most notably comprehensive literature reviews and the comparative analysis of relevant cases, with quantitative techniques, particularly the systematic implementation of on-site visual observations. This integration facilitates both the contextual interpretation of the site within the broader discourse of heritage management and the empirical assessment of its present physical, social, and intellectual conditions.

Comparative studies indicate that interpretation approaches in MULs reveal recurring patterns in the provision of physical, social, and intellectual accessibility (Ali & Abouelfadl, 2022; Bonadei et al., 2017). Approaches based on a mix of top-down and bottom-up frameworks, or the HUL methodology, tend to create physical, social, and intellectual access by combining participatory processes with spatial and historical analysis (Bonadei et al., 2017). Similarly, morpho-typological and stratigraphic analyses enhance all three forms of accessibility by revealing structural continuities and deep-time transformations within the urban fabric, which allows for a better understanding of how these elements interact and contribute to the overall accessibility of urban environments (Diceglie, 2023). In contrast, value-based discussions and multidimensional comparative analyses primarily facilitate social accessibility (Ebejer et al., 2023; Łakomy, 2021). They encourage people to become more involved in their communities and help them understand each other better, but they lack intellectual accessibility, which refers to the ability to engage with complex ideas and information that are necessary for informed decision-making (Ebejer et al., 2023; Łakomy, 2021). Methods that use statistical analyses of satellite images, non-destructive testing (NDT) or sampling techniques don't usually support accessibility. They provide data-driven insights but overlook real-life experiences. These approaches rarely provide direct accessibility gains, as their focus lies in diagnostic evaluation rather than public interpretation (Moreno et al., 2023; Pardela et al., 2022; Serrano-Chacón et al., 2025), which limits their effectiveness in enhancing user engagement and understanding of the data presented. The commons-based graphic platform study focuses on social and intellectual access (Şahin Körmeçli, 2024). The dynamic integration of heritage protection and social development facilitates access in all three areas: physical, social, and intellectual (Wang et al., 2019). These groupings demonstrate that each interpretive strategy provides a distinct type of accessibility, which influences how archaeological layers in dense historic settings can be interpreted or remain hidden in modern heritage management. Presentation-orientated approaches, such as the establishment of culture-led tourist routes, archaeological parks, museums, or cultural documentation initiatives, frequently yield guidebooks, interpretive

media, and tourism strategies. The result suggests that increased public visibility of heritage layers typically stimulates communication- and tourism-based policy instruments (Diceglie, 2023; Ebejer et al., 2023; Wang et al., 2019). The Kadifekale case demonstrates how social challenges, such as security issues and migration-related pressures, further intensify inaccessibility due to the absence of such interpretation approaches. These conditions contribute to both physical neglect and the intellectual invisibility of heritage. To address this, a pedestrian ring is proposed to connect key focal points, integrating co-production and educational spaces that support heritage-based skills and public engagement (Figure 9). This intervention aims to enhance the everyday use and perception of periodical layers, reinforcing their continuity within contemporary urban life.

There is a clear link between the type of conservation or presentation methods chosen and the policies and practices that were created to address the heritage problems of MULs. Regular monitoring, structural care, and routine maintenance consistently lead to the formulation of renovation and management plans, as well as vegetation monitoring schemes aligned with sustainable urban and heritage management policies, demonstrating that basic preventive conservation often produces regulatory frameworks aimed at long-term management (Ali & Abouelfadl, 2022; Łakomy, 2021; Moreno et al., 2023; Pardela et al., 2022; Serrano-Chacón et al., 2025). Conservation strategies involving reconstruction, adaptive reuse, and rehabilitation tend to generate more comprehensive management plans and general frameworks for fortified heritage, reflecting their broader spatial and functional impacts on historic environments. Where studies combine cultural and natural presentation practices, such as integrating residential parks, cemeteries, and natural green systems, the resulting outputs align with nature-based planning policies and sustainable development strategies within MULs (Łakomy, 2021). In contrast, highly technical conservation practices, including systematic monitoring or diagnostic assessments, often culminate in specialised protocols for the structural diagnosis of city walls, highlighting their focus on engineering-driven risk mitigation rather than broad, interpretive, or public-facing policies (Serrano-Chacón et al., 2025). While case studies and empirical research dominate, complementary methods ranging from spatial analysis and historical documentation to advanced diagnostic and digital techniques help reveal both physical conditions and perceptual dimensions. Similarly, interpretation approaches vary in their capacity to generate accessibility: participatory and HUL-based strategies tend to enable integrated access, whereas technical methods remain limited to diagnostic functions (Table 3).

Table 3 Proposed Solutions

CHALLENGES OF THE SITE	PROPOSED SOLUTIONS IN SIMILAR CASES			PROPOSED SOLUTIONS		
	conservation	*presentation*	*policy and practice*	*conservation*	*presentation*	*policy and practice*
A lack of accessibility in physical, visual, and intellectual terms, limiting public engagement with the city's archaeological layers	Regular Monitoring, Structural Care and Maintenance, Adaptive Reuse, Rehabilitation	A Culture-Led Touristic Path, Archaeological Park, Museum, Green Areas	Renovation and Management Plan, General Framework for Fortified Heritage Referring to Values Set, Nature-Based Solutions and Planning for Different Zones of Greenery Within MHLs	Structural Care and Maintenance, Rehabilitation, Adaptive Reuse	A Culture-Led Touristic Path, Archaeological Park	Renovation and Management Plan
A lack of integration, both physical and societal	Public Dissemination, Communication Activities, Urban Greenery System Consisting of Investigation, Design, Maintenance, Adaptive Reuse	Museumification, New Gaze and Rejuvenation, Combining Residential Park and Cemeteries with Natural Greenery, Greenbelt Park, Residential Recreation Space, Modern Public Transport Station, Residential, Leisure Square	Guidebook, Short Animated Film, General Guidelines of for Post-City wall Areas, Sustainable Development Plan	Public Dissemination, Communication Activities, Urban Greenery System Consisting of Investigation, Design, Maintenance, Adaptive Reuse	Greenbelt Park, Recreation Space	Sustainable Tourism Strategy, Sustainable Development Plan
Invisible periodic layers are not incorporated into contemporary urban planning and public narratives	Reconstruction, Regular Monitoring, Maintenance	Cultural Documents of The City, Public Gardens, Public Park,	Management Plan, Vegetation Monitoring Plan to Implement Sustainable Urban and Heritage Management Policies, Protocol for The Global Structural Diagnosis of The City Wall	Regular Monitoring, Maintenance	Public Gardens, Public Park	Management Plan

This study contributes to debates on MULs by conceptualizing AS as an urban base that shapes both the physical structure and the cultural continuity of the city. In Kadifekale, this perspective extends conventional HUL-based approaches by connecting the invisibility of archaeological heritage to disruptions in physical, social, and intellectual accessibility. Accordingly, the study develops an integrated analytical framework that links accessibility, interpretation, and heritage integration, offering a context-sensitive approach for managing invisible periodic layers within rapidly transforming HULs.

Although the empirical findings identify different periodic layers, framing them within the HUL approach demonstrates how these invisible periodic layers continue to shape contemporary socio-spatial dynamics. By directly connecting these findings to the urban base conceptual framework, it becomes evident that managing multi-layered urban heritage requires transcending the static preservation of isolated monuments. Consequently, the Kadifekale case reveals the active role of similar heritage elements within the broader urban base, illustrating that the dynamic integration of historical stratifications is essential for robust heritage management in MULs.

The results of these studies highlighted that the type of conservation or presentation practice directly shapes the policy strategies developed, revealing how specific interventions contribute to making otherwise invisible periodic layers more governable, interpretable, and sustainably managed within dense historic urban fabrics. Preventive conservation measures often lead to long-term management strategies, while adaptive reuse and presentation-orientated approaches generate broader planning and tourism policies. In contrast, highly technical interventions primarily result in specialised diagnostic protocols. These results show that the visibility and integration of periodical layers within MULs depend not only on physical conservation. It also depends on the alignment of interpretation, accessibility, and policy-making processes within a holistic heritage management framework. In this context, the proposed strategies address the discontinuity of the city walls through the establishment of a pedestrian network reconnecting key focal points, the integration of the Smyrna Theatre excavation area as a controlled-access archaeological node within a risk-sensitive framework, and the activation of underused spaces through co-production and educational functions. These interventions aim to enhance physical, social, and intellectual accessibility while responding to site-specific constraints such as topography, disaster risk, and security concerns. In doing so, the proposed programs not only support the visibility of the city walls but also foster intellectual accessibility for residents and irregular migrant populations while addressing their basic socio-spatial needs in the area. Furthermore, the completion and implementation of the previously initiated but currently inactive Archaeology and History Park project (Figure 8) is essential to ensure the long-term visibility, accessibility, and integration of the archaeological layers within the HUL.

5. Conclusion

This study demonstrates that invisible periodical layers within HULs should be understood not merely as urban base physical remains but as integral components of cultural continuity, urban identity and collective memory. In this context, the concept of the urban base provides both a tangible and conceptual framework for interpreting the relationship between historical layers and contemporary spatial practices. Accordingly, the findings emphasize the importance of integrated, participatory, and place-based approaches that combine conservation, presentation, and accessibility to ensure the effective inclusion of these layers in everyday urban life.

The case shows the persistent challenges of integrating deeply embedded archaeological heritage into modern planning processes. Despite long-standing recognition of İzmir's archaeological potential, planning practices have largely treated such areas as isolated entities, limiting their visibility, accessibility, and socio-cultural integration. In Kadifekale, environmental risks, uncontrolled urbanization, and inadequate interpretive strategies have further reinforced the

physical and metaphorical invisibility of the city walls, despite their role as the foundation of the contemporary urban fabric.

Through the presentation of the concept of the urban base within the HUL framework, this study contributes to ongoing debates in heritage management, proposing a transferable approach for MULs. This approach highlights the visibility of the city walls, physically, socially, and intellectually, by defining the characteristics of key focal points and linking them through a pedestrian network, integrating the archaeological excavation area as a controlled-access archaeological node within a risk-sensitive framework, and revitalizing underused spaces through co-production and educational functions. It highlights the need for context-sensitive strategies that integrate heritage into urban governance and daily life practice, offering a framework for addressing visibility and accessibility challenges in comparable historic environments.

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The dataset is unpublished and archived at İzmir Institute of Technology. The authors are members of the research team that contributed to the creation of the dataset. The dataset has been re-evaluated and interpreted in accordance with the aims of the present study. Ethics committee permission is not required.

CRediT Authorship Contribution Statement

Beylem Doğa Tabur: Writing – review & editing, Writing – original draft, Methodology, Investigation, Analysis, Data curation, Conceptualization, Data visualization. Mine Turan: Writing – review & editing, Writing – original draft, Methodology, Investigation, Analysis, Data curation, Conceptualization.

Declaration of Competing 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 paper.

Data Availability

Data will be made available on request.

Ethics Committee Approval

Ethics committee permission is not required.

References

Ababneh, A., Darabseh, F. M., & Aloudat, A. S. (2016). The management of natural and cultural heritage: A comparative study from Jordan. *The Historic Environment: Policy & Practice, 7*(1), 3-24. https://doi.org/10.1080/17567505.2016.1142686

Ali, M. A., & Abouelfadl, H. (2022). Stitching the gap between contemporary archaeology and the city through "urban dots": Case study of Kōm al-Nāḍūra Area, Alexandria, Egypt. *Alexandria Engineering Journal, 61*(12), 12891-12914. https://doi.org/10.1016/j.aej.2022.06.020

Bonadei, R., Cisani, M., & Viani, E. (2017). City walls as historic urban landscape: A case study on participatory education. *Almatourism-Journal of Tourism, Culture and Territorial Development, 8*(7), 75-88. https://doi.org/10.6092/issn.2036-5195/6756

Council of Europe. (1992). *European Convention on the Protection of the Archaeological Heritage (Revised).* https://rm.coe.int/168007bd25

Demirtas-Milz, N. (2013), The regime of informality in Turkey. *International Journal of Urban and Regional Research, 37*(3), 689-714. https://doi.org/10.1111/1468-2427.12005

Diceglie, A. (2023). Restoration of the city walls of Monopoli in Puglia (Italy)—The 16th century house within the walls: From the discovery of the gunboat to the recovery of the basement. *Sustainability, 15*(3), 2300. https://doi.org/10.3390/su15032300

Dines, N. (2002). Urban renewal, immigration, and contested claims to public space: The case of Piazza Garibaldi in Naples. *GeoJournal, 58*(2), 177-188. https://doi.org/10.1023/B:GEJO.0000010837.87618.59

Ebejer, J., Staniewska, A., Środulska-Wielgus, J., & Wielgus, K. (2023). Values as a base for the viable adaptive reuse of fortified heritage in urban contexts. *Muzeológia a kultúrne dedičstvo*, *11*(2), 41-72. https://doi.org/10.46284/mkd.2023.11.2.3

Ersoy, A., & Çakmak, O. (2025). Smyrna/İzmir antik kenti kazılarından bir grup Roma dönemi cam buluntusu. *KATMAN 1*(1), 19-34. https://doi.org/10.5281/zenodo.18034498

Ersoy, A., Kaya, N., Selçuk, S., & Esen, V. (2015). Antik Smyrna/İzmir 2011-2013. H. Dönmez (Ed.)*, 36. Kazı Sonuçları Toplantısı* içinde (Cilt 2, ss. 17-34). T.C. Kültür ve Turizm Bakanlığı.

Ertan, T., & Eğercioğlu, Y. (2016) The effects of urban renewal politics on historic urban regeneration projects: Case of Kadifekale. *International Journal of Environmental Science 1,* 41-47.

ICAHM. (1990). *Charter for the protection and management of the archaeological heritage (Lausanne Charter).* https://admin.icomos.org/wp-content/uploads/2023/01/arch_e.pdf

ICOMOS. (1964). *International charter for the conservation and restoration of monuments and sites (The Venice Charter).* https://www.icomos.org/images/DOCUMENTS/Charters/venice_e.pdf

ICOMOS. (1987). *Charter for the conservation of historic towns and urban areas (Washington Charter).* https://civvih.icomos.org/wp-content/uploads/2022/03/Charter-of-Washington_10_1987.pdf

ICOMOS. (1994). *The Nara document on authenticity.* https://www.iccrom.org/sites/default/files/publications/2020-05/convern8_06_thenaradocu_ing.pdf

ICOMOS. (1999). *International cultural tourism charter managing tourism at places of heritage significance (The Charter Ethos).* https://admin.icomos.org/wp_content/uploads/2020/10/INTERNATIONAL_CULTURAL_TOURISM_CHARTER.pdf

ICOMOS. (2008). *The ICOMOS charter for the interpretation and presentation of cultural heritage sites.* https://admin.icomos.org/wp-content/uploads/2025/03/interpretation_FREN.pdf

ICOMOS. (2011). *The Valletta Principles for the safeguarding and management of historic cities, towns and urban areas.* https://admin.icomos.org/wp_content/uploads/2025/03/Valletta_Principles_GA_EN_FR_28_11_2011.pdf

ICOMOS. (2017). *Salalah guidelines for the management of public archaeological sites.* https://admin.icomos.org/wp-content/uploads/2023/01/GA2017_6-3-3_SalalahGuidelines_EN_adopted-15122017.pdf

ICOMOS., & IFLA. (2017). *ICOMOS_IFLA document on historic urban public parks.* https://admin.icomos.org/wp-content/uploads/2023/01/GA2017_6-3-2_HistoricUrbanPublicParks_EN_adopted-15122017.pdf

International Museums Office. (1931). *The Athens Charter for the Restoration of Historic Monuments.* https://civvih.icomos.org/wp-content/uploads/2022/03/The-Athens-Charter_1931.pdf

İzmir Institute of Technology Archive. (2022). *RES511 Preservation and Development Methods of Historic Environment course dataset* [Unpublished data set]. İzmir Institute of Technology.

Łakomy, K. (2021). Site-specific determinants and remains of medieval city city walls as the potential for creating urban greenery systems based on the example of historical towns of the Opole Voivodeship. *Sustainability, 13*(13), 7032. https://doi.org/10.3390/su13137032

Kütükoğlu, M. (2001). İzmir. In TDV Islam Encyclopedia (Vol. 23, pp. 524_526). https://islamansiklopedisi.org.tr/izmir

Moreno, M., Ortiz, P., & Ortiz, R. (2023). Analysis of the impact of green urban areas in historic fortified cities using Landsat historical series and Normalized Difference Indices. *Scientific Reports, 13*(1), 8982. https://doi.org/10.1038/s41598-023-35844-8

Municipality of Konak, Department of Conservation of Cultural Heritage. (n.d.). *Archaeology and History Park Plan* [Unpublished archival document]. Konak Municipal Archives (No archival record number), İzmir, Türkiye.

Mutlu Kılıç, E. (2025). The opportunities offered by the "Actor-network Theory" in decoding data obtained from oral history narratives in urban studies: The case of İzmir Kadifekale urban renewal project. *Planning, 35*(2), 211-240. https://doi.org/10.14744/planlama.2025.98470

Mutlu Kılıç, E., & Göksu, A. E. (2018). Bir kentsel dönüşüm deneyimi: Kadifekale-Uzundere ikileminde bireysel öyküler üzerine düşünmek. *Planlama Dergisi, 28*(2), 201-217.

Oner, A. C., Durmaz-Drinkwater, B., & Grant, R. J. (2020). Precarity of refugees: The case of Basmane-İzmir, Turkey. *Journal of Ethnic and Migration Studies, 47*(20), 4651_4670. https://doi.org/10.1080/1369183X.2020.1732591

Pardela, Ł., Lis, A., Iwankowski, P., Wilkaniec, A., & Theile, M. (2022). The importance of seeking a win-win solution in shaping the vegetation of military heritage landscapes: The role of legibility, naturalness and user preference. *Landscape and Urban Planning, 221*, 104377. https://doi.org/10.1016/j.landurbplan.2022.104377

Ripp, M., & Rodwell, D. (2015). The geography of urban heritage. *The Historic Environment: Policy & Practice, 6*(3), 240-276. https://doi.org/10.1080/17567505.2015.1100362

Saraçoğlu, C., & Demirtaş-Milz, N. (2014). Disasters as an ideological strategy for governing neoliberal urban transformation in Turkey: Insights from Izmir/Kadifekale. *Disasters, 38*, 178_201. https://doi.org/10.1111/disa.12038

Serrano-Chacón, A. R., Mascort-Albea, E. J., Romero-Hernández, R., Canivell, J., Muñoz-Chavero, F., Hidalgo-Fort, E., & Jaramillo-Morilla, A. (2025). Structural assessment of the medieval city wall of Seville (Spain) using low_cost accelerometers. *Journal of Cultural Heritage, 73,* 225_235. https://doi.org/10.1016/j.culher.2025.03.012

Şahin Körmeçli, P. (2024). Understanding the historic center by using network analysis with mental mapping method: The case study of Amasra, Turkey. *Sustainability, 16*(13), 5387. https://doi.org/10.3390/su16135387

UNESCO. (1976). *Recommendation concerning the Safeguarding and Contemporary Role of Historic Areas (Nairobi Recommendation).* https://www.unesco.org/en/legal-affairs/recommendation-concerning-safeguarding-and-contemporary-role-historic-areas

UNESCO. (2011). *Recommendation on the historic urban landscape.* https://whc.unesco.org/en/soc/

UNESCO. (2019). *State of Conservation Information System.* https://whc.unesco.org/en/hul/

Wang, S., Jiang, Y., Xu, Y., Zhang, L., Li, X., & Zhu, L. (2019). Sustainability of historical heritage: The conservation of the Xi'an city wall. *Sustainability, 11*(3), 740. https://doi.org/10.3390/su11030740

Yetiskul, E., & Kul, F. (2023) Agglomeration of population and employment in the urbanization – industrialization interaction: The case of Izmir. *Journal of Design for Resilience in Architecture and Planning 4(*1), 16-30. https://doi.org/10.47818/DRArch.2023.v4i1080

Yıldız, A., & Uzgören, E. (2016). Limits to temporary protection: Non-camp Syrian refugees in İzmir, Turkey. *Southeast European and Black Sea Studies, 16*(2), 195_211. https://doi.org/10.1080/14683857.2016.1165492

Yılmaz, A., & Zafer Kurt, Ö. (2022). Waiting for regeneration: Temporalities of gentrification in İzmir Ballıkuyu neighborhood. *Journal of Housing and the Built Environment, 37*(4), 1971_1995. https://doi.org/10.1007/s10901-022-09933-5

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Spatial and economic effects of TOKI practices in the context of public housing investments: The Erzincan example

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Abstract

Housing Development Administration of the Republic of Türkiye (TOKI), which was established as a public legal entity in 1984 to provide solutions to urbanization and housing problems, became the most important actor in steering urbanization and housing policies with the powers granted to it after 2002. This study analyzes public housing production in Türkiye through TOKI's housing policies, with a particular focus on the transformation of housing policy that has occurred since 2002. The aim of the study is to examine the economic and spatial impact of public housing investments at the local level, focusing on the Erzincan city center as an exploratory case study, where TOKI has invested the most, and as an example of non-metropolitan provinces. The study attempts to measure the impact of TOKI investments at the local level, both economically and spatially, through a total of seven variables using the descriptive analysis method and the spatial analysis method. The analysis revealed that TOKI manifested exclusively as an earthquake, disaster, or social housing practice, devoid of any discernible direct economic impact. It has been observed that the practices of TOKI exerted a multifaceted influence on the urban spatial development, exhibiting both positive and negative spatial implications.

Keywords: Erzincan city center, housing policy, public housing investment, spatial and economic impact, TOKI

1. Introduction

The impact of public housing investments in urban areas can be explained by economic, social, and spatial factors (Amidu et al., 2016). Housing investments also have social, economic, and spatial impacts. Housing is a fundamental human need that impacts individuals' well-being across all nations, exerting significant social and economic influence on people's lives (Moreno-Monroy et al., 2020). The public housing sector's investment and policy decisions are influenced by the priorities set by the public sector. Usually, the most common approach to public housing investment has been in the form of mass housing production, both internationally and nationally. Housing Development Administration of the Republic of Türkiye (TOKI) was established as a public legal entity in 1984 to provide solutions to urbanization and housing problems. With the powers granted to it after 2002, it became the most important actor in steering housing policies. Housing policies established within the scope of the neoliberal economic program shape the urban space through the planning process, design, construction process, and related legislation. In 2003, a significant policy change occurred where the central government, through TOKI, took over responsibilities, thus affecting the organization of the urban space. As a result of these powers assumed by TOKI, an almost unlimited right of use over urban lands, obtaining planning and development rights has caused several urban problems. First of all, a conceptual framework is needed to observe the effects of the state, society, and space relations on large-scale urban projects. With the decline of the welfare state approach in the world and the rise of neoliberal policies, the place of public administrations in the housing sector was transferred to the private sector/market, and a new era began in housing policies (Beyazıt & Yarım, 2020).

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Studies on TOKI conducted in the literature after 2002 are as follows: on the spatial development process (Yenigül, 2009), on urban transformation and renewal (İslam, 2009; Kandaloğlu, 2012; Solmaz, 2013; Kas, 2014), on the production of urban space (Akın, 2007; Öznam, 2010; Acar Özler, 2012; Özbilen, 2014; Akkaya, 2018), on housing policies (Olgun, 2014; Yüksel, 2014; Turut, 2018; Yılmaz, 2018), on social welfare state and of housing finance (Koçançı, 2014; Özpolat, 2014; Coşkun, 2014; Kurt, 2020; Yeşilbağ, 2020; Tatlı Çolak & Türk, 2022), on the housing production process (Altay 2004; Sağ 2011; Koca, 2012; Ek, 2012; Kara 2012), on the social dimension (Arslan, 2011). However, studies on the impact of TOKI projects on both the economic and spatial development of cities are limited. Tantan and Türk (2024) urbanization policies (Yaman, 2011; Akkoç, 2018), on examined the impact of public housing investments on the economic development of provinces at the macro level using the panel data method. According to the findings of their study, although private sector housing investments have affected the development of provinces at the macro level, it was concluded that public housing investment and production did not play a decisive role in the economic development of provinces. However, studies on the spatial and economic effects of public housing investments at the micro level are quite limited. Micro-level studies have mostly focused on spatial effects (Gürbüz et al., 2023; Yılmaz Şimşek, 2021; Erdem, 2016).

In this sense, there is a need to measure the impact of TOKI at the micro level, which is an important actor and determinant in terms of urbanization and housing policies in cities. In this context, some research questions were aligned:

- How have public housing policies affected the shaping the urban space in Türkiye?

- What are the effects of TOKI, which has broad powers as a result of the legal regulations after 2002, on the economic and spatial development of the Erzincan Central district, where TOKI has invested the most among the non-metropolitan provinces in Türkiye?

To better comprehend the economic and spatial impacts, the focus of this study was placed on a city that does not hold a metropolitan status. Therefore, Erzincan city center was selected as the case area. The aim of this article is to analyze the spatial and economic impact and change created by TOKI housing investments in the Central district of Erzincan during the period between 2004 and 2018. In this study, Erzincan is examined as an exploratory case study. Exploratory case study is a deep-dive qualitative research method used to investigate a distinct or new phenomenon where little preliminary research exists. The main goal of exploratory case study is to identify patterns and generate fresh insights, rather than test existing theories (Mills et al., 2010; Yin, 2009).

When the number of housing units produced by TOKI in 14 non-metropolitan provinces between 2004 and 2018 are compared, it is seen that TOKI produced the highest amount of housing units in Erzincan (see Figure 1). Between 2004 and 2018, 11,577 housing units were produced in Erzincan, followed by Edirne with 5,661 units, Düzce with 6,114 units, Kırıkkale with 4,781 units, Bolu with 4,701 units, Hakkâri and Bitlis with 3,966 units, Çanakkale with 2,813 units, Burdur with 2,671 units, Kastamonu with 2,630 units, Bilecik with 2,518 units, Giresun with 2,452 units, Rize with 2,270 units, and Siirt with 1,279 units (Housing Development Administration of the Republic of Türkiye, n.d.).

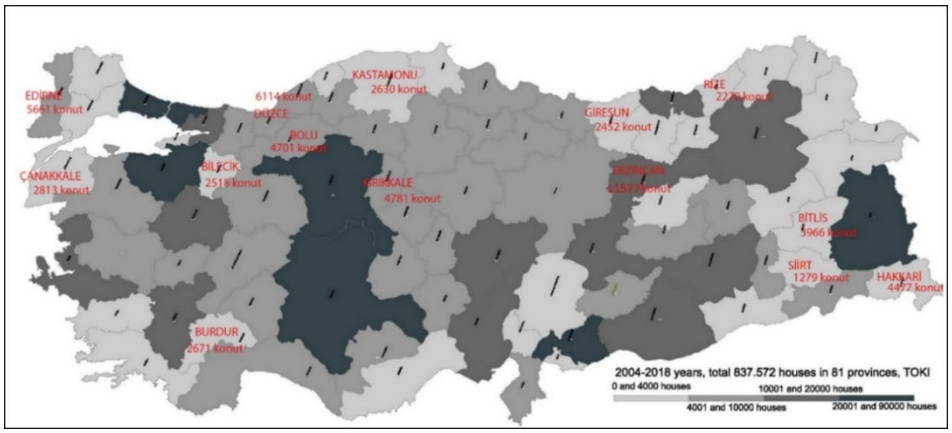


Figure 1 Housing production by TOKI between 2004-2018 (Status in 81 provinces and 14 provinces) (Housing Development Administration of the Republic of Türkiye, n.d.)

There are several reasons why Erzincan was selected as the case study area. Firstly, it received the highest amount of public housing investment between 2004 and 2018 among the 14 provinces that are not metropolitan areas. Secondly, the largest amount of investment within the province was made in the city center. Between 2004 and 2018, a total of 11,577 housing units of various project types were produced in Erzincan. Public investment in Erzincan was higher in 2014 and 2015 compared to other years. However, 8,516 of these projects are located in the city center (Figure 2). Therefore, Erzincan, which received the most investment among the 14 non-metropolitan provinces, was selected as the study area.

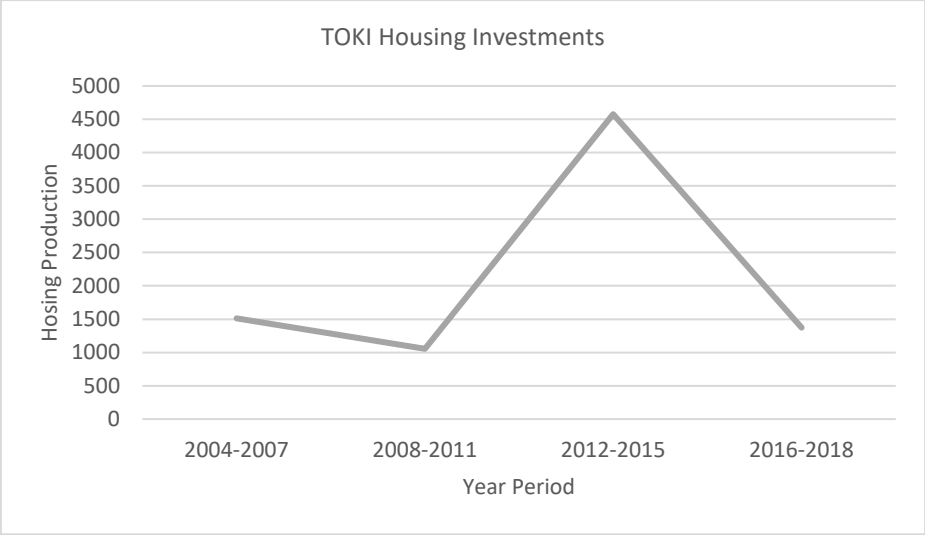


Figure 2 Housing production by TOKI between 2004-2018 (Erzincan city center) (Housing Development Administration of the Republic of Türkiye, n.d.)

Thirdly, the level of development of Erzincan within the region was another consideration. Indeed, considering the current period, Erzincan ranks 25th among 81 provinces and has the highest GDP in its region (KUDAKA, 2019). In other words, this shows that Erzincan has economic and spatial dynamism. Fourthly, there is the diversity in public housing investments throughout the province and in the city center. TOKI's main strategy is to provide social housing for low- and middle-income groups, along with the necessary service units and infrastructure. In this context, TOKI's housing practices, carried out through joint protocols with various public institutions, include housing for the poorest segments of society, urban transformation applications, social housing applications for low- and middle-income groups, and agricultural village housing projects. All of these applications are found in Erzincan and its city center (Housing Development Administration of the Republic of Türkiye, n.d.). Fifthly, the existence of demand in the formation of public housing investments was considered. Indeed, public housing projects implemented throughout the province and in the city center have been determined by the demand collection method. According to this method, requests are determined by the Governorship, District Governorship, and Municipalities.

In the second section following the introduction, literature review is presented. In this section, the understanding of housing policy that shapes urban space in the context of the historical process and the role of TOKI within the scope of housing policy and its effects are examined. Also, spatial and economic impacts of public housing investments at the local scale are explored. The third section consists of three sub-sections. In the first sub-section, the characteristics of the Erzincan Central district, which was selected as a sample, are described, while in the second sub-section, TOKI housing investments are explained. In the third sub-section, data, design, and analysis findings are given. The fourth section of the article is devoted to results and the general evaluation.

2. Literature Review

2.1. Policies for Public Housing Investments and the TOKI Example

Governments, which have direct or indirect effects on housing supply and quality, housing standards, and urban planning, create housing policy through legislation, programs, and implementation actions. In the literature, considering the roles of the public and private sectors in housing production, housing policy is divided into three basic approaches (Manoochehri, 2009; Kemeny, 1995; Esping-Andersen, 1990). These include the Marxist, Social-Democratic, and Neo-Liberal approaches. The first involves an intensive state intervention, the second involves a partial state intervention, and the third mostly entails a non-state intervention (Al-Hafith et al., 2019; Manoochehri, 2009; Doling, 1997). Since the ideologies of countries are influential in the formation of housing policies and housing has many different functions other than shelter, states have resorted to producing policies regarding the housing problem. Improving the quality of housing, providing access to affordable housing, and increasing housing supply are the most important goals of housing policy. The core of housing policy has been social housing policies (Organisation for Economic Co-operation and Development, 2021; Ulusoy, 2020; Şiriner Önver, 2016; Alkan & Uğurlar, 2015; Şentürk, 2011). As an extension of the neoliberal process, in the globalizing world, the state has shrunk in its role as a provider of regulatory public services. In the 21st century, European housing markets have created significant instability with the global crisis (Zhang & Ball, 2016; Alkan & Uğurlar, 2015). In this context, strategies such as the downsizing of the state, deregulation, privatization, political reforms, and transformation of socio-economic policies have become the fundamental policies of countries (Feigenbaum & Henig, 1994).

According to Buckley et al. (2016) and Balaban (2012), policies have been developed to launch a large-scale mass housing construction to accelerate and increase housing production, especially in rapidly and dynamically developing countries. One example is the Brazilian government's Minha Casa, Minha Vida (My Home, My Life) social housing program, which was launched in 2009 with the goal of producing 3.4 million homes by the end of 2014. In China, 3.3 million new social housing units were produced in 2010 alone (Altunok & Uğurlu, 2021). Furthermore, a program to produce 36 million social housing units was initiated in China between 2011 and 2015 (Shi et al., 2016). Pakistan launched the Naya Pakistan Housing Programme (NPHP) in 2018 with a target of providing 5 million affordable housing units to low- and middle-income groups by 2023, and has developed models for providing affordable housing (Nadeem et al., 2020). In Iran, the Mehr Housing Project, planned in 2007, aimed to provide housing to needy families by constructing approximately 2 million housing units within 5 years, with a target of producing only 150,000 units per year (Ghaedrahmati & Zarghamfard, 2021; Shahraki et al., 2020; Abbaszadeh, 2016). Latin American countries have also improved their housing production processes with plans to improve the supply of affordable land to provide affordable housing (Rojas, 2018). For instance, the Colombian government launched a 100,000-unit free housing program for impoverished groups in 2012 (Murray & Clapham, 2015). One of the policies followed is to provide public housing investments through a centralized public institution with financial and managerial power (Tatlı Colak and Turk, 2022).

Although the construction sector has held an important place in fixed capital formation since the foundation of the Republic of Türkiye, two critical turning points brought about the acceleration of the sector: (1) especially the second half of the 1990s, and (2) the transformations in economic policies in the 1980s, the effects of which were seen in the 2000s (Purkis, 2016). When the urbanization process in Türkiye within the framework of housing policies is considered in terms of periods, it has followed a course in which the official ideology played the leading role in the first period, gecekondus in the second period, cooperatives, which had a more widespread effect throughout the country, in the third period, and structures that separated cities with the cooperation of capital and TOKI in the last period (Arslan, 2014). After 2000, the housing development in Türkiye was shaped by capitalist-neoliberal approaches and the influence of the global economy. In the first decade of the 2000s, public institutions approached housing production

with a market logic framework, and legal regulations were renewed to emphasize entrepreneurship (Koca, 2015a). After 2002, with the legal regulations established in 1984 and the renewed effect of TOKI, shopping malls, and residence-type housing investments gained importance (Baykal et al., 2018). After 2002, in the process that mostly attracted the attention of large-scale, institutionalized capital groups, public institutions became new investment partners to get a share of housing investments (Koca, 2015b). During this process, TOKI's institutional structure was developed, and its powers were expanded with legal regulations. Balaban (2012) states that in Türkiye, the central government has supported the recent construction boom by making various legal arrangements and changes, especially within the framework of urban planning (authority to prepare zoning plans, legal regulations regarding public lands and properties, legal regulations regarding "urban transformation"), to increase housing production and transform informal settlements by strengthening TOKI and encouraging construction activities. Following the legal and institutional changes, TOKI was provided with 64.5 million m^2 of public land that can be used to develop housing projects, and many mass housing projects were initiated by TOKI in almost every province in Türkiye (Balaban 2012). In this period, when the rate of housing production increased rapidly, and the construction sector grew strongly after 2002, new legislation on urban transformation was enacted, and changes were made to the mass housing legislation. The government's mass housing practices increased TOKI's influence during this period. Compared to previous periods, TOKI and its subsidiary Emlak Konut, which produced a high number of housing units, entered into partnerships with large-scale companies within the framework of revenue-sharing projects (Kömürcüoğlu, 2017). In the literature, in the results of the research conducted on TOKI project applications, Coşkun (2015) stated that although there are successful aspects of the TOKI model on the basic characteristics and the effectiveness of its financial structure, TOKI activities and related financial results are not transparent enough, and the financing structure may cause risk/effectiveness problems. While this study is focused on TOKI's institutional structure, Eşkinat (2015) focuses on its practices. In the 1980s, TOKI, which was declared as the primary authorized institution to meet the housing needs of low-income people, made a move in housing production after 2003. While many people who became homeowners at prices they could not have imagined before were happy with the developments, TOKI has become a much-discussed institution due to the emphasis given to luxury housing, the construction of low-quality housing for the poor, large-budget works given mostly to capital groups close to the political power, its exemption from inspection, its being equipped with indescribable and unlimited authority, the unfair competition it creates, and similar reasons (Eşkinat, 2015). Again, the spatial effects of TOKI investments have been expressed in the literature. In a study conducted for Gaziantep (Gürbüz et al., 2023), it was stated that treasury and agricultural lands on the city periphery were opened to development as a result of TOKI investments, and constructions were carried out in a way that was contrary to the architectural aesthetics of the city. As a result of such a development, construction did not occur in the form of sprawl, but in the form of oil stains (Gürbüz et al., 2023). In a study conducted in terms of the construction sector, Kömürcüoğlu (2017) analyzed the effects of TOKI, construction, and urban transformation laws on the construction sector and found that while the policies in the 1980s and 1990s mostly resulted in favor of small- and medium-sized companies, the policies after 2000s mostly resulted in favor of large-scale companies. In a study that provides a descriptive analysis of the reflection of housing policy on space (Yeşilbağ, 2020), before the 2002 Republic of Türkiye elections when the Justice and Development Party (AKP), which was assigned to form a government, approximately 3.8 million houses (an annual average of 236 thousand) were built in 16 years (between 1987-2002), while a total of 8.3 million houses (an annual average of 516 thousand) were completed between 2003-2018 after the AKP came to power in 2002. Of this amount, 10% was realized by TOKI. This corresponds to an increase of 118% compared to the previous period. The 8.3 million houses built during the AKP years correspond to one-third of the total housing stock in Türkiye. In other words, this data shows that one out of every three houses was built during the AKP years (Yeşilbağ 2020, pn.108). In a similar study, Marschall et al. (2016) examined the relationship between distribution politics and the AKP's electoral success by focusing on TOKI housing projects. It was found that in

districts where TOKI built more houses, the probability of winning all three local elections was considerably higher than in the districts where TOKI made fewer housing investments, the number of TOKI houses increased as the districts lost population, and TOKI houses were positively and significantly associated with urbanization in the districts where the AKP won the most, thus urbanization and politics played an important role in TOKI housing investments rather than factors related to housing need and demand. However, the opposite is true in the districts where the AKP lost the most, and it is also stated in the results of the study by Marschall et al. (2016) that TOKI housing investments are more related to population growth.

2.2. The Spatial and Economic Impacts of Public Housing Investments at the Local Scale

Small and medium-sized cities (SMCs) offer several advantages in terms of scale when considered outside of developed theories and approaches. In particular, SMCs provide the opportunity for a more detailed examination and analysis of their political, economic, social, cultural, spatial, and physical characteristics (Bell & Jayne, 2009). However, information on the characteristics of SMCs and how to address their specific features is limited. The dynamics of SMCs differ from those of metropolitan areas. These cities have important functions for national and regional development (Bell & Jayne, 2009). Therefore, most countries invest in SMCs depending on their national and regional development approaches. The impact of economic conditions on public investment decisions depends on the government level (Fisher & Peters, 2016).

Residential areas, being one of the basic functional areas of a city, are directly related to the spatial development and planning process of the city. Therefore, housing investments have a significant impact on public investments (Tepe, 2010). However, information on the economic and spatial impacts of public housing investments in cities of this scale is limited. Yet, the effects of public housing investments are more easily measured in small- and medium-sized settlements compared to metropolitan areas.

In small- and medium-sized settlements, public housing investments are a strong economic catalyst in terms of job creation potential, and they can also strengthen local supply chains and support local service sectors related to construction (Alper, 2017). Public housing in small and medium-sized settlements is seen not only as a social service but also as a fundamental economic infrastructure (Kenna, 2010). In other words, public housing investments have a direct economic impact at the local level. Studies have shown that public investments have significant effects on the values of immovable properties such as workplaces, residences, plots, and land in their immediate vicinity, as well as on the overall development direction of the city (Erdem, 2016). Investment in housing construction is not only a key factor that determines the well-being of the population and increases the activity of businesses, but also a necessary condition to ensure a stable social and economic development and economic growth in the city (Ovsiannikova et al., 2017). On the other hand, affordable housing policies significantly contribute to job creation and economic growth by stimulating construction and related sectors. When housing costs decrease, household income increases, which is reflected in consumer spending and stimulates local economies (Akinsulire et al., 2024).

When considering the spatial impacts of public housing investments, they can affect the growth of the city, as well as bring about changes in the immediate vicinity of the areas where they develop. In small-to-medium-sized settlements, public investment projects may have the potential to change the direction of urban development. For example, in a small city like Karaman in Türkiye, it has been observed that public housing production causes the fragmentation of the urban area. Both luxury and social housing projects are generally located in the urban periphery, which causes low-income groups to live far from city centers and amenities, while leading to the emergence of "inward-looking" luxury areas that increase social stratification and individualization (Sürmeli Söğüt, 2025). A similar situation applies to public housing projects in Van. Public housing projects have changed the development axis by defining a new development route (Gürbüz et al., 2023). One of the most important dynamics of change in urban space is housing production. Today, housing production is

seen as an investment tool and comes to the forefront through its exchange value rather than its use value to meet a basic need such as shelter (Kovankaya & Türkün, 2023). Public housing projects can increase spatial dynamics in their immediate surroundings. They can accelerate private sector investments. They can lead to development in terms of social and technical infrastructure areas. They can also cause changes in land values (Rabiega, 1984). It is said that the size of the city causes costs to increase, thus moving away from both efficiency and effectiveness. Medium-sized cities have an advantage in this respect (Fainstein & Campbell, 2011). Compared to large cities, the limited size of medium-sized cities also has advantages in establishing tighter communication and cooperation among social units and in providing easier access to urban public spaces (Yazar, 2015). Economic benefits such as job creation and increased local spending are crucial for stimulating growth, while social impacts like improved community cohesion and better health are essential for enhancing overall quality of life. Policies that integrate both economic and social aspects tend to be more effective in delivering comprehensive and lasting improvements in housing and community well-being (Akinsulire et. al., 2024).

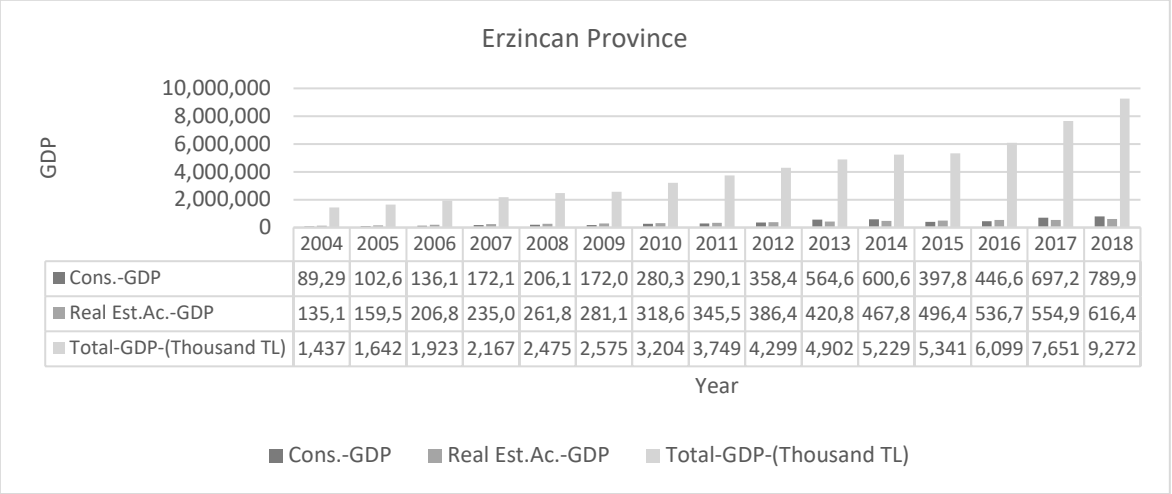
3. Analysis of TOKI Practices in the Context of Public Sector Housing Investments in Erzincan Central District

3.1. Erzincan Context

Erzincan is a province that can be reached via the D-100 (E-80) Highway, which starts from the western end of Türkiye and extends to the border gates in the east, and on the railway route since the date of the Republic, and by air since 1988. The geographical structure also shaped the economic characteristics of the settlements in the province. Located on the main transportation route, the Central district has developed as the only center of attraction in terms of services and industrial sectors throughout the province. The center is the district with the highest population and the most developed district in terms of the socio-economic development criteria of the Erzincan province, and it has a value above the average of Türkiye in terms of these criteria. The Erzincan provincial center is located in the central part of the province, on the D-100 Highway route. Most of the city was destroyed by the earthquakes that occurred in 1939 and 1992. The city was almost rebuilt after that and therefore showed a planned development with its urban infrastructure. The military areas and university campuses in the north of the city and the large public areas in the east are the uses that determine the social life of the city. Erzincan University, founded in 2006, has revitalized the socio-cultural and economic structure of the city. The city develops linearly in the east-west direction. However, the settlement, which is also the center of the migration movement within the province, is developing on agricultural lands in the plain. The development of Erzincan city center is focused on services and industrial sectors (Erzincan Center Municipality, 2010).

The Erzincan province, with a surface area of 11,640 km2, is the fourth largest province in the Eastern Anatolia Region, after Erzurum, Van, and Malatya, and the 24th largest province in the country. However, Erzincan is among the provinces that experience out-migration because more than half of the provincial land consists of mountainous areas and is exposed to natural disasters from time to time. For this reason, with 18.7 people per square kilometer, it is the second province with the lowest population density in the country after Tunceli. Although some districts of Erzincan, which have 9 districts including the central district, remain within the functional influence area of neighboring provinces due to proximity and geographical conditions, some districts of neighboring provinces outside the provincial borders also fall within the functional area of influence of the city of Erzincan. Today, Erzincan develops largely in the retail trade and service sector. However, agriculture is still the dominant sector. Up to 40 industrial buildings in the province were sold within the scope of privatization (Karadeniz & Altınbilek, 2018). In the economic development of Erzincan province, agriculture, forestry activities, public administration, education, human health and social service activities, industry, and service activities seem to be more dominant in GDP. Although the impact of construction and real estate activities on GDP is less than that of other activities, it is also

seen that construction and real estate activities have increased over the years (Figure 3), (Turkish Statistical Institute, 2016).



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Cons.-GDP	89,29	102,6	136,1	172,1	206,1	172,0	280,3	290,1	358,4	564,6	600,6	397,8	446,6	697,2	789,9
Real Est.Ac.-GDP	135,1	159,5	206,8	235,0	261,8	281,1	318,6	345,5	386,4	420,8	467,8	496,4	536,7	554,9	616,4
Total-GDP-(Thousand TL)	1,437	1,642	1,923	2,167	2,475	2,575	3,204	3,749	4,299	4,902	5,229	5,341	6,099	7,651	9,272

Figure 3 Gross domestic product, construction GDP, real estate GDP status of the province (Turkish Statistical Institute, 2016)

3.2. TOKI's Investments

In Erzincan, a non-metropolitan province where TOKI produced the highest amount of housing between 2004 and 2018, 11577 houses of different housing project types were produced. TOKI's strategy is to provide social housing and necessary service units for low and middle-income groups by completing their infrastructure. Accordingly, the method of developing mass housing projects in cooperation with the Governorship, District Governorate or Municipalities to supply housing buyers through preliminary demand collection in districts and towns with a population of 40,000 or less, within the scope of different protocols signed by TOKI with institutions such as the Ministry of National Defense, the Ministry of Internal Affairs, and the General Staff, housing application has been made in line with the needs of these institutions, poor houses produced in cooperation with TOKI and the General Directorate of Social Assistance for the poorest and non-household segments of the society, urban transformation practices by cooperating with municipalities in order to transform and improve slum areas and areas at disaster risk, social housing applications for low-income and middle-income groups, Agricultural Village housing projects, implemented with the cooperation of the General Directorate of Disaster Affairs or with the application of the competent authorities at the municipality or governorship level of a province, in order to bring the infrastructure and social facilities available in the city centers to the villages, It implements different housing programs such as (Housing Development Administration of the Republic of Türkiye, n.d.). In this article, since investments were made predominantly in the Central district of the Erzincan province, the analysis was made only in this district. The types and numbers of investments made by TOKI in the central district are shown in Table 1.

Table 1 TOKI's Housing Project Types and Number in the Central District of Erzincan Province

Project Types	Number of Residences
Urban Regeneration and Development Project	2073
Administration Housing Application	4635
The Agricultural Village Projects	408
Demand Organization	1282
Military Housing (HAIT)	118
Total	8516

Ref: TOKI, housing statistics (Housing Development Administration of the Republic of Türkiye, n.d.)

When examined by years, the housing project areas completed by TOKI are classified in four different periods, taking into account the completion times of the construction (Figure 4). The first period, between 2004 and 2007, within the scope of the Administration's housing application, 633 housing projects in the Mengüceli District in 3 stages, within the scope of the slum transformation project implementation, 880 housing projects in 2 stages in the Çarşı District, thus a total of 1513 houses were produced.

In the second period, between 2008 and 2011, within the scope of the Agriculture Village application in the Central district, 42 housing projects within the borders of Çukurkuyu Town, 277 housing projects in Yaylabaşı Town, within the scope of the social housing application, a 16-classroom primary school building in Geçit Town, 304 housing projects with a trade center, 176 housing projects in İnönü neighborhood, within the scope of poor housing, a total of 1055 houses were produced, including 256 housing projects in Fatih neighborhood, thus a total of 1055 houses was produced.

In the third period, between 2012 and 2015, within the scope of the social housing application in the Central district, 144 housing projects within the borders of Gülabibey neighborhood, 1187 housing projects in Kavakyolu Town, 757 housing projects in Ulalar Town, 240 housing projects in Çağlayan town, 251 housing projects in Çukurkuyu town that total of 4577 houses were produced, including 118 housing projects in Cumhuriyet neighborhood within the scope of lodging housing, 560 housing projects in Taksim neighborhood within the scope of urban transformation, and 1320 housing projects in Geçit town within the scope of demand gathering method, thus a total of 4577 houses were produced.

In the fourth period, between 2016 and 2018, 89 housing projects were built in Akyazı town within the scope of the Agriculture Village application in the Central district, within the scope of the demand gathering method, including 340 housing projects in Yanlızbağ town, 586 housing projects in Yoğurtlu neighborhood, and 356 housing projects in Kavakyolu town, thus a total of 1371 houses were produced (Figure 4), (Housing Development Administration of the Republic of Türkiye, n.d.).

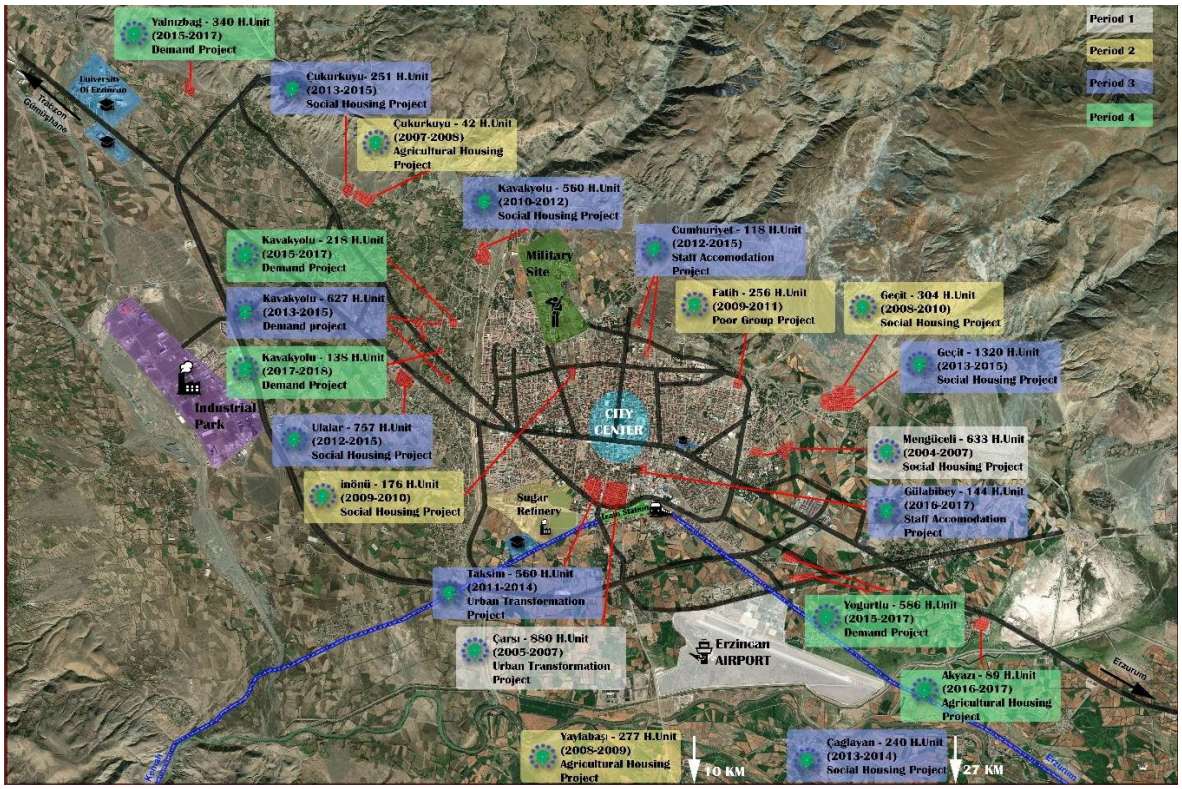


Figure 4 Central district TOKI housing investments between 2000 and 2018 (Housing Development Administration of the Republic of Türkiye, n.d.)

3.3. Data, Design, and Analysis

In this study, the spatial and economic impact and change created by TOKI housing investments in the Central district of the Erzincan province are analyzed by focusing on the period between 2004 and 2018. In this study, Erzincan city is examined as an exploratory case study.

At the local level, spatial change can be explained by urban growth, land use, or land cover changes over a specific period. Analyzing past trends in urban growth, land use, and land cover changes is important for evaluating current and future land use policies (Liu, 2018). CORINE data is used for various purposes in Europe, such as to determine the effects of urbanization and agricultural activities on land cover changes, to monitor and manage changes in natural areas. Therefore, many studies use CORINE data to detect urban sprawl, land use, and land cover change (Czyża et al., 2023; Aksoy et al., 2022; Çetin et al., 2021; Şahin et al., 2021; Cieślak et al., 2020). In this study, CORINE data was used to understand the spatial impact of TOKI housing investments in a small-to-medium-sized urban area that does not have metropolitan characteristics at the local level — in other words, to detect spatial growth or land use change during the specified period. However, it is clear that simply assessing spatial growth or land use patterns is insufficient. Observing changes in urban areas can often be done through the manual interpretation of aerial photographs. Indeed, comparing different images of residential areas allows for the visualization of construction activities (Kressler & Steinnocher, 2001). This study examines where TOKI housing investments were made during the specified period, what kind of urban fabric they created, and whether they caused development in their surroundings over time. On the other hand, it is also possible to examine real estate sales data spatially and temporally in the examination of spatial impact (Erdoğan & Memduhoğlu, 2019). In particular, spatial statistics are widely used to determine neighborhood effects in the housing market (Anselin, 2018). In this study, it is necessary to examine housing sales values spatially and temporally between the specified periods. However, housing sales data for the period between 2004-2018 for the central settlement of Erzincan are not available. Therefore, this data could not be used in the study. In contrast, to understand the dynamism of the housing market and, in particular, the impact of TOKI projects on the surrounding area, the number of land use changes within the 500 m and 1000 m buffer zones of these projects was analyzed. Land use changes include conversions from undeveloped to developed or from undeveloped land to building plots. Land use change data was obtained from the Land Registry and Cadastre Information System (TAKBIS) system.

The impact of construction activities is important in determining the economic impact of housing investments at the local level. This is because housing projects provide significant gross added value to the local economy by creating direct employment during the construction phase and indirect and triggered employment during the operation and management phases (Wardrip et al., 2011). The construction sector acts as the locomotive of the economy by affecting more than 200 sub-sectors (Aydın, 2016). Indeed, Alkay et al. (2019) based their measurement of the economic impact of construction activities on data such as planning permits or construction permits. Accordingly, in this study, the number of construction permits, and occupancy permits, housing sales data, and housing sales figures in the immediate surroundings (500 m and 1000 m) of TOKI projects for the determined period were used to understand the change in terms of spatial and economic dimensions. On the other hand, it is stated that the population variable is an important factor that positively affects the economic growth performance of cities (Sun et al., 2021). Therefore, population data was also used as a variable in the study. On the other hand, local-scale housing investments can act as economic catalysts in terms of job creation and the sustainability of services (Tibaijuka, 2009). Therefore, the variable of change in the number of business licenses during the determined period was also used in this study. To further understand the economic impact, the number of housing sales within the 500m and 1000m buffer zones of TOKI projects was analyzed. Sales figures in the immediate surroundings of TOKI projects indicate whether or not these projects have an economic impact on the surrounding area. These sales figures were obtained from the TAKBIS system.

In addition, to support the analyses conducted under the headings of economic and spatial dimensions, the impact of TOKI was revealed by conducting short face-to-face interviews with important actors who are influential in the district center as local and central government, between March 20-24, 2023 (see Table 2). According to the results of these face-to-face interviews, the effectiveness of TOKI was measured, and the extent of its impact was revealed through short interviews with important actors in terms of their authority and influence at the local level.

Table 2 Institutions and Organizations Interviewed in the Central District of Erzincan Province

Category	Interviewees	Interview Results	Time (Minute)
Public Sector	Erzincan Governorship / Provincial Planning Directorate	TOKI initially came to build hospitals, schools, and police stations. However, there is a housing shortage in the province.	20
	Erzincan Municipality / Private Secretary Directorate	TOKI is needed in the city for low-income and disaster housing.	15
	Erzincan Municipality / Deputy Mayor	The factors increasing housing prices are the revaluation rate, inflation, profit increase, trade volume, and new zoning regulations; TOKI has no influence on this.	30
	Land Registry Office / Land Registry Director	The construction sector is quite active in the city due to renovation and remodeling projects.	20
Professional Chamber	Chamber of Industry and Trade/General Secretary	The investment and social life expenses are limited, housing is seen as an investment. However, it is not bought to be rented out, but as an investment for oneself and one's children.	20
Private Sector	Fuar Construction Company	It is stated that TOKI has no impact on the city's economy. The subcontractors who undertook the work are not paying local businesses.	30
	Dağ Real Estate Office	Housing for low-income and disaster relief is needed in the city through TOKI. Apart from that, housing production is carried out with local contractors for local development.	30

3.3.1. Analysis for Changes in Spatial Dimension

For the analysis, three variables are used to understand whether housing investments affect spatial change in Erzincan city. For this purpose, the variables examined under the title of spatial dimension are the change between 2004 and 2018 based on CORINE data and the change data between 2004 and 2018 based on satellite images (see Table 3).

Table 3 Variables Used in the Study

Analysis for Changes in Spatial Dimension		
No	Variables	Source
V1	The change between 2004 and 2018	CORINE data (Ministry of Agriculture and Forestry, 2022)
V2	The change data between 2004 and 2018	Satellite images (Google, n.d.)
V3	Number of land use changes in the immediate surroundings (500m. and 1000m.) of TOKI projects	Land Registry and Cadastre Information System (TAKBIS)
Analysis for Changes in the Economic Dimension		
V4	Total building permit change in the central district between 2004 and 2018	Erzincan Municipality (Erzincan Center Municipality, 2023)
V5	Change in the number of business licenses in the city center between 2004 and 2018	Erzincan Municipality (Erzincan Center Municipality, 2023)
V6	Number of housing sales in the city center between 2013 and 2018	TUIK (Turkish Statistical Institute, 2023)
V7	Housing sales figures in the immediate surrondings (500m. and 1000m.) of TOKI projects.	Land Registry and Cadastre Information System (TAKBIS)

For variable V1, the CORINE data is used, and the data represents the land cover/use classification determined by the European Environment Agency. Within the scope of the data,

artificial areas and natural restrictive boundaries that show land cover/use with the computer-aided visual interpretation method on satellite images are determined. In the study, the spatial development of the Erzincan city center between 2004 and 2018 is analyzed within the scope of the data (Ministry of Agriculture and Forestry, 2022). Accordingly, in the Central district of Erzincan province with a surface area of 11,903 km², the urban area, which is an artificial zone, has increased by 0.12% in average between 2000 and 2018, forest and semi-natural areas increased by 0.54%, and agricultural areas decreased by 1.03%. The artificial zone area of the central district was 529 ha between 2000 and 2006. The area has decreased to 397.40 ha between 2006 and 2012, and 316.84 ha between 2012 and 2018. A total area of 714.24 hectares has been transformed into an urban area. The data demonstrates the spatial growth in the urban region. However, the data does not provide any information about the extent or characteristics of spatial change. For another variable, V2, satellite images (Google, n.d.) are used to understand the spatial change of the city area in Erzincan city center before and after TOKI housing production. A comparison is made using satellite images between 2004 and 2018. Besides, the population data of the Central district of Erzincan province and the data containing floor heights of neighborhood-based buildings are examined, and comparisons are made in the increase in city area.

According to the analysis, the increase in the city area between 1987 and 2006 was 31.37%. The increased value is proportional to the population increase between 1985 and 2000 (Yücer & Erener, 2016). Although there is no population data for the Central district of Erzincan city between 2004 and 2006, the population information is analyzed within the scope of the growth in the city area with the population distribution data obtained from the information of the existing years. While population growth was at a relatively constant level from 2007 to 2010. The population increased by 13% in 2010. It had remained at a relatively constant level until 2018. There was a significant population increase of 46% in 2018 (see Figure 5). Compared to 2007, the population increased by 54,239 people in 2018, and this increase corresponds to 0.5% in average. Considering the same dates for Türkiye, population growth is calculated as 0.1% in average. As an example of dynamic and non-dynamic cities in terms of population, Antalya province has an average population increase of 0.3%, Istanbul, Ankara, Bursa, and Sırnak provinces have an average population increase of 0.2%, Izmir, Bayburt, Adıyaman, and Balıkesir provinces have an average population increase of 0.1%. The population of Kars and Ardahan provinces decreased by 0.1% in average between these years. It is calculated that the population of Artvin province remains constant. It can be concluded that this increase in the central district of Erzincan is at the same rate as the dynamic cities and that spatial growth in the city area is inevitable with the population increase in this period (see Figure 5), (Turkish Statistical Institute, 2020).

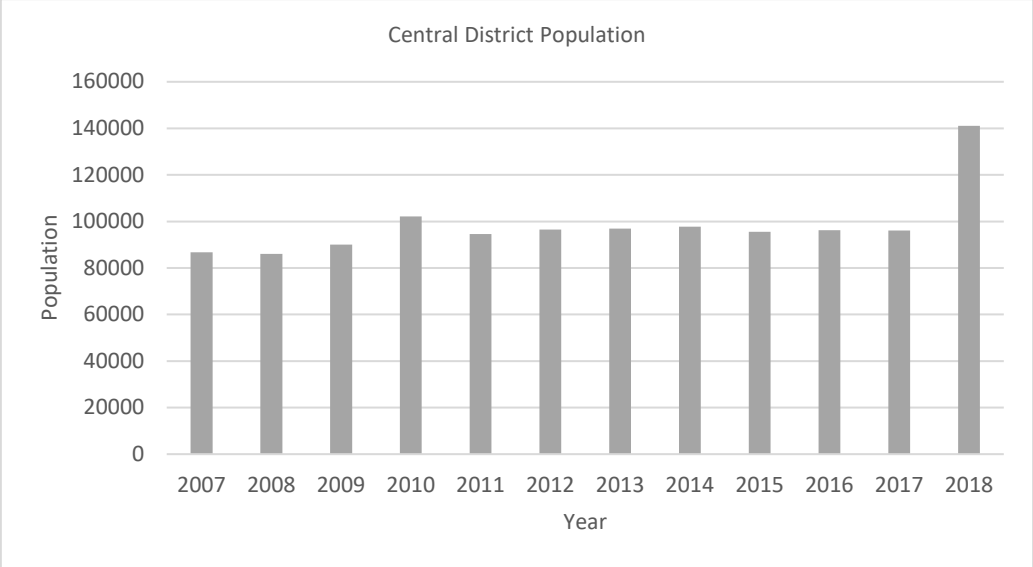


Figure 5 Erzincan province central district population data between 2007 and 2018 (Turkish Statistical Institute, 2020)

Most of the existing buildings in the city have 1 or 2 storeys. 1-storey buildings; In Yenimahalle, İnönü, Cumhuriyet, Akşemsettin, Atatürk, Fatih, Halitpaşa, Kızılay, Hocabey, Taksim, Gülabibey, Karaağaç, İzzetpaşa, and Ersevenler neighborhoods, 2-storey buildings; In Mengüceli, Bahçelievler, Barbaros, Başbağlar, and Kazımkarabekir neighborhoods, 3-storey buildings; In Aslanlı, Yavuzselim, Ergenekon, Mimarsinan, and Yunusemre neighborhoods. It is concentrated in the Çarşı neighborhood with 4-storey buildings (see Figure 6).

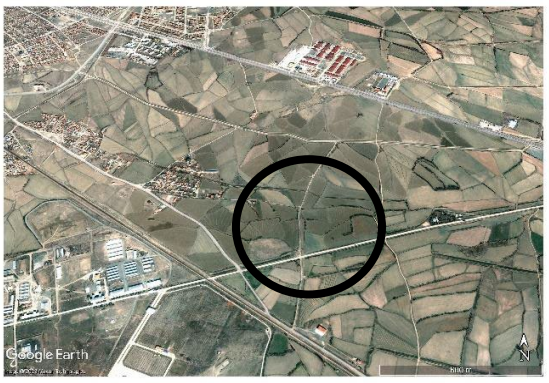
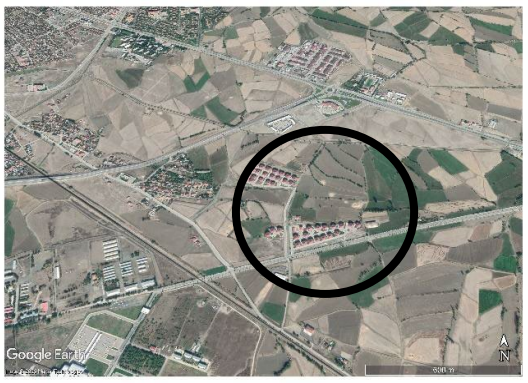
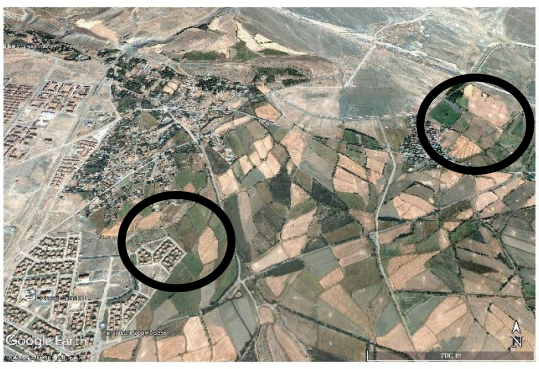
Figure 6 Erzincan province central district neighborhood map (Erzincan Center Municipality, 2023)

Unlike other cities, in Erzincan, apart from the commercial center area, low-rise buildings are located in the neighborhoods in the city core, and high-rise (3-4) buildings are located on the city periphery. It is thought that the earthquakes that occurred over time had an impact on the development of this situation (Erzincan Center Municipality, 2010).

When the satellite images in Figure 7 are examined, after the TOKI projects, there are some changes in the space depending on the project type (Google, n.d.). For example, in the central neighborhoods of Taksim and Çarşı, the texture created by single-storey or 2-storey, dilapidated, and earthquake-prone buildings has created a change in the space towards the concept of mass housing consisting of four-storey buildings. The practices in the towns of Kavakyolu, Ulalar, and Yoğurtlu have created living spaces within themselves and created a different spatial texture from the surroundings. However, according to the analysis, the projects with the agricultural village projects do not create any construction around them, and there is no spatial growth.

CORINE data shows that the urban area has grown spatially. However, this data does not provide any information about the extent or characteristics of spatial change. In contrast, satellite images (Google, n.d.) were used to determine the spatial changes in the urban fabric of Erzincan city center before and after the TOKI housing construction.

	
Satellite image of the center district in 2004	Satellite image of the center district in 2018
	
Satellite image of Taksim-Carsi district in 2005	Satellite image of Taksim-Carsi district in 2018
	
Satellite image of central-Cumhuriyet district in 2004	Satellite image of central-Cumhuriyet district in 2018
	
Satellite image of Cukurkuyu district in 2004	Satellite image of Cukurkuyu district in 2018

	
Satellite image of Caglayan district in 2006	Satellite image of Caglayan district in 2018
	
Satellite image of Ulalar-Kavakyolu district in 2004	Satellite image of Ulalar-Kavakyolu district in 2018
	
Satellite image of Yogurtlu district in 2004	Satellite image of Yogurtlu district in 2018
	
Satellite image of Gecit-Menguceli district in 2004	Satellite image of Gecit-Menguceli district in 2018

Satellite image of Yaylabasi district in 2004

Satellite image of Yaylabasi district in 2018

Satellite image of Yalnızbag district in 2006

Satellite image of Yalnızbag district in 2018

Satellite image of Akyazi district in 2005

Satellite image of Akyazi district in 2018

Figure 7 Satellite images of Erzincan central district between 2004 and 2018 (Google, n.d.)

This study analyzes land use change procedures in the immediate surroundings of TOKI projects. (V3). Among these projects, the Taksim Project (Projects 9-10 listed in Table 4) is an urban transformation and development project that began in 2011 in two phases and was defined in 2014 as the construction of 560 residences, a primary school with 16 classrooms, a mosque, and a library. Within the scope of this study, two buffer zones were identified at distances of 500 m and 1000 m from the project. Accordingly, land use change transactions were examined on a total of 642 properties between 2004 and 2018 (See Table 4). It was determined that 10 land use change transactions occurred on 12 properties located within the project area, and 22 land use change transactions occurred on 477 properties within 500 meters of the project. Within 1000 meters, 42 land use change transactions occurred on 153 properties. This indicates that land use change transactions occurred on 642 properties in the immediate vicinity during the 15-year period. Based on this number, it was determined that there were five land use change transactions per year, which does not indicate significant real estate activity. Projects 11, 12, and 13 were not examined separately due to their proximity to the Taksim Project. Projects located in Mengüceli and Geçit

were considered together due to their proximity (Projects 1, 2, 3, 4, and 5 in Table 4). The analysis included properties within 500 meters of these projects. It has been determined that 32 land use changes occurred in 32 properties within a 500 m distance, and 75 land use changes occurred in 75 properties within a 1000 m distance. Furthermore, the projects in Kavakyolu and Ulalar neighborhoods were analyzed together due to their proximity (projects numbered 18 in Table 4). According to the analyses, it was determined that 397 land use changes occurred in 646 properties within a 500 m distance of the Kavakyolu projects. For the research period (2004-2018), the average is calculated as 26 changes per year. This indicates that the region is dynamic in terms of urban development. For the Ulalar settlement (project number 18 in Table 4), 20 land use changes occurred in 115 properties within a 500 m distance, and 10 land use changes occurred in 74 properties within a 1000 m distance. For the Çukurkuyu settlement (projects numbered 19 and 20 in Table 4), 20 land use changes occurred in 115 properties within a 500 m distance, and 10 land use changes occurred in 74 properties within a 1000 m distance. 22 properties underwent 22 land use change procedures within a 500 m distance, and 19 properties underwent 18 land use change procedures within a 1000 m distance. Other projects were analyzed separately due to their distance from the central district. In the Çağlayan settlement (project number 21 in Table 4), no land use change procedures were carried out on 22 properties within a 500 m distance, and three land use change procedures were carried out on 15 properties within a 1000 m distance. In the Yalnızbağ settlement (project number 22 in Table 4), 51 land use change procedures were carried out on 47 properties within a 500 m distance, and 17 land use change procedures were carried out on 15 properties within a 1000 m distance. In the Yoğurtlu neighborhood (project number 23 in Table 4), 24 properties within a 500 m distance, two land use change procedures were carried out. 22 properties within a 1000 m distance, five land use change procedures were carried out. In the Akyazı settlement (project number 24 in Table 4), within a 500 m distance. It was determined that there were 22 land use change transactions on 22 properties within a 1000 m distance, 34 land use change transactions on 27 properties within a 1000 m distance, 12 land use change transactions on 11 properties within a 500 m distance in Yaylabaşı town, and 11 land use change transactions on 11 properties within a 1000 m distance. It was concluded that the number of land use change transactions in these projects is not high and that development activity is stagnant in these project areas.

Table 4 Number of Land Use Changes in Buffer Zones of TOKI Projects, Period 2004-2018

			500 m.	1000 m.	500 m.	1000 m.	500 m.	1000 m.
TOKI Project Group/ Project Name	Project Type	TOKI Housing Number	Land-Block/Parcel Numbers	Land-Block/Parcel Numbers	Parcel Area m2	Parcel Area m2	Land Use Change Numbers	Land Use Change Numbers
1- Mengüceli Project Stage 1 2-Mengüceli Project Stage 2 3-Mengüceli Project Stage 3	Social Housing	153 368 112	32 (30%)	75 (70%)	17,351.27 (23%)	57,177.60 (77%)	32 (30%)	75 (70%)
4-Geçit Project Stage 1 5-Geçit Project Stage 2 6-İnönü Project	Social Housing	304 1320 176						
7-Fatih Project	Poor Housing	256						
8-Cumhuriyet Project	Military Housing	118	75 (70%)	32 (30%)	57,177.60 (77%)	17,351.27 (23%)	75 (70%)	32 (30%)
9-Taksim Project Stage 1 10-Taksim Project Stage 2	Urban Transformation and Development Project	96 464						
11-Çarşı Project Stage 1 12-Çarşı Project Stage 2	Urban Transformation and	368 512						

13-Gülabibey Project	Development Project Social Housing	144	489 (76%)	153 (24%)	204,446.30 (73%)	75,451.56 (27%)	32 (43%)	42 (57%)
14-Kavakyolu Project Stage 1 15-Kavakyolu Project Stage 2 16-Kavakyolu Project Stage 3 17-Kavakyolu Project Stage 4	Social Housing Demand Organization	560 627 218 138	646		544,638.09		397	
18-Ulalar	Social Housing	757	115 (61%)	74 (39%)	224,997.79 (81%)	51,723.43 (19%)	20 (67%)	10 (33%)
19-Çukurkuyu	Social Housing	251	22 (55%)	18 (45%)	20,286.56 (68%)	9,339.78 (32%)	22 (46%)	19 (54%)
20-Çukurkuyu	Agricultural Village	42						
21-Çağlayan	Social Housing	240	22 (59%)	15 (41%)	16,655.61 (20%)	67,260.33 (80%)	0	3
22-Yalnızbağ	Demand Organization	340	47 (76%)	15 (24%)	23,836.72 (83%)	4,957.22 (17%)	51 (75%)	17 (25%)
23-Yoğurtlu.	Demand Organization	586	24 (52%)	22 (48%)	10,982.00 (55%)	8,944.87 (45%)	2 (29%)	5 (71%)
24-Akyazı	Agricultural Village	89	22 (45%)	27 (55%)	5,973.39 (14%)	37,646.20 (86%)	22 (39%)	34 (61%)
25-Yaylabaşı	Agricultural Village	277	11 (50%)	11 (50%)	9,992.01 (54%)	8,639.18 (46%)	12 (52%)	11 (48%)

3.3.2. Analysis for Changes in the Economic Dimension

Four variables were determined, and an attempt was made to understand whether housing investments impact city economic development. For this purpose, the variables are: 'Total building permit change in the central district between 2004 and 2018', 'Change in the number of business licenses in the city center between 2004 and 2018', 'Number of housing sales in the city center between 2013 and 2018' and 'the number of housing sales in the immediate surroundings (500 m and 1000 m) of TOKI projects.'

The economic vitality of the district center is understood with the variable of total building permit change in the central district between 2004 and 2018. The total building permit in the Erzincan Central district between 2004 and 2018 (V4) is examined according to the graph in Figure 8. The period spanning from 2004 to 2010 was marked by significant fluctuations. There is a significant increase in 2010. According to Figure 8, the highest production was in 2014; this situation continued in 2015, but started to decline after 2015 (Erzincan Center Municipality, 2023).

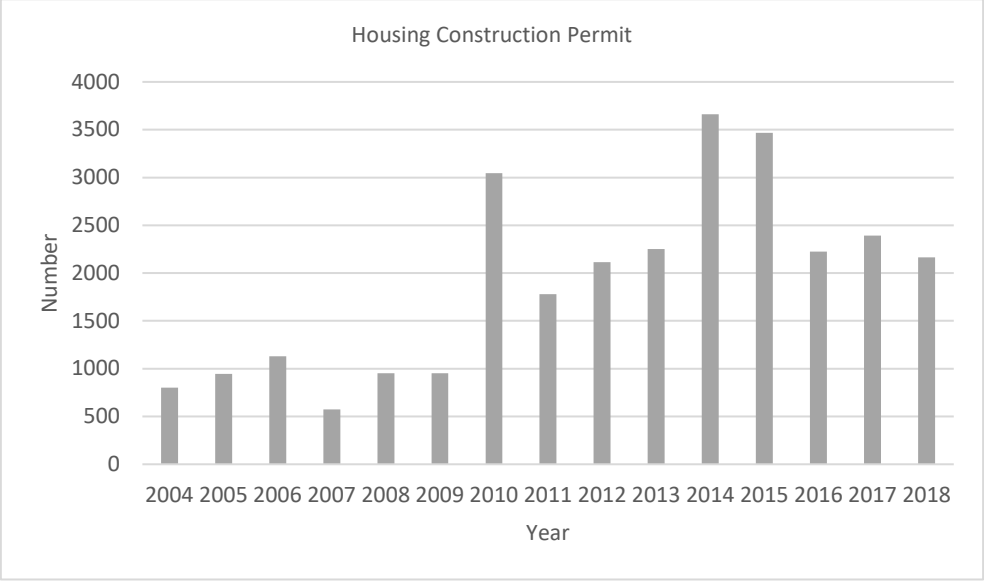


Figure 8 Erzincan province housing construction permit status between 2004 and 2018 (Erzincan Center Municipality, 2023)

On the other hand, when examining the permit and settlement situation of the Central district in 2004, there was no public housing investment that year. In 2004, there was mainly private housing investment, and most new constructions were in the İnönü neighborhood. The Cumhuriyet neighborhood showed a less intense development in that term (Figure 9). TOKI produced a total of 1055 houses between 2008 and 2011. The most production was made by TOKI between 2012 and 2015. That is, the housing production of the construction sector in the central district is not in direct proportion to TOKI.

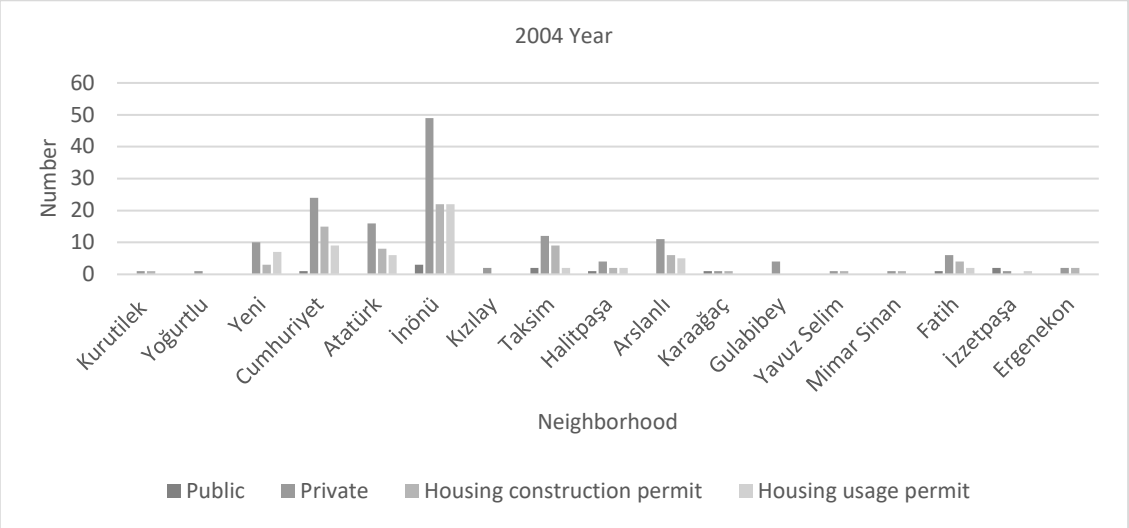


Figure 9 Erzincan central district housing license and settlement status in 2004 (Erzincan Center Municipality, 2023)

On the other hand, in 2018, new construction or building renovation took place mostly in the Cumhuriyet neighborhood, followed by İnönü, Atatürk, and Mimarsinan neighborhoods, respectively (Figure 10).

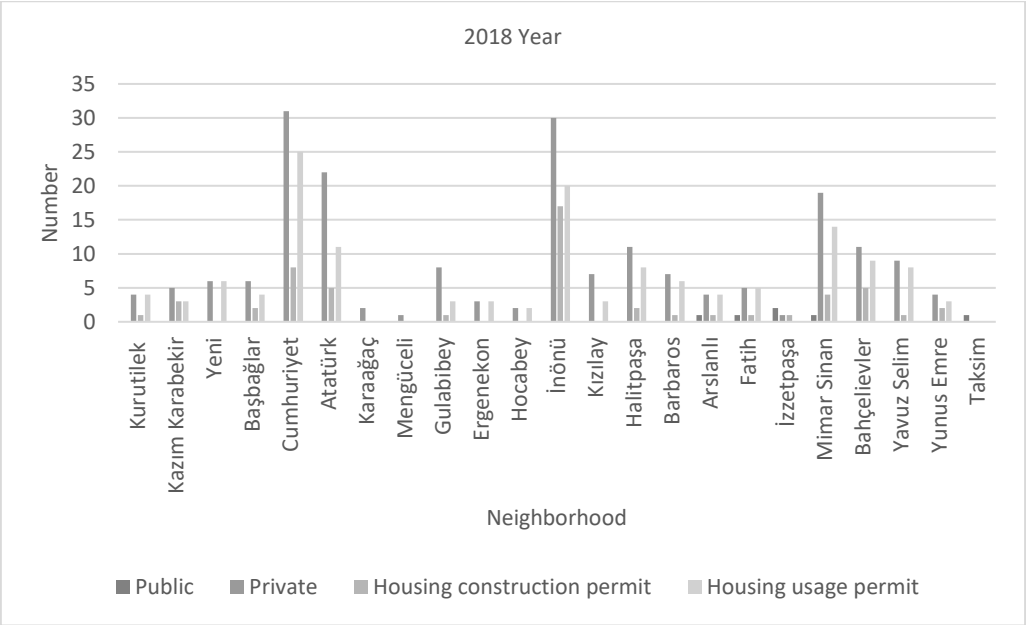


Figure 10 Erzincan central district housing license and settlement status in 2018 (Erzincan Center Municipality, 2023)

The change in the number of business licenses in the city center between 2004 and 2018 (V5) and the existence and vitality of commerce in the city center are examined. There is no significant decrease between 2005 and 2018. However, the year with the highest number of workplaces opened was 2014 (Figure 11). This period saw the highest number of houses produced by TOKI in

the district, in comparison to other years. Therefore, a correlation can be established between the number of business openings and the 4,577 houses produced by TOKI between 2012 and 2015.

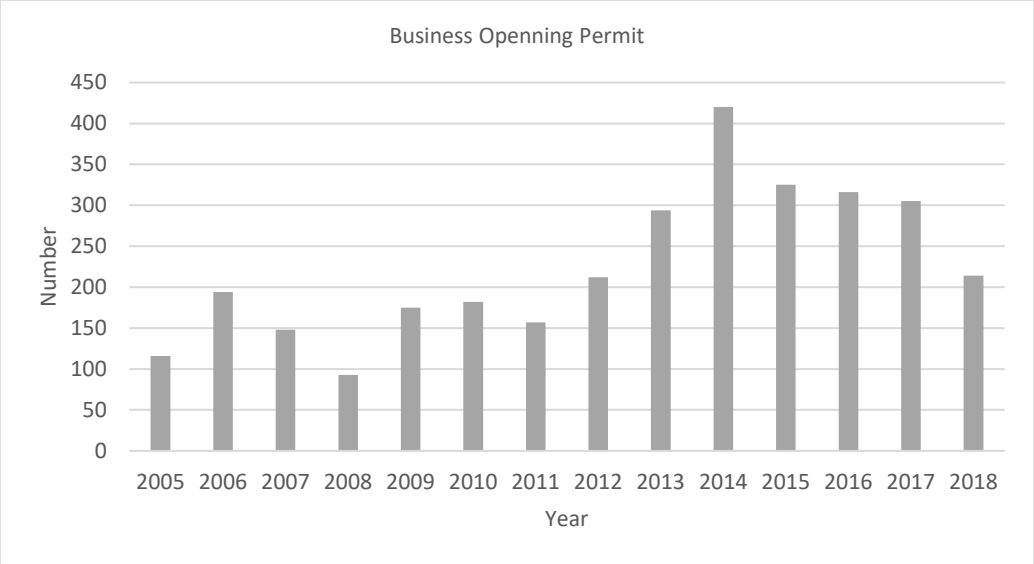


Figure 11 Business license status in Erzincan central district (Erzincan Center Municipality, 2023)

The number of housing sales in the city center between 2004 and 2018 (V6) is examined after 2013 due to a lack of data. When these years are examined, sales in the province were almost at the same rate between 2012 and 2015, which were the years when TOKI produced the most, while mortgage sales were at the highest rate in 2013. They decreased at the same rate in 2014 and 2018 (Figure 12).

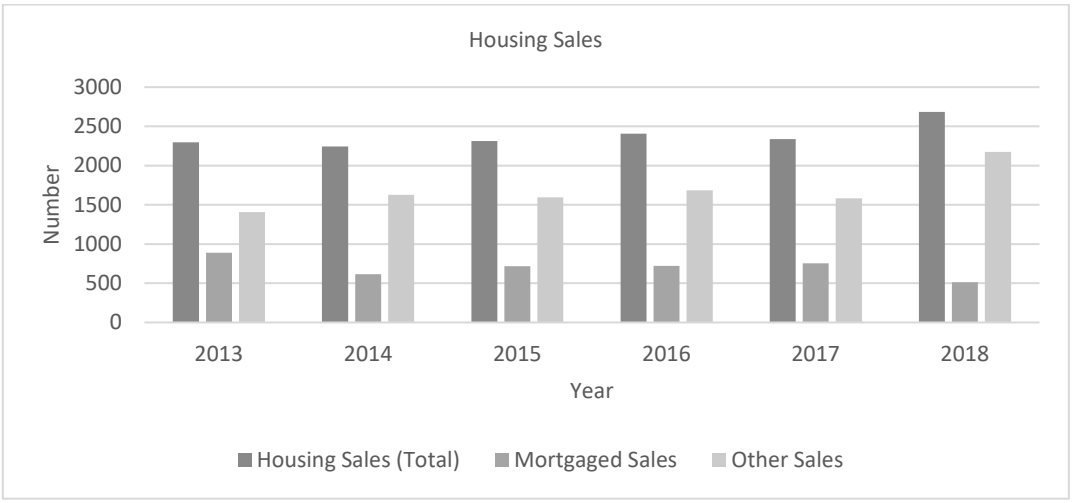


Figure 12 Housing sales situation in Erzincan province 2013-2018 (Turkish Statistical Institute, 2023)

This study attempted to measure the impact of TOKI investments, both economically and spatially, through a total of seven variables (see Table 3) using the descriptive analysis method. According to the findings, while the population of the Central district increased by 5% between 2004 and 2018, it is seen that TOKI investments are not shaped according to the needs of the population. During this period, two major urban transformation and development projects were carried out in the central district, and the city was transformed spatially. In these projects, the principle of on-site transformation, not displacement, has been adopted. Other projects carried out outside the center are demand projects carried out with the weighted demand collection method and agricultural village projects. The most basic effect of spatial change is that the treasury and public lands on the city periphery were opened to development, creating a change in the growth direction of the city. However, these projects did not create a spatial growth effect in their surroundings but changed the character of the place. The main reason for this can be related to the

fact that the rate of population growth and urbanization is not high. On the other hand, TOKI had no effect in the context of the variables examined in economic terms.

To understand the economic impact of TOKI housing investments in the city center of Erzincan between 2004 and 2018, the number of housing sales in the immediate vicinity (500 m and 1000 m) of TOKİ projects was analyzed (V7). Sales transactions for a total of 642 properties within the Taksim Project (Projects 9-10 in Table 5) were examined between 2004 and 2018. 23 sales transactions were recorded for 12 properties located within the project area. In the Hocabey neighborhood, 500m from the project, 193 sales transactions were recorded for 477 properties. In the Halitpaşa neighborhood, 1000m. from the project, 99 sales transactions were recorded for 153 properties. This indicates that sales transactions occurred for 642 properties over the 15-year research period. Considering this on an annual basis, the number of sales transactions is 21, which does not reflect significant real estate activity. Projects 11, 12, and 13 in Table 5 were not examined separately due to their proximity to the Taksim Project. The projects located in the Mengüceli and Geçit settlements (projects 1, 2, 3, 4, and 5 in Table 5) were evaluated together due to their proximity. It was determined that seven sales transactions occurred in 32 properties within 500 m of the projects, and 41 sales transactions occurred in 75 properties within 1000 m of the projects. The projects in the Kavakyolu and Ulalar settlements (projects 14, 15, 15, 17, and 18 in Table 5) were analyzed together due to their proximity. Accordingly, it was determined that 587 sales transactions occurred in 646 properties within 500 m of the Kavakyolu projects. For the research period (2004-2018), the average is calculated as 39 transactions per year. This indicates that the region is active in terms of sales transactions. For Ulalar, 83 sales transactions occurred in 115 properties within 500 m, within 1000 m. 72 sales transactions were completed on 74 properties within a certain distance. In Çukurkuyu town, 11 sales transactions were completed on 22 properties within a 500 m distance, and two sales transactions were completed on 18 properties within a 1000 m distance. In Çağlayan settlement (Project No. 21 in Table 5), 2 sales transactions were completed on 22 properties within a 500 m distance, and seven sales transactions were completed on 15 properties within a 1000 m distance. In Yalnızbağ settlement (Project No. 22 in Table 5), 18 sales transactions were completed on 47 properties within a 500 m distance, and two sales transactions were completed on 15 properties within a 1000 m distance. In Yoğurtlu neighborhood (Project No. 23 in Table 5), eight sales transactions were completed on 24 properties within a 500 m distance, and 1000 m. It was determined that there were 10 sales transactions in 22 properties within a 500 m distance in the Akyazı settlement (project number 24 in Table 5), no sales transactions in 22 properties within a 500 m distance, seven sales transactions in 27 properties within a 1000 m distance, six sales transactions in 11 properties within a 500 m distance in the Yaylabaşı town, and six sales transactions in 11 properties within a 1000 m distance. It was concluded that there was no sales transaction activity in these project areas, as this rate was not high for the research period.

Table 5 Housing Sales Numbers in Buffer Zones of TOKI Projects, Period 2004 – 2018

			500 m.	1000 m.	500 m.	1000 m.	500 m.	1000 m.
TOKI Project Group/ Project Name	Project Type	TOKI Housing Number	Land-Block/Parcel Numbers	Land-Block/Parcel Numbers	Parcel Area m2	Parcel Area m2	Housing Sales Numbers	Housing Sales Numbers
1- Mengüceli Project Stage 1 2-Mengüceli Project Stage 2 3-Mengüceli Project Stage 3	Social Housing	153 368 112	32 (30%)	75 (70%)	17,351.27 (23%)	57,177.60 (77%)	7 (15%)	41 (85%)
4-Geçit Project Stage 1 5-Geçit Project Stage 2 6-İnönü Project	Social Housing	304 1320 176						
7-Fatih Project	Poor Housing	256						
8-Cumhuriyet Project	Military Housing	118	75 (70%)	32 (30%)	57,177.60 (77%)	17,351.27 (23%)	41 (85%)	7 (15%)

9-Taksim Project Stage 1 10-Taksim Project Stage 2	Urban Transformation and Development Project	96 464	489 (76%)	153 (24%)	204,446.30 (73%)	75,451.56 (27%)	216 (69%)	99 (31%)
11-Çarşı Project Stage 1 12-Çarşı Project Stage 2	Urban Transformation and Development Project	368 512						
13-Gülabibey Project	Social Housing	144						
14-Kavakyolu Project Stage 1 15-Kavakyolu Project Stage 2 16-Kavakyolu Project Stage 3 17-Kavakyolu Project Stage 4	Social Housing Demand Organization	560 627 218 138	646		544,638.09		587	
18-Ulalar	Social Housing	757	115 (61%)	74 (39%)	224,997.79 (81%)	51,723.43 (19%)	83 (54%)	72 (46%)
19-Çukurkuyu	Social Housing	251	22 (55%)	18 (45%)	20,286.56 (68%)	9,339.78 (32%)	11 (85%)	2 (15%)
20-Çukurkuyu	Agricultural Village	42						
21-Çağlayan	Social Housing	240	22 (60%)	15 (40%)	16,655.61 (20%)	67,260.33 (80%)	2 (22%)	7 (78%)
22-Yalnızbağ	Demand Organization	340	47 (76%)	15 (24%)	23,836.72 (83%)	4,957.22 (17%)	18 (90%)	2 (10%)
23-Yoğurtlu.	Demand Organization	586	24 (52%)	22 (48%)	10,982.00 (55%)	8,944.87 (45%)	8 (45%)	10 (55%)
24-Akyazı	Agricultural Village	89	22 (45%)	27 (55%)	5,973.39 (14%)	37,646.20 (86%)	0	7
25-Yaylabaşı	Agricultural Village	277	11 (50%)	11 (50%)	9,992.01 (54%)	8,639.18 (46%)	6 (50%)	6 (50%)

4. Conclusion and Evaluation

This study aimed to understand the impact of TOKI housing investments in the central region of Erzincan province between 2004 and 2018, focusing on spatial and economic dimensions. It sought to answer questions such as: What is the impact of public housing policies on the shaping processes of urban areas in Türkiye, and how has TOKI, which has extensive powers as a result of legal regulations after 2002, impacted the economic and spatial development of Erzincan Central district, a non-metropolitan province where TOKI has made the most investments? The scope of this study was to interpret the transformation of public housing policy in Türkiye, particularly since 2002, through the lens of a medium-sized city. To understand the economic and spatial impact of this transformation in the context of public investments, the study examined the central region of a non-metropolitan province where the most housing production occurred between 2004 and 2018. In Türkiye, the legislation introduced after 2002 regarding the shaping of urban areas through housing policies boosted the quantity of housing produced, and it was decided that this would be carried out through TOKI. The analyses in this study were interpreted based on the data obtained. The significant limitation of this study is the lack of locally produced, city-level data. The study was particularly limited because there was not enough data collected at the local level during the research period between 2004 and 2018. This data was produced by institutions and the national statistics agency. The chosen analysis in the study focuses on the micro level and the study's reliance on descriptive comparisons. Therefore, the study does not provide a comprehensive evaluation of the extensive impact of TOKİ investments.

This study revealed the economic and spatial impacts of TOKI investments in the central Erzincan region at the urban scale. Accordingly, the effects of TOKI public housing investments on the economic and spatial development of the central Erzincan region are both positive and negative.

The findings show that while TOKI investments create a spatial impact, they do not play a decisive role economically. Similarly, Yılmaz Şimşek's (2021) study shows that TOKI's housing production activities in Van province did not have a positive impact on the spatial development of the city; on the contrary, it created a new development path that forced authorities to act in terms of service provision and created a necessary development axis for cities (Gürbüz et al., 2023).

The research period revealed that the analysis of property type changes and housing sales transactions recorded in the land registry around TOKI projects did not yield meaningful results. In fact, while TOKI has had a positive impact on the spatial transformation of the city through two transformation projects carried out in cooperation with local administrations, aimed at transforming dilapidated areas in the disaster-prone city center into planned settlements, it has had a negative impact in its projects in neighborhoods outside the city center. In particular, it has led to negative consequences in the west-northwest development of the city in terms of the city's architectural character and the increasing costs of infrastructure services such as transportation, electricity, and water. This situation shows that its almost unlimited usage rights, planning and development rights, and the power to implement projects on almost any plot of land it desires have led to criticisms such as disrupting urban integrity, invalidating local planning practices, changing the direction of the city's growth and development, and creating increased infrastructure and transportation costs while exercising these powers (Tantan & Türk, 2024). Du et al. (2017) revealed an inequality in housing demand between small and large cities in China and stated that small cities have their own housing demand models different from large cities in China. Therefore, it is argued that housing policy cannot be effective unless local conditions are taken into account. The Erzincan example reveals that public housing policy shaped urban space between 2004 and 2018, with diverse housing projects implemented in the central district and villages regardless of actual needs. It was found that TOKİ (Housing Development Administration of Türkiye) projects caused spatial changes depending on the project type. In the central neighborhoods of Taksim and Çarşı, the urban fabric, consisting of dilapidated single-storey or two-storey buildings at risk of earthquakes, shifted towards four-storey structures and a mass housing concept. Projects involving agricultural villages did not create surrounding urban development or spatial growth. The projects in Kavakyolu, Ulalar, and Yoğurtlu created self-contained living spaces and resulted in a distinct spatial texture from their surroundings. While the artificial urban area of the central district decreased between 2000 and 2006, the urban area grew between 2006 and 2012. TOKİ construction during these years was directly proportional to this growth.

This demonstrates a linear relationship between TOKI projects and the growth of the urban area. Furthermore, based on field interviews, it was concluded that TOKI is desirable in the city as an earthquake, disaster, or social housing project, but does not play a decisive economic role. This article aims to understand the impact of public housing investments on small city units and to contribute to the development of different methods and analyses for future studies on public investments. Further studies that use statistical data at the local level are needed to better grasp the economic and spatial impacts of housing policies on cities.

CRediT Authorship Contribution Statement

Banu Tantan: Writing – review & editing, Writing – original draft, Methodology, Investigation, Analysis, Data curation, Conceptualization, Data visualization. Şevkiye Şence Türk: Writing – review & editing, Writing – original draft, Methodology, Investigation, Analysis, Data curation, Conceptualization, Data visualization.

Declaration of Competing 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 paper.

Data Availability

Data will be made available on request.

Ethics Committee Approval

Ethics committee permission is not required.

Note

This study was produced from the "Doctoral Thesis" of the first author of Istanbul Technical University Graduate Education Institute. The title of the thesis is "The Impact of Public Housing Investments on the Economic and Spatial: The Case of Turkey (TOKI)". The first author has been awarded the degree of doctor of philosophy the graduate school division of urban and regional planning urban and regional planning graduate program at 2024 year.

References

Abbaszadeh, G. (2016). Pathology of mass housing projects in Iran (Mehr Housing Plan). *Journal of Fundamental and Applied Sciences*, *8*(3S), 885-915.

Acar Özler, O. (2012). *Ankara güneybatı çeperinde kent mekânının üretimi* [The production of urban space in the southwestern periphery of Ankara] (Publication No. 329158) [Doctoral dissertation, Middle East Technical University]. Middle East Technical University Institutional Repository.

Akın, E. (2007). *Kentsel gelişme ve kentsel rantlar: Ankara örneği* [Urban development and urban windfall gains: The Ankara example] [Doctoral dissertation, Ankara University]. Ankara University Open Archive.

Akinsulire, A. A., Idemudia, C., Okwandu, A. C., & Iwuanyanwu, O. (2024). Economic and social impact of affordable housing policies: A comparative review. *International Journal of Applied Research in Social Sciences*, *6*(7), 1433-1448.

Akkaya, D. (2018). *Kamu kurumları aracılığıyla kent merkezlerinde yapılan kentsel dönüşüm uygulamalarında hak sahipliği dağılımı için bir model önerisi* [A model proposal for distribution in urban transformation practices in city centers through public institutions] [Doctoral dissertation, Yıldız Technical University]. Council of Higher Education Thesis Center.

Akkoç, Y. S. (2018). *Kentsel dönüşüm projelerinin çevre etiği bağlamında değerlendirilmesi: Ankara örneği* [Evaluation of urban transformation projects in the context of environmental ethics: The Ankara example] [Doctoral dissertation, Ankara University]. Council of Higher Education Thesis Center.

Aksoy, T., Dabanli, A., Çetin, M., Şenyel Kürkçüoğlu, M. A., Cengiz, A. E., Çabuk, S. N., Ağaçsapan, B., & Çabuk, A. (2022). Evaluation of comparing urban area land use change with Urban Atlas and CORINE data. *Environmental Science and Pollution Research*, *29*(19), 28995-29015. https://doi.org/10.1007/s11356-021-17766-y

Al-Hafith, O., Satish, B. K., & Wilde, P. (2019). Assessing housing approaches for Iraq: Learning from world spatial experience. *Habitat International*, *89*, Article 102001. https://doi.org/10.1016/j.habitatint.2019.102001

Alkan, L., & Uğurlar, A. (2015). *Türkiye'de konut sorunu ve konut politikaları* [Housing problem and housing policies in Turkey] (Report No. 1). Kent Araştırmaları Enstitüsü.

Alkay, E., Watkins, C., & Övenç, G. (2019). Economic indicators and housing development: Regional-based exploratory analysis in Turkey. *Marmara Üniversitesi İktisadi ve İdari Bilimler Dergisi*, *41*(1), 1-22.

Alper, A. E. (2017). İnşaat sektörünün ekonomik büyümedeki rolü: Türkiye örneği [The role of the construction sector in economic growth: The case of Türkiye]. *Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *26*(2), 239-252.

Altay, C. (2004). *Toplu konutta katılımcı grupların sürece yönelik değer yargıları: Eryaman dördüncü etap örneği, Ankara* [Value judgments of participating groups regarding the process in mass housing: The Eryaman fourth phase example, Ankara] [Doctoral dissertation, Bilkent University]. Bilkent University Institutional Repository.

Altunok, Ş., & Uğurlu, Ö. (2021). Türkiye'nin konut sektöründe ve sosyal konut üretiminde yol arayışları: Konut piyasasına devlet müdahalesinde Çin örneği [Turkey's search for solutions in the housing sector and social housing production: The Chinese example in state intervention in the housing market]. *Çağdaş Yerel Yönetimler Dergisi*, *30*(4), 1-27.

Amidu, A.-R., Agboola, A. O., & Musa, M. (2016). Causal relationship between private housing investment and economic growth: An empirical study. *International Journal of Housing Markets and Analysis*, *9*(2), 272-286. https://doi.org/10.1108/IJHMA-05-2015-0022

Anselin, L. (2018). *Spatial clustering (2)*. GeoDa Center for Geospatial Analysis and Computation.

Arslan, H. (2011). *Sosyal dışlanma ve kentsel haklar bağlamında Türkiye'de kentsel dönüşüm: İzmir-Narlıdere kentsel yenileme uygulaması (Narkent projesi) örneği* [Urban transformation in Türkiye in the context of social exclusion and urban rights: The example of İzmir-Narlıdere urban renewal application] [Doctoral dissertation, Mimar Sinan Fine Arts University]. Council of Higher Education Thesis Center.

Arslan, H. (2014). Türkiye'nin kentleşme sürecinde konut politikalarının evrimi [The evolution of housing policies in Turkey's urbanization process]. *Akademik Bakış Dergisi*, (40), 118.

Aydın, A. (2016). *Investigating the relationship between the recent investments in the construction sector and some economic indicators of Turkey* (Order No. 31677879) [Doctoral dissertation, Middle East Technical University]. ProQuest Dissertations & Theses Global.

Balaban, O. (2012). The negative effects of construction boom on urban planning and environment in Turkey: Unraveling the role of the public sector. *Habitat International*, *36*(1), 26_35. https://doi.org/10.1016/j.habitatint.2011.05.003

Baykal, T., Dikme, H., & Karacan, R. (2018). Causality analysis of the relationship between housing costs and housing supply in Turkey in terms of public housing policies. *Social Sciences Research Journal*, *7*(2), 161-171.

Bell, D., & Jayne, M. (2009). Small cities? Towards a research agenda. *International Journal of Urban and Regional Research*, *33*(3), 683-699. https://doi.org/10.1111/j.1468-2427.2009.00886.x

Beyazıt, E., & Yarım, U. S. (2020). Housing policies in different welfare state models. *Journal of History School*, *13*(48), 3604-3623.

Buckley, R. M., Kallergis, A., & Waine, L. (2016). Addressing the housing challenge: Avoiding the Ozymandias syndrome. *Environment and Urbanization*, *28*(1), 119-138. https://doi.org/10.1177/0956247815627523

Çetin, M., Aksoy, T., Çabuk, S. N., Kürkçüoğlu, M. A. S., & Çabuk, A. (2021). Employing remote sensing techniques to monitor the influence of newly established universities on the urban development process in the respective cities. *Land Use Policy*, *109*, Article 105705. https://doi.org/10.1016/j.landusepol.2021.105705

Cieślak, I., Biłozor, A., & Szuniewicz, K. (2020). The use of the CORINE Land Cover (CLC) database for analyzing urban sprawl. *Remote Sensing*, *12*(2), Article 282. https://doi.org/10.3390/rs12020282

Coşkun, Y. (2014). *Türkiye'deki kurumsal konut finansman sisteminin analizi* [Analysis of the corporate housing finance system in Türkiye] [Doktora tezi, Ankara Üniversitesi]. Ankara Üniversitesi Açık Erişim Sistemi.

Coşkun, Y. (2015). Analysis of the Housing Development Agency (TOKI) model and its financial structure. *Muhasebe Bilim Dünyası Dergisi*, *17*(3), 617-638.

Czyża, S., Szuniewicz, K., Cieślak, I., Biłozor, A., & Bajerowski, T. (2023). An analysis of the spatial development of European cities based on their geometry and the CORINE Land Cover (CLC) database. *International Journal of Environmental Research and Public Health*, *20*(3), Article 2049. https://doi.org/10.3390/ijerph20032049

Doling, J. (1997). *Comparative housing policies: Governments and housing in advanced industrialized countries*. St. Martin's Press.

Du, J., Yang, Y., Li, D., & Zuo, J. (2017). Do investment and improvement demand outweigh basic consumption demand in the housing market? Evidence from small cities in Jiangsu, China. *Habitat International*, *66*, 24-31. https://doi.org/10.1016/j.habitatint.2017.05.006

Ek, F. İ. (2012). *Toplu konut uzlaşıları ve kalite bağlamında tasarım örgütlenmesine etkileri* [Mass housing agreements and their effects on design organization in the context of quality] [Doktora tezi, İzmir Yüksek Teknoloji Enstitüsü]. YÖK Tez Merkezi.

Erdem, N. (2016). Büyük ölçekli kamu yatırımlarının uygulandığı bölgelerdeki taşınmaz değer artışı ve kentleşme üzerinde etkisi: Osmaniye ili örneği [The impact on immovable valuation and urbanization in regional implementations of large-scale public investments: The case of Osmaniye province]. *Uluslararası Sosyal Araştırmalar Dergisi*, *9*(47), 475-486.

Erdoğan, S., & Memduhoğlu, A. (2019). A spatiotemporal exploratory analysis of real estate sales in Turkey using GIS. *Journal of European Real Estate Research*, *12*(2), 207-226. https://doi.org/10.1108/JERER-06-2018-0024

Erzincan Center Municipality. (2010). *Erzincan (City Center) revision zoning plan and plan explanation report*.

Erzincan Center Municipality. (2023). *Urban planning and housing development data* [Unpublished dataset]. (Access Date: 2022)

Esping-Andersen, G. (1990). *The three worlds of welfare capitalism*. Polity Press.

Eşkinat, R. (2015). Türk inşaat sektöründe (TOKİ'nin) yeri ve etkisi [Place and effect of (TOKİ) in the Turkish construction sector]. *Dumlupınar Üniversitesi Sosyal Bilimler Dergisi*, (32), 177_188. https://dergipark.org.tr/tr/pub/dpusbe/issue/4774/65755

Fainstein, S. S., & Campbell, S. (Eds.). (2011). *Readings in urban theory* (3rd ed.). Blackwell Publishing.

Feigenbaum, H. B., & Henig, J. R. (1994). The political underpinnings of privatization: A typology. *World Politics*, *46*(2), 185-208. https://doi.org/10.2307/2950672

Fisher, R. C., & Peters, J. S. (2016). The impact of economic conditions on public investment decisions: Evidence from US states. *Applied Economics*, *48*(23), 2158_2173. https://doi.org/10.1080/00036846.2015.1119725

Ghaedrahmati, S., & Zarghamfard, M. (2021). Housing policy and demographic changes: The case of Iran. *International Journal of Housing Markets and Analysis*, *14*(1), 1-13. https://doi.org/10.1108/IJHMA-06-2019-0064

Google. (n.d.). [Google Maps location data for study area]. (Access Date: 2023) https://www.google.com/maps/

Gürbüz, H., Koca, B., & Altınoluk, D. (2023). Türkiye'de neoliberal konut politikaları: Gaziantep örneği [Neoliberal housing policies in Turkey: The case of Gaziantep]. *Kent Akademisi*, *16*(1), 122-137. https://doi.org/10.35674/kent.1153719

Housing Development Administration of the Republic of Türkiye. (n.d.). *TOKI official website*. (Access Date: 29.06.2022) http://www.toki.gov.tr

İslam, T. (2009). *Devlet eksenli soylulaşma ve yerel halk: Neslişah ve Hatice Sultan mahalleleri (Sulukule) örneği* [State-led gentrification and local people: The example of Neslişah and Hatice Sultan neighborhoods-Sulukule] [Doktora tezi, Yıldız Teknik Üniversitesi]. YÖK Tez Merkezi.

Kandaloğlu, N. (2012). *Kentsel dönüşüm ve bir dağıtım modeli önerisi* [Urban transformation and the proposed distribution model] [Doktora tezi, İstanbul Teknik Üniversitesi]. YÖK Tez Merkezi.

Kara, M. (2012). *Gecekondu dönüşüm projelerinin konut sorununun çözümündeki rolü: Ankara ili Gültepe ve Yatıkmusluk mahalleleri örneği* [The role of slum transformation projects in solving the housing problem: The example of Gültepe and Yatıkmusluk neighborhoods in Ankara province] [Doktora tezi, Süleyman Demirel Üniversitesi]. YÖK Tez Merkezi.

Karadeniz, V., & Altınbilek, M. S. (2018). Erzincan ilinin topografik analizi ve idari sınırlar ilişkisi, bazı sorunlar [Topographic analysis and administrative relationship between Erzincan province, some problems]. *Erzincan Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *11*(1), 283-304.

Kas, M. (2014). *Konut sorununun çözümünde kentsel dönüşüme kullanıcı katılımının sağlanması üzerine bir yöntem araştırması: Konya örneği* [A methodological study on ensuring user participation in urban transformation to solve the housing problem: The Konya Province example] [Doktora tezi, Selçuk Üniversitesi]. YÖK Tez Merkezi.

Kemeny, J. (1995). *From public housing to the social market: Rental policy strategies in comparative perspective*. Routledge.

Kenna, P. (2010). International instruments on housing rights. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *2*(1), 1-21. https://doi.org/10.1061/(ASCE)LA.1943-4170.0000018

Koca, D. (2012). *Türkiye'de çağdaş konut üretiminin yeniden haritalandırılması: Konut örüntüleri ve pazarlama stratejileri üzerine bir durum çalışması* [Re-mapping contemporary housing production in Turkey: A case study on housing patterns and marketing strategies] [Doktora tezi, Orta Doğu Teknik Üniversitesi]. ODTÜ Kurumsal Akademik Arşiv.

Koca, D. (2015a). Türkiye'de çağdaş konut üretiminin yeniden okunması [Reinterpreting contemporary housing production in Turkey]. *Tasarım+Kuram*, *11*(19), 19-36.

Koca, D. (2015b). 2000 sonrası konut üretim sürecindeki değişimler ve kentleşme üzerine etkisi [Changes in housing production after 2000 and their effects on urbanization]. *Uluslararası Kent Araştırmaları Kongresi Bildiri Kitabı*, 590-605.

Koçançı, M. (2014). *Türkiye'de sosyal konut politikaları ile yoksulluğun yönetimi* [Social housing policies and poverty management in Türkiye] [Doktora tezi, Gazi Üniversitesi]. YÖK Tez Merkezi.

Kovankaya, E. İ., & Türkün, A. (2023). Orta ölçekli kentlerde konut üretimi: Aydın'da yerel müteahhitler [Housing production in mid-sized cities: Local building contractors in Aydın]. *Planlama*, *33*(2), 218–233. https://doi.org/10.14744/planlama.2023.44827

Kömürcüoğlu, M. (2017). Toplu konut ve kentsel dönüşüm uygulamalarının girişimcilik ve iş fırsatları açısından etkileri [Effects of public housing and urban renewal projects on entrepreneurship and business opportunities]. *PESA Uluslararası Sosyal Araştırmalar Dergisi*, *3*(3), 112-125.

Kressler, F. P., & Steinnocher, K. T. (2001). Monitoring urban development using satellite images. In *Remote sensing of urban areas* (Regensburger Geographische Schriften, Heft 35, pp. 140-147). Universität Regensburg.

Kurt, T. (2020). *Kentsel dönüşüm uygulamalarında yenilikçi ve alternatif finansman modelleri: TOKİ örneği* [Innovative and alternative financing models in urban transformation practices: TOKİ example] [Doktora tezi, Marmara Üniversitesi]. YÖK Tez Merkezi.

Liu, Y. (2018). Introduction to land use and rural sustainability in China. *Land Use Policy*, *74*, 1-4. https://doi.org/10.1016/j.landusepol.2018.01.032

Manoochehri, J. (2009). *Social policy and housing: Reflection of social values* [Doctoral dissertation, University College London]. UCL Discovery.

Marschall, M., Aydogan, A., & Bulut, A. (2016). Does housing create votes? Explaining the electoral success of the AKP in Turkey. *Electoral Studies*, *42*, 201-212. https://doi.org/10.1016/j.electstud.2016.03.003

Moreno-Monroy, A., Gars, J., Matsumoto, T., Crook, J., Ahrend, R., & Schumann, A. (2020). *Housing policies for sustainable and inclusive cities*. OECD Publishing.

Mills, A. J., Durepos, G., & Wiebe, E. (2010). Exploratory case study. In A. J. Mills, G. Durepos, & E. Wiebe (Eds.), *Encyclopedia of case study research* (pp. 372_373). SAGE Publications. https://doi.org/10.4135/9781412957397.n139

Ministry of Agriculture and Forestry. (2022). *CORINE land cover dataset*. (Access Date: 2022) https://corine.tarimorman.gov.tr/corineportal_araziortususiniflari.html

Murray, C., & Clapham, D. (2015). Housing policies in Latin America: Overview of the four largest economies. *International Journal of Housing Policy*, *15*(3), 347_364. https://doi.org/10.1080/14616718.2015.1055090

Nadeem, M., Asim, M., Muiz, A., Abbas, Q., & Nadeem, M. (2020). Is it a dream or reality of five million housing units construction in Pakistan? A review of house construction approaches and measures. *Pakistan Economic and Social Review*, *58*(2), 269-296.

Olgun, H. (2014). *Türkiye'de sosyal konut politikası: Seçilmiş Avrupa ülkeleriyle karşılaştırmalı bir analiz* [Social housing policy in Türkiye: A comparative analysis with selected European countries] [Doktora tezi, Gazi Üniversitesi]. YÖK Tez Merkezi.

Organisation for Economic Co-operation and Development. (2021). *PH1.2 Housing policy objectives and obstacles* (OECD Affordable Housing Database). OECD Directorate of Employment, Labour and Social Affairs. (Access Date: 15.07.2021) http://oe.cd/ahd

Ovsiannikova, T., Rabtsevich, O., & Yugova, I. (2017). Evaluation of the multiplier effect of housing investments on the city economy. *AIP Conference Proceedings*, *1800*(1), Article 050001. https://doi.org/10.1063/1.4973061

Özbilen, E. (2014). *Toplu konutlarda konut topluluğu ölçeğinde bir değerlendirme yöntemi önerisi: TOKİ Ankara örneği* [A proposed evaluation method for mass housing projects at the housing community scale: The TOKİ Ankara example] [Doktora tezi, Gazi Üniversitesi]. YÖK Tez Merkezi.

Öznam, B. (2010). *İstanbul'da kamu kontrolünde yaptırılan toplu konut alanlarının yeşil alan kriterleri açısından değerlendirilmesi: Ataşehir-Esenkent-Halkalı örnekleri* [Evaluation of publicly constructed mass housing areas in Istanbul in terms of green space criteria: Ataşehir-Esenkent-Halkalı examples] [Doktora tezi, İstanbul Üniversitesi]. YÖK Tez Merkezi.

Özpolat, A. (2014). *Türkiye'de kentleşme politikaları ve konut talebini etkileyen faktörler: SVEC analizi* [Factors influencing urbanization policies and housing demand in Türkiye] [Doktora tezi, Gaziantep Üniversitesi]. YÖK Tez Merkezi.

Purkis, S. (2016). İstanbul'da inşaat odaklı birikimin durdurulamayan yükselişi: Konut fazlasına karşın artan konut açığı [Relentless escalation of construction-centred accumulation in Istanbul: Housing gap in spite of the housing surplus]. *Mülkiye Dergisi*, *40*(4), 91-111.

Rabiega, W. A. (1984). The property value impacts of public housing projects in low and moderate density residential neighborhoods. *Land Economics*, *60*(2), 174-179. https://doi.org/10.2307/3145971

Rojas, E. (2018). "No time to waste" in applying the lessons from Latin America's 50 years of housing policies. *Environment and Urbanization*, *31*(1), 177-192. https://doi.org/10.1177/0956247818781499

Sağ, N. S. (2011). *Dönüşüme bağlı kentsel gelişmenin yönetilmesinde bir araç olarak akıllı büyüme; Konya kenti örneği* [Smart growth as a tool in managing transformation-driven urban development; the case of Konya city] [Doktora tezi, İstanbul Üniversitesi]. YÖK Tez Merkezi.

Shahraki, S. Z., Ahmadifard, N., Farhadikhah, H., Mehrabani, B. F., Haydari, A., Abdali, Y., Fallah, V. A., Farhadi, E., Cividino, S., Vinci, S., & Salvati, L. (2020). Spatial planning, urban governance and the economic context: The case of 'Mehr' Housing Plan, Iran. *Land*, *9*(5), Article 169. https://doi.org/10.3390/land9050169

Solmaz, Y. (2013). *Kentsel dönüşüm ve kentsel hareketler: İstanbul'da kent hakkı mücadeleleri* [Urban transformation and urban movements: Struggles for the right to the city in Istanbul] [Doktora tezi, Yıldız Teknik Üniversitesi]. YÖK Tez Merkezi.

Sun, B., Zhang, T., Wang, Y., Zhang, L., & Li, W. (2021). Are mega-cities wrecking urban hierarchies? A cross-national study on the evolution of city_size distribution. *Cities*, *108*, Article 102999. https://doi.org/10.1016/j.cities.2020.102999

Sürmeli Söğüt, İ. (2025). Housing practices of TOKI in Karaman within the context of social and spatial segregation. *Uluslararası İktisadi ve İdari İncelemeler Dergisi*, (48), 315_336. https://doi.org/10.18092/ulikidder.1524312

Şahin, G., Çabuk, S. N., & Çetin, M. (2021). The change detection in coastal settlements using image processing techniques: A case study of Korfez. *Environmental Science and Pollution Research*, *28*(48), 68670-68685. https://doi.org/10.1007/s11356-021-16660-x

Şentürk, M. (2011). *Kentsel müdahaleler açısından İstanbul* [Istanbul in terms of urban interventions] [Doktora tezi, İstanbul Üniversitesi]. İstanbul Üniversitesi Açık Erişim Sistemi.

Şiriner Önver, M. (2016). *Konut ve konut politikası* [Housing and housing policy]. IJOPEC Publication.

Tantan, B., & Türk, Ş. Ş. (2024). The impact of public housing investments on the economic development of provinces: The case of Turkey (TOKI). *Journal of Urban Planning and Development*, *150*(1), Article 05024001. https://doi.org/10.1061/JUPDDM.UPENG-4622

Tatlı Çolak, N., & Türk, Ş. S. (2022). TOKI's impact on transaction costs in planning and land development: Looking at large-scale housing projects in Istanbul's Avcılar-Ispartakule region. *Habitat International*, *119*, Article 102492. https://doi.org/10.1016/j.habitatint.2021.102492

Tepe, E. (2010). *İstanbul'da yeni gelişen büyük ölçekli konut yerleşimlerinin değerlendirilmesi: Büyükçekmece ve Tuzla örnekleri* [Evaluation of new large scale residential settlements in Istanbul: The cases of Büyükçekmece and Tuzla] [Yüksek lisans tezi, İstanbul Teknik Üniversitesi]. İTÜ Ulusal Tez Merkezi.

Tibaijuka, K. T. (2009). *Building prosperity: The centrality of housing in economic development*. Earthscan.

Turkish Statistical Institute. (2016). *Gross domestic product by province, 2004-2014* (Press Release No. 24920). (Access Date: 2021) https://data.tuik.gov.tr

Turkish Statistical Institute. (2020). *Address based population registration system (ABPRS) results, 2007-2019*. (Access Date: 2020) https://data.tuik.gov.tr

Turkish Statistical Institute. (2023). *House sales statistics, 2013_2023*. (Access Date:2023) https://data.tuik.gov.tr

Turut, H. (2018). *Türkiye'de orta ölçekli iki kentin neoliberal kentleşme deneyimi: Eskişehir ve Konya örnekleri* [Neoliberal urbanization experiences in two medium-sized cities in Türkiye: The cases of Eskişehir and Konya] [Doktora tezi, Ankara Üniversitesi]. YÖK Tez Merkezi.

Ulusoy, A. E. (2020). Türkiye'de konut politikaları: Tarihsel süreç ve aktörlerin rolü [Housing policies in Turkey: Historical process and the role of actors]. *Kamu Yönetimi ve Politikaları Dergisi*, *1*(3), 87-123.

Wardrip, K., Williams, L., & Hague, S. (2011). *The role of affordable housing in creating jobs and stimulating local economic development: A review of the literature*. Center for Housing Policy.

Yaman, M. (2011). *Kentsel dönüşüm uygulamaları Ankara Büyükşehir Belediyesi: Dikmen Vadisi 3. Etap örneği* [Urban transformation projects in Ankara Metropolitan Municipality: The example of Dikmen Valley Stage 3] [Doktora tezi, Ankara Üniversitesi]. YÖK Tez Merkezi.

Yazar, K. H. (2015). *Küreselleşme sürecinde orta ölçekli kentlerin önemi ve Türkiye üzerinde bir inceleme* [The importance of mid-size cities in the process of globalisation and a research on Turkey]. Atatürk Kültür, Dil ve Tarih Yüksek Kurumu. http://www.ayk.gov.tr

Yenigül, S. B. (2009). *Metropoliten kent etkisindeki yerleşimlerin dönüşüm sürecinin çözümlenmesi: Ankara örneği* [Analyzing the transformation process of settlements under the influence of metropolitan cities: The Ankara province example] [Doktora tezi, Gazi Üniversitesi]. YÖK Tez Merkezi.

Yeşilbağ, M. (2020). İnşaat sektörünün kriz dinamikleri: Güncel bir değerlendirme [Crisis dynamics of the construction sector: A recent assessment]. *Mülkiye Dergisi*, *44*(1), 101-130.

Yılmaz, O. K. (2018). *Kentsel dönüşüm ve Türkiye: Belediyelerin uygulamalara yönelik yaklaşımları üzerine bir araştırma* [Urban transformation and Turkey: A study on municipalities' approaches to implementation] [Doktora tezi, Marmara Üniversitesi]. YÖK Tez Merkezi.

Yılmaz Şimşek, Z. (2021). *Van kentinde konut üretim faaliyetleri ve kentin mekânsal gelişimine etkileri* [Housing production activities in Van city and their effects on the spatial development of the city] [Doktora tezi, Van Yüzüncü Yıl Üniversitesi]. YÖK Tez Merkezi.

Yin, R. K. (2009). *Case study research: Design and methods* (4th ed.). SAGE Publications.

Yücer, E., & Erener, A. (2016). Kentsel alan değişiminin uydu görüntüleri ile zamansal takibi [Temporal tracking of changes in urban areas through satellite images]. In *Uluslararası Erzincan Sempozyumu Bildirileri* (Vol. 2, pp. 169-179). Erzincan Üniversitesi.

Yüksel, H. (2014). *Sosyal politika unsuru olarak Toplu Konut İdaresi (TOKİ) uygulamaları: Isparta ili Çünür ve Akkent mahallelerinde Toplu Konut İdaresi Başkanlığı'nca yapılan konutlarda ikamet eden konut sakinlerine yönelik bir alan araştırması* [TOKİ practices as a social policy element] [Doktora tezi, Süleyman Demirel Üniversitesi]. YÖK Tez Merkezi.

Zhang, X. Q., & Ball, M. (2016). Housing the planet: Evolution of global housing policies. *Habitat International*, *54*(3), 161-165. https://doi.org/10.1016/j.habitatint.2015.11.028

Resume

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Photographic counter-memory as urban resilience: Evaluating Murat Germen's photographic practice in Istanbul's urban transformation since 2000

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Abstract

In the post-2000 period, Istanbul has become one of the most intense cases of neoliberal spatial restructuring in the developing world, driven by state-market alliances that systematically opened non-commodified spaces to real estate capital. This article argues that such transformations operate not only in economic terms but also as mnemonic policies: the erasure of collective memory is a structural mechanism through which hegemonic power generates docile space and undermines counter-hegemonic potentials. The article distinguishes two modalities of erasure across two cases of urban transformation. The first is aggressive erasure, exemplified by Fikirtepe, where the accelerated application of Law on the Transformation of Areas Under Disaster Risk outpaced community resistance and made the continuity of embodied and collective memory impossible. The second is aesthetic recoding, operating in the transformation of Bağdat Avenue in Kadıköy, where the gradual replacement of neighbourhood-based social life by luxury apartments and commercial consumption spaces enacts what Neil Leach calls 'aesthetic anaesthesia'. Against this backdrop, the article treats the photographic practice of Murat Germen - a photographer and academic who holds the most extensive archive of Istanbul's contemporary transformation - as its primary object. Drawing on the counter-archive - the photographic refusal of the terms of official representation - the article examines Germen's counter-memorial narratives across both sites and their public resonance. His Fikirtepe documentation captures the threshold at which anamnesis remains possible; his Bağdat Avenue work reveals the gap between spatial promise and eroded identity. Employing Gillian Rose's qualitative visual methodology alongside an analysis of Germen's reception across institutional contexts, the article finds that photographic counter-memory constitutes a meaningful but constrained form of 'urban resilience' - understood not in its technocratic sense of 'bouncing back', but as the social capacity of communities to sustain contested memory under conditions of imposed transformation - a formulation that draws on critical resilience scholarship. The article's primary theoretical contribution is a distinction between two functions of photographic counter-memory, whose efficacy is conditioned by the modality of erasure each confronts. A testimonial function - the preservation of evidence for future challenge - operates robustly across both erasure modalities, while a mobilizing function - the generation of counter-hegemonic solidarity - depends on the legibility of loss that each modality of mnemonic erasure permits. Photographic counter-memory does not reverse physical transformation, but it sustains the social capacity to recognize, archive, and contest ongoing erasure.

Keywords: mnemonic policy, neoliberal urbanism, photographic counter-memory, urban resilience, visual methodology

1. Introduction

Since 2000, Istanbul's urban landscape has undergone transformation at a pace and scale exceeding that of almost any comparable city of such historical density. Entire historical neighbourhoods like Sulukule and Tarlabaşı were cleared of their residents and rebuilt under a legislative framework specifically designed in 2005 to accelerate demolition and shorten the time

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available for legal challenge, collective organization, or documentation via Law No. 5366. While Law No. 5366[1] had already established the template, its reach was limited to designated heritage areas. Law No. 6306 (the Law on the Transformation of Areas Under Disaster Risk, 2012) extended this instrument across the entire city; neighbourhoods like Tozkoparan, Okmeydanı and Fikirtepe were legally designated as risk zones (Figure 1). This reduced the gap between the declaration of a structure as 'risky' and its physical demolition to a point at which resistance was blocked before it could begin: by the time communities could mobilize, the bulldozers had already moved in. The regulatory framework effectively compressed the time available for legal challenge, collective organization, and documentation.

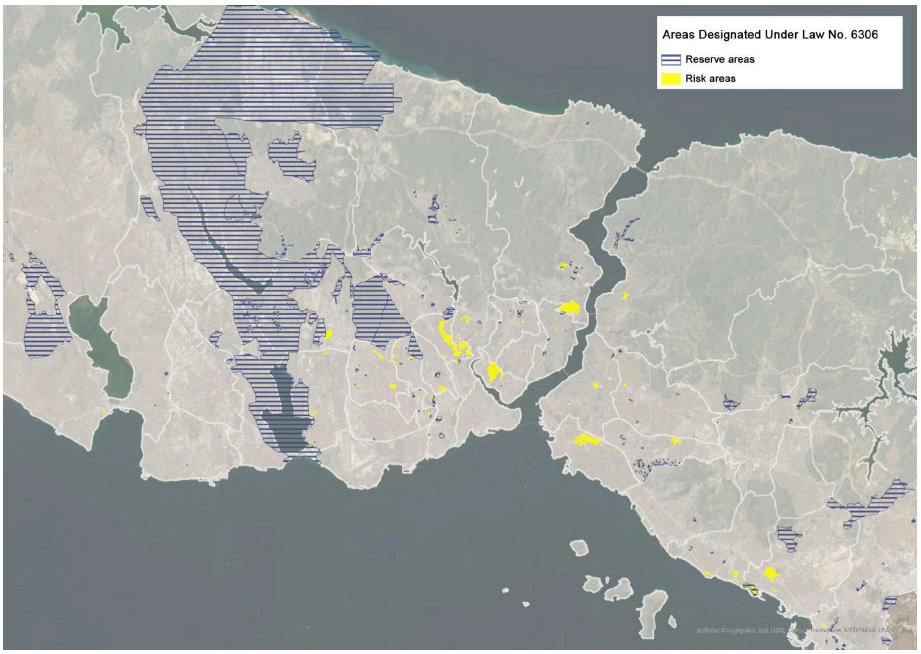

Figure 1 Risk Areas and Reserve Areas Designated Under Law No. 6306 (İstanbul Planlama Ajansı, 2024)

The systematic erasure of urban memory is not unique to Istanbul. Shao's (2013) account of Shanghai documents how large-scale redevelopment between 1990 and 2010 displaced millions of residents through a process deliberately paced to outrun collective mourning - what Shao calls 'everyday domicide', the normalization of home destruction under the banner of modernization. A different but related dynamic characterizes Dubai: Elsheshtawy (2010) shows how a built environment engineered for prestige and global investment appeal systematically crowds out the social spaces that fall outside the spectacle. Bağdat Avenue - the prestigious commercial axis of Istanbul's Kadıköy district and the second case this article examines - offers a direct parallel. What sets Istanbul apart is not the logic itself, but its configuration: the simultaneous operation of aggressive coercion and gradual aestheticization within the same metropolitan governance area, producing two distinct erasure modalities that the following analysis examines in parallel.

Türkiye's post-2000 urban policy provides the institutional framework through which this configuration takes specific form. Çavuşoğlu and Strutz (2014) trace how successive governments made the construction sector the visible material expression of its hegemonic project. The legislative infrastructure assembled to sustain this project, above all Law No. 6306, handed central government the power to declare areas 'risky', acquire property by compulsion, and proceed to demolition without local authority approval or meaningful community engagement. Kuyucu (2014) shows that the law's strategic ambiguity was not a legislative imprecision but an instrument, designed to foreclose judicial review while leaving TOKİ with effective discretion over entire

[1] *Law on Conservation by Renovation and Use by Revitalization of the Deteriorated Historical and Cultural Immovable Property* *https://kvmgm.ktb.gov.tr/TR-43250/law-on-conservation-by-renovation-and-use-by-revitalization-of-the-deteriorated-historical-and-cultural-immovable-property-5366.html*

neighbourhoods. Saraçoğlu and Demirtaş-Milz (2014) name this as disaster ideology: the reframing of political expropriation as technical necessity. As Batuman (2025) puts it, “there is a hidden relationship between slowness and remembering, and between speed and forgetting”- a formulation that connects the temporal design of urban law directly to the organized production of amnesia. The cumulative result, as Aksoy (2012) captures it, is a city that “ceases to be a real city” (p. 93): not uneven modernization, but the deliberate conversion of layered urban space into a surface without historical depth.

This article proposes that the systematic speed of Istanbul's post-2000 urban transformation cannot be adequately theorized as economic policy alone. Alongside Harvey's (2003) widely cited framework of accumulation by dispossession, post-2000 Istanbul's transformation operates simultaneously as what this article terms a mnemonic policy, a process that can be interpreted as producing systematic mnemonic erasure held within urban space. Urban demolition, in this reading, does not only destroy the neighbourhood incidentally while pursuing rent extraction. It also destroys the mnemonic infrastructure embedded in it - the physical framework of cadres sociaux (Halbwachs, 1980), bodily practice (Connerton, 1989), and anamnetic attachment (Leach, 1999) through which communities maintain collective subjectivity and the capacity for counter-hegemonic identification.

This article identifies two distinct modalities through which this mnemonic erasure operates. The first - aggressive erasure - is exemplified by Fikirtepe, where concentrated application of Law No. 6306 created conditions in which community resistance, documentation, and collective grieving were made impossible before they could begin. The second - aesthetic recoding - operates in the Bağdat Avenue periphery, where no demolition order was ever declared and yet the silent replacement of neighbourhood-scale social life by commercial consumption and accumulation structures has produced what Leach (1999) calls ‘aesthetic anaesthesia’: an environment in which sensory pleasure neutralizes critical consciousness and dissolves the affective bonds sustaining mnemonic attachment to place. Fikirtepe and Bağdat Avenue at Kadıköy represent the two faces of a single hegemonic memory policy - one that erases through dispossession and speed, the other through aestheticization and gradual erosion.

Against this backdrop, the article evaluates critical photographic practice as a prospect of urban resilience. The concept of photographic counter-memory designates not only the documentary recording of what is lost but the active challenge to the terms on which certain realities are made visible, documented, and shared. The primary object of analysis is the photographic work of Murat Germen, a leading photographer (and academic) in Türkiye whose practice spans both sites under examination. What makes Germen’s photography critically important is his intellectual positioning while documenting the erasure processes.

The article addresses three related questions: in what specific ways does post-2000 Istanbul's transformation constitute a mnemonic policy and how do the two cases illuminate its structurally distinct modalities? Through what visual and discursive strategies does photographic practice construct counter-memorial narratives, and does the same practice operate differently when confronting two structurally distinct erasure modalities? What are the real limits of photographic counter-memory as a mechanism of urban resilience? These questions are addressed through a qualitative visual methodology grounded in Rose's (2016) tripartite framework of production, image, and audiencing, combined with interpretive close reading of Germen's work.

This article makes three interconnected contributions to the existing literature. Theoretically, it introduces and develops the concept of mnemonic policy as a necessary supplement to economic accounts of urban transformation - a framework that connects Harvey's accumulation by dispossession with the organized erasure of collective memory. Empirically, it distinguishes two structurally distinct modalities of mnemonic erasure - aggressive erasure and aesthetic recoding - and traces their differential consequences for photographic counter-memory. Analytically, it proposes a distinction between the testimonial and mobilizing functions of photographic counter-

memory as a tool for evaluating counter-memorial efficacy under different conditions of urban transformation. These contributions build on existing work on photography and urban displacement (Shao, 2013; Elsheshtawy, 2010), critical resilience studies (Davoudi, 2012), and visual urbanism (Rose, 2016).

2. Theoretical Framework

The theoretical framework operates across three tiers: a primary tier supplying its core explanatory architecture (Harvey's accumulation by dispossession, Gramsci's theory of hegemony, and Leach's account of mnemonic infrastructure and aesthetic anaesthesia); a secondary tier grounding the analysis of what urban transformation destroys (Halbwachs's collective memory, Connerton's bodily memory, Nora's distinction between living and institutionalized memory, and Huyssen's urban palimpsest); and a third tier evaluating photographic practice as counter-hegemonic response (Sekula's counter-archive, Tagg's critique of photographic authority, Azoulay's civil contract, and Tello's counter-memory aesthetics). Urban resilience, the article's evaluative horizon, is addressed separately at the end of this framework.

Neoliberal Urbanism, Hegemony, and Memory Erasure

The analytical foundation rests on a shared premise across critical urban theory and political economy: that urban transformation under neoliberalism is not a neutral modernization process but a spatial strategy of capital accumulation. David Harvey's concept of accumulation by dispossession - the capture of previously non-commodified spaces, commons, and use values for market exploitation - provides the foundational economic logic of post-2000 Istanbul's transformation. As Kuyucu and Ünsal (2010) show, Istanbul's transformation operates specifically as state-led property transfer: the state is not merely a facilitator but an active agent of capital redistribution.

This spatial logic is given its most compact theoretical formulation by Lefebvre (1991), for whom space is simultaneously the product and the instrument of power: *"(Social) space is a (social) product […] in addition to being a means of production it is also a means of control, and hence of domination, of power"* (p. 26). Yet 'accumulation by dispossession' alone is insufficient to account for the full scope of what is at stake. Antonio Gramsci's theory of hegemony introduces the dimension that Harvey's economic model risks overlooking: the production of consent. In Türkiye's post-2000 context, Çavuşoğlu and Strutz (2014) reveal how, by identifying construction with development, progress, and modernization, the ruling Party produced social consent for dispossession across social classes. Türkün (2011) further identifies the governing coalition through which this hegemony functions: central state, TOKİ[2], private capital, and media together normalize demolition as opportunity, with "*gecekondu*" (squatter's house) and "*riskli yapı*" (risky building) functioning as discursive instruments that degrade the urban image of targeted neighbourhoods before a single wall is touched.

Batuman (2018) extends this analysis by showing how urban space functions not merely as the scene of hegemonic politics but as its productive apparatus claiming that the ruling Party has built its hegemony through its success in urban politics and the new kind of Islamic urbanism it generated. This spatial production of ideology is what makes mnemonic erasure not a byproduct but a requirement: the new built environment must overwrite the old one not only physically but semiotically, replacing its memory-bearing surfaces with surfaces that carry the ruling hegemony's own signification.

Batuman (2022a) draws on this dual analytical horizon in reflecting that urban transformation is simultaneously an economic and a mnemonic-cultural operation - neither dimension reducible to

[2] *TOKİ - Toplu Konut İdaresi Başkanlığı - Türkiye's Mass Housing Administration, established 1984 and significantly expanded after 2002. It operates as the state's primary instrument for urban redevelopment, controlling land allocation and construction contracts across transformation zones.*

the other. Aksoy (2014) confirms: "*In Türkiye, the government uses the city not only as a growth machine, but also as the site of a socio-political transformation project*" (p. 27). It is at this intersection that Neil Leach's contribution becomes decisive. Leach (1999) proposes that the built environment functions as a mnemonic infrastructure. Its architectural forms do not merely shelter activity; they actively trigger memory, identity, and affective attachment - a process Leach terms 'anamnesis' - the capacity of space to evoke buried memories and sustain collective subjectivity. When this infrastructure is demolished, what is lost is not only physical shelter but the cognitive and emotional anchoring of the community. Leach terms the inverse process 'aesthetic anaesthesia': sensory pleasure, in this condition, neutralizes critical consciousness and dissolves the affective bonds that sustain counter-hegemonic identification.

Collective Memory, Urban Space, and Bodily Memory

For Halbwachs (1980), memory is not a private archive stored in individual minds but a fundamentally social construct maintained by group practices and material environments. Space and memory are mutually constitutive: communities shape space in their own image, and space in turn inscribes itself into the thought and memory of communities. When that space is destroyed, the *cadres sociaux* - the social frameworks within which memory operates - collapse, and what is lost cannot be recovered by any act of individual recollection alone. Nora's (1989) distinction between '*lieux de mémoire'* and '*milieu de mémoire'* sharpens this analysis: Istanbul's accelerated transformation converts living memory environments into sites of either erasure or institutionalized commemoration - both of which, paradoxically, mark the death of living memory rather than its continuity.

Huyssen's (2003) account of urban palimpsests provides the spatial concept that best names what hegemonic memory policy destroys. Cities are best understood as palimpsests: stratified spatial texts in which multiple temporal layers coexist within the same material environment. This temporal thickness is what large-scale urban redevelopment irreversibly breaks down.

Connerton (1989) adds a dimension crucial to evaluating both the consequences of displacement and the limits of photographic counter-memory. The most durable form of social memory resides not in texts or images but in bodily practices - the habituated rhythms through which communities inhabit space. When a community is displaced, this bodily archive is irreversibly severed. This is where photography reaches its defining limit: it can preserve visual traces of demolished environments, but it cannot recover the embodied, lived dimensions of the social life they once sustained.

Photography as Counter-Hegemonic Practice

Tagg (1988) provides the necessary caution: photography carries no inherent guarantee of truthful documentation. Its evidentiary authority is not a product of any direct relationship to reality but of the institutional frameworks that confer it. Sekula (1984, 1986) translates this into an explicit politics: the counter-archive is a practice that refuses the terms on which official representation operates, insisting on the politics of seeing. In Murat Germen's own critical characterization, the photograph functions as evidence of what he describes as a 'crime scene' (Germen, 2019a).

Tello's (2019) critical genealogy adds an aesthetic dimension to Sekula's approach, arguing that counter-memory is most productively understood as a non-dialectical practice of accumulation - the 'and–and formula' - in which multiple heterogeneous histories are held in productive tension rather than resolved into a singular counter-narrative. Its aesthetic form is montage, and in its most extreme form, hoarder montage (the layered accumulation of fragments), producing a temporal web in which "*the past is not yet passed*" (Tello, 2019, p. 397).

Azoulay (2008) adds an ethical dimension: photography constitutes a civil contract between photographer, photographed subject, and viewer - one that generates political claims exceeding the intentions of any single participant and creates a form of civic space capable of persisting even under conditions of political closure. Germen articulates this as personal commitment: "*I genuinely*

feel responsibility. The reason I want to continue photographing the different events I have had the chance to witness here is that I am able to use this struggle as an example in national and international events" (Germen, 2020a).

Urban Resilience as Social Capacity

Urban resilience has moved a long way from its origins. What began as an ecological metaphor of 'bouncing back' (Holling, 1973) has become a set of socially differentiated accounts of adaptive capacity under stress (Davoudi, 2012; Meerow et al., 2016), and critical scholarship has pressed harder still, asking of any resilience claim: resilience of what, for whom, and against what forces (MacKinnon & Derickson, 2013; Cretney, 2014). This article takes the term in its most socially grounded sense - the capacity of communities to sustain collective memory, social networks, and the grounds for political contestation under rapid, externally imposed transformation. Photographic counter-memory is one such practice, though a partial one. It does not preserve the physical fabric of neighbourhoods, and it cannot restore the bodily archive of displaced communities (Connerton, 1989). What it sustains is the social capacity to recognize, archive, and contest ongoing erasure - and that capacity is what the article assesses as the resilience potential of the photographic counter-archive.

3. Methodology

This article employs a qualitative visual methodology adapted from Rose's (2016) model for the critical analysis of visual materials. Rose proposes that photographic meaning is not located in the image alone but distributed across three distinct sites: the site of production (the conditions under which an image is made); the site of the image itself (its content, composition, and formal properties); and the site of audiencing (the contexts in which images are encountered, circulated, and interpreted). Applying the method to the question of urban resilience requires specifying, in the context of Murat Germen's counter-archival practice across Fikirtepe and Bağdat Avenue, what each site contributes to the central question: can photography constitute a meaningful form of resistance to mnemonic erasure?

Visual Corpus and Selection Criteria

The visual corpus for this study comprises 10 photographs drawn from four of Murat Germen's documentary series: '*Sanctity and Despotism of Progress*' (Fikirtepe, 2012-2015), '*98 Windows*' (Fikirtepe, 2013-2014), '*Transformal*' (Bağdat Avenue and wider Istanbul, 2007-ongoing), and '*İnşa*' (Construct) (broader Istanbul construction culture, with selected images from sites of aesthetic recoding, 2014-ongoing). Images were selected according to three criteria: (1) direct relevance to one of the two erasure modalities under analysis; (2) availability of documented institutional reception - exhibition, press coverage, or academic citation - sufficient to permit audiencing analysis; and (3) visual distinctiveness, specifically the capacity to illustrate a discrete photographic strategy rather than repeating an already-represented approach within the corpus. Images known to have circulated across both activist/journalistic and arts/architecture institutional contexts were prioritized, as their dual circulation provides the most direct evidence for the reception asymmetry that is the article's central empirical finding. The two cases are made comparable by controlling for photographer, city context, and time period, isolating the modality of erasure as the central axis of comparison between them. Table 1 lists these images by series, date, case context, and role in the analysis.

Table 1 Analyzed Images from Murat Germen's Photographic Corpus, by Series, Date, Case/Context, and Role in the Analysis

Image	Series	Date	Case / Context	Role in the Analysis
Fig. 2 'Çivi' (Nail)	Sanctity and Despotism of Progress	2014	Fikirtepe - aggressive erasure	Threshold image: a single standing dwelling amid a cleared lot; visual testimony to imminent demolition.
Fig. 3 '98 Windows'	98 Windows (installation)	2013-2014	Fikirtepe - aggressive erasure	Assembled window fragments materialize the gap between the erased mnemonic infrastructure and the towers replacing it.
Fig. 4 Drone view	Erasing Memory (unpublished)	2014	Fikirtepe - aggressive erasure	Aerial 'apocalyptic dystopian landscape'; exposes the totality of demolition beyond the ground-level frame.
Figs. 6–7 Rendering vs. built form	Transformal	2014-ongoing	Bağdat Avenue - aesthetic recoding	Juxtaposes architectural promise with delivered environment; documents the gap central to the second case.
Fig. 8 'Rupture'	Sarmal (Helix)	2017	Bağdat Avenue / Istanbul - institutional reception	Evidence for the audiencing analysis: circulation within an art/architecture exhibition context.

Source: Author, based on Germen's published and exhibited photographic series (See references and İstanbul Planlama Ajansı (2024) to Germen (2017))

Visual Analysis Procedure

Analysis at the site of the image proceeded through a structured set of compositional and semantic categories. The first four draw on Rose's (2016) compositional interpretation framework, which identifies spatial organisation - including perspective, angle, framing, scale, and the visual arrangement of figures - as the primary locus of an image's effects (Rose, 2016, pp. 62–83): (1) framing and perspective - the spatial boundaries of the image, camera distance, and angle of approach and elevation; (2) spatial extent and distance - the width, depth, interval and distance between forms within the image, and the effects of apparent closeness or remoteness between pictured elements and the spectator (Kress & van Leeuwen, 2006, as cited in Rose, 2016, p.70); (3) content and human presence - what the image actually shows and the logic of focalisation, specifically who is represented, how, and from whose vantage (Bal, 1991, pp. as cited in Rose, 2016, p. 71); (4) visual temporality - the juxtaposition of temporal states within or across images, understood here through Tello's (2019, p. 397) account of montage as a practice in which "the past is not yet passed." Two further categories were developed by the author in response to the specific visual conditions of the corpus: (5) visual promise and delivery - an analytical category specific to Germen's 'Transformal' series, tracing the gap between the rendered architectural representations on construction barriers and the built outcomes documented subsequently; and (6) spatial legibility - the degree to which demolished, transitional, or newly constructed environments retain the "codes of recognition" (Bryson, 1991, p. 65, as cited in Rose, 2016, p. 57) through which a space can be read as a carrier of social memory.

Interpretive Analysis of Photographic Reception

The site of audiencing is explored through interpretive analysis of the written and institutional contexts in which Germen's work has circulated: press interviews, exhibition texts, critical essays, and international academic platforms. The reception corpus comprises 15 sources gathered through systematic documentation: 5 press interviews (Turkish and international, 2013-2025), 4 exhibition catalogue texts and curatorial statements, 4 critical essays in architecture and design publications, and 2 academic citations. Sources were collected through Germen's documented bibliography, institutional archives of exhibiting venues (Alan İstanbul, Yapı Kredi Culture Center, Collect Gallery), and database searches (Google Scholar, JSTOR). The interpretive approach treats these materials not as transparent testimony to viewer response but as discursive formations - evidence of the institutional channels and interpretive communities through which photographic

meaning is socially constructed. This approach reveals an asymmetry that is itself a finding: the significantly different reception profiles of Germen's Fikirtepe and Bağdat Avenue work show that the two modalities of erasure do not generate equivalent counter-memorial visibility, even when documented by the same photographer.

Case Selection

The selection of Murat Germen as the primary object of analysis rests on three criteria: breadth, since Germen holds the most extensive archive on the contemporary transformation of Istanbul (Küper-Büsch, 2019); positioning, since his dual identity as practitioner - a trained architect and urban designer who turned to photography as critical practice - and as academic situates his work within the counter-archival tradition (Sekula, 1984), making the relationship between photographic strategy and theoretical intent unusually transparent; and circulation, since his work has generated substantial and varied discursive response across national and international platforms, making audiencing empirically well-documented as well as theoretically important.

4. Two Modalities of Mnemonic Erasure in Istanbul: Fikirtepe and Bağdat Avenue

Fikirtepe and Bağdat Avenue are not random samples of Istanbul's transformation but comparative cases chosen because they instantiate the same mnemonic policy through diametrically opposed means. In Fikirtepe, the mechanism is aggressive erasure: state-backed demolition, legislatively accelerated, that moved faster than community resistance could organize or collective mourning consolidate. In Bağdat Avenue, it is aesthetic recoding: a market-driven replacement of neighbourhood-scale social life in which desire, rather than decree, secures consent. Both sites are extensively documented in Murat Germen's photographic archive, which controls for photographer, city context, and political period and isolates the spatial logic of erasure itself.

4.1. Fikirtepe: Aggressive Erasure and the Organized Erasure of Memory

Fikirtepe, a *gecekondu* neighbourhood on Istanbul's Anatolian side, was declared a risky area under Law No. 6306 and designated as the first pilot zone for its application. Ünver and Suri (2020) documented the legal and physical dimensions of this acceleration: the law empowered the central government to designate structures as risky, initiate land acquisition, and proceed to demolition without requiring local authority approval, bypassing the planning frameworks that might otherwise have introduced delay. A UN-supported investigation estimated that displacement pressure across just eight neighbourhoods in the zone reached 80,000 people (Lovering & Türkmen, 2011, as cited in Çavuşoğlu & Strutz, 2014). The municipality initially designated tenants as rights-holders, before quietly excluding them as the process advanced. In practice, forced evictions occurred before legal challenges could reach a court ruling - with tenants receiving no compensation and TOKİ social housing allocated overwhelmingly to market-rate buyers rather than displaced residents (Türkün, 2014).

The social and political legitimation of this process operated through the social mix argument: the claim that redevelopment would produce socially diverse, integrated communities. Bülbül Akın and Türkün (2019) examine this claim closely, finding that the social mix rationale functioned primarily as a discursive instrument of consent production: the actual outcome was the spatial dispersal of low-income residents, the dissolution of their social networks, and the replacement of their dwellings with units oriented toward higher-income demand. In Gramscian terms, this naturalized dispossession as opportunity. Batuman (2022a) captures this mnemonic cost: "*Whether it was a 'gecekondu' neighbourhood or a 'varoş'* (slum/squatter settlement), *in both cases the price of this relocation was the loss of the neighbourhood as a social space… "The 'gecekondu' neighbourhood is still kept alive in the memories of the recently departed, and the 'varoş' in which former 'gecekondu' dwellers were still actively engaged.*" (p.94) This formulation maps Connerton's (1989) distinction between cognitive and habitual memory onto the specific topography of

Fikirtepe's forced relocations: what is lost is not only shelter, but the embodied spatial practice through which the neighbourhood constitutes its inhabitants as a remembering community.

Murat Germen's photographic documentation of Fikirtepe, which began in 2012[3] and was first exhibited in 2013 at Alan İstanbul under the title *'Sanctity and Despotism of Progress'*[4], operates at the threshold where anamnesis is still possible but already threatened. His images focus not on completed destruction but on its intermediate states: half-demolished walls through which interior spaces remain legible; the 2014 dated *'Çivi'* (nail) [5] (Figure 2) photograph in which a single house stands intact in the middle of a cleared lot[6]. His *'98 Windows'* installation - 98 framed window photographs assembled into a vertical structure referencing the tower blocks that would replace them - materializes the gap between the mnemonic infrastructure being destroyed and the architecturally inert environment being built in its place (Figure 3). The use of drones and specialist lenses to produce large-scale 'apocalyptic dystopian landscapes' (Küper-Büsch, 2019) exposes the totality of destruction that ground-level photography, like ground-level experience, cannot hold in a single frame (Figure 4).

Figure 2 'Çivi' (Nail), exhibited at the 'Şehir Nerede' exhibition at Yunt Gallery, 2023 (Germen, 2023a)

The *'Çivi'* (Nail) photograph (Figure 2, 2014) turns on a single compositional asymmetry: one standing dwelling, framed frontally with its domestic windows still intact, occupies the centre-left, while the lot around it has been cleared to all four edges of the frame. The disparity in scale between the surviving structure and the emptied terrain amplifies the dwelling's isolation without tipping into pathos; it reads, in Germen's own formulation, as testimony to a crime scene. No one appears in the image - no residents, no construction workers, no witnesses. That absence does specific work, stripping individual narrative from the frame and leaving the dwelling standing as evidence rather than as story, while the emptiness produces a visual stillness that sits oddly against the violence of the demolition that made it. Germen shoots from ground level, which preserves the dwelling's domestic scale and refuses the aerial view that would turn the scene into a spectacle of ruin instead of a record of habitation. The threshold moment, in other words, is made visible as a structural condition - not asserted, but built into the composition.

[3] *Germen, 2020a*

[4] *'İlerlemenin Kutsallığı ve Zorbalığı' https://alanistanbul.com/portfolio/ilerlemenin-kutsalligi-ve-zorbaligi/*

[5] *a.k.a 'Babil Kulesi' (the Tower of Babel)*

[6] During the demolitions, there stood a single house in the middle of a large lot, still standing like the Tower of Babel (Germen, 2019b).

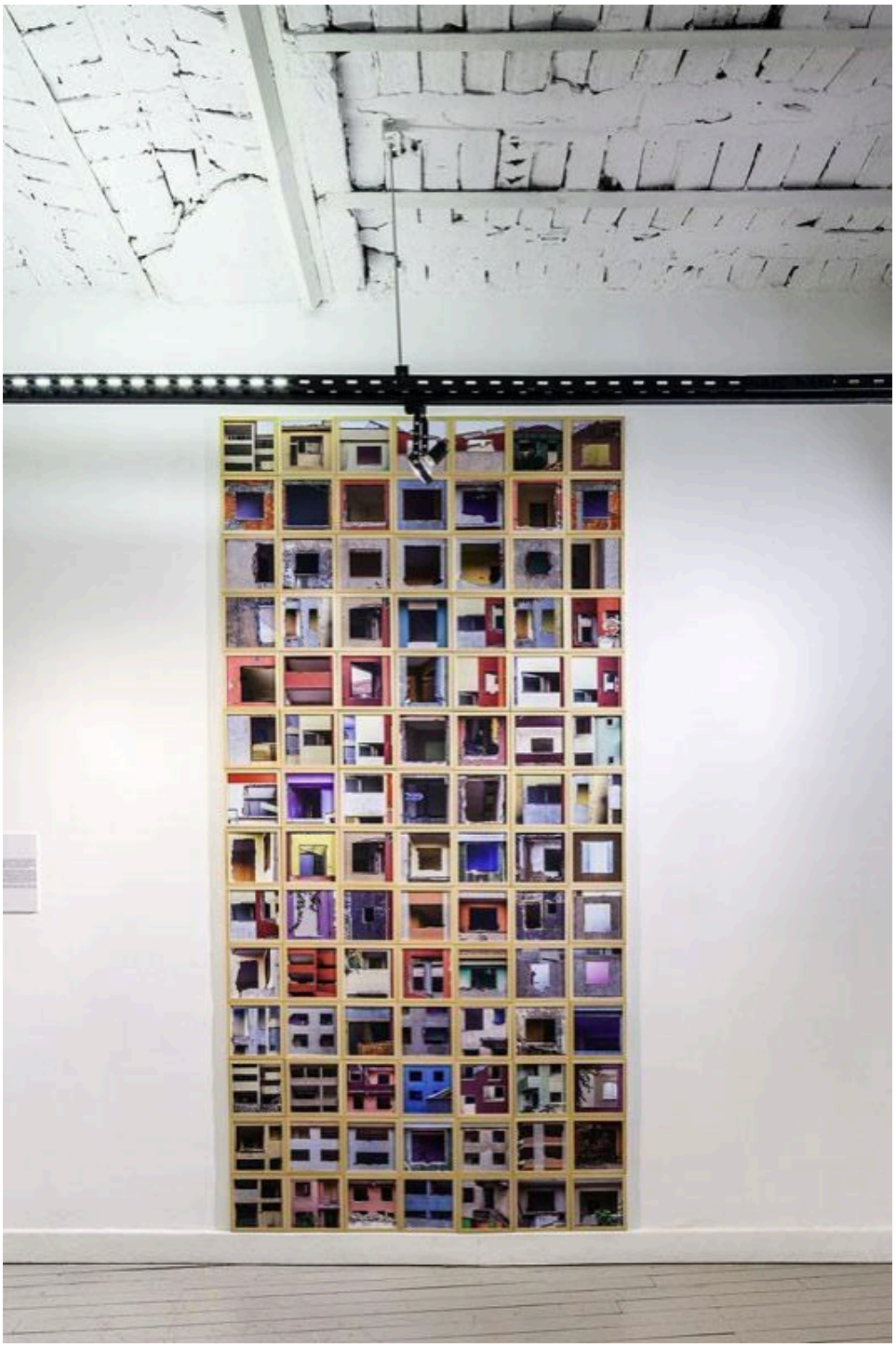

Figure 3 '98 Windows' (Germen, 2013)

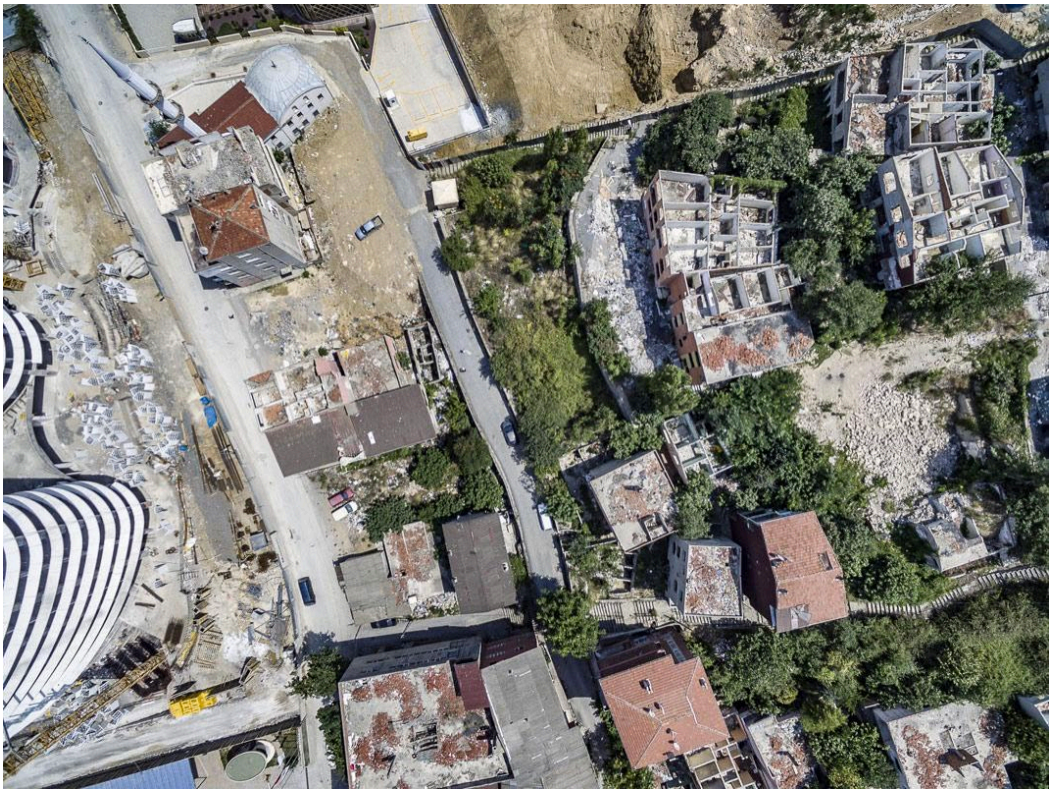

Figure 4 Fikirtepe transformation via drone view, from unpublished 'Erasing Memory' series (Germen, 2014a)

4.2. Bağdat Avenue: Aesthetic Recoding and the Attrition of the Familiar

The transformation of the Bağdat Avenue periphery presents a spatial logic so different from Fikirtepe's that the term 'urban transformation' can obscure rather than illuminate the difference. Neither was any area formally declared risky under Law No. 6306, nor was any community legally displaced by decree. And yet, as Koylan's (2018) extensive sociological study documents, the neighbourhood has undergone continuous demolition and reconstruction since 2012 - driven not by legal force but by something arguably more durable: the desire of property owners themselves. In Koylan's analysis, urban transformation in Bağdat Avenue functions as a 'desiring machine' - a mechanism that does not impose transformation from above but generates and circulates desires that make residents willing participants in their own neighbourhood's erasure. This desire is not innocent - it is the precise mechanism through which hegemonic consent operates at the level of mnemonic policy.

Çoban Çınar and Özkan Töre (2023) document the material form of this dissolution: parcel-by-parcel demolition and reconstruction driven by rent extraction, in which individual property owners negotiate with developers for maximum floor-area ratios, producing buildings that are taller, denser, and architecturally uniform while the street-level fabric is progressively replaced by luxury residences and global chains. This process generates no identifiable moment of loss because it proceeds through the aggregation of individually rational, consented decisions. The result is what Leach (1999) terms 'aesthetic anaesthesia' (defined in Section 2): desire and consumption perform the work that coercion performs in Fikirtepe, leaving the neighbourhood mnemonically empty without a visible moment of rupture.

Batuman's (2022b) diagnosis extends to Bağdat Avenue's mode of erasure - one operating through aestheticization rather than demolition: *"Both the erasure of public spaces from the urban fabric and collective memory, and the fervour of construction activity, produce flattened spaces."* The "flattening" Batuman identifies resonates directly with Huyssen's (2003) palimpsest metaphor: what is produced is a depthless surface from which the sedimented layers of collective memory have been suppressed - a city that is legible as image while remaining opaque as history.

Koylan (2018) captures this condition through the concept of "*birikememe tarihi (a history of inability to accumulate)*" (p.2) - a history in which the logic of constant renewal prevents anything from aging into meaning. One of Koylan's participants remarked: "*I came to understand that demolition resembles a kind of memory loss that a person slowly gets used to*" (p. 201).

Germen's photographic response to Bağdat Avenue - developed in part through his '*İnşa*' (Construct) series (Germen 2007) - operates through a visual strategy structurally different from his Fikirtepe work (Figure 5). Where Fikirtepe demanded the capture of threshold moments before demolition was complete, Bağdat Avenue demands the uncovering of a gap that is inherently invisible. His signature strategy begins before construction is complete: he systematically photographs the 3D computer-rendering prints displayed on the metal or wooden barriers surrounding construction sites - images of a life promised to future residents - in order to return later and document whether that promise was kept.

The '*Transformal*' images (Figures 6, 7) ask to be read differently - not for what has been destroyed but for what is promised and withheld. The photographs in this series share a compositional structure: a rendering, digitally produced and lit to evoke warmth, sociability, and architectural prestige, is mounted on a construction barrier and shot in situ, hemmed in by the site it conceals. The rendered figures are relaxed, affluent, spatially expansive; behind and around them sit raw concrete, scaffolding, and fencing. The dissonance is there in the frame, though it takes a knowing eye to catch. What neither the renders nor the barrier photographs contain, at any point, is an existing neighbourhood resident - the social life the renderings advertise bears no relation to the social life of the street behind the barrier. Counter-memory here operates on the future rather than the past, documenting not what was but what was pledged.

Fikirtepe and Bağdat Avenue do not represent two different urban policies. They represent the same mnemonic policy operating through two structurally distinct spatial forms - one that erases through coercion and speed, the other through desire and gradual erosion.

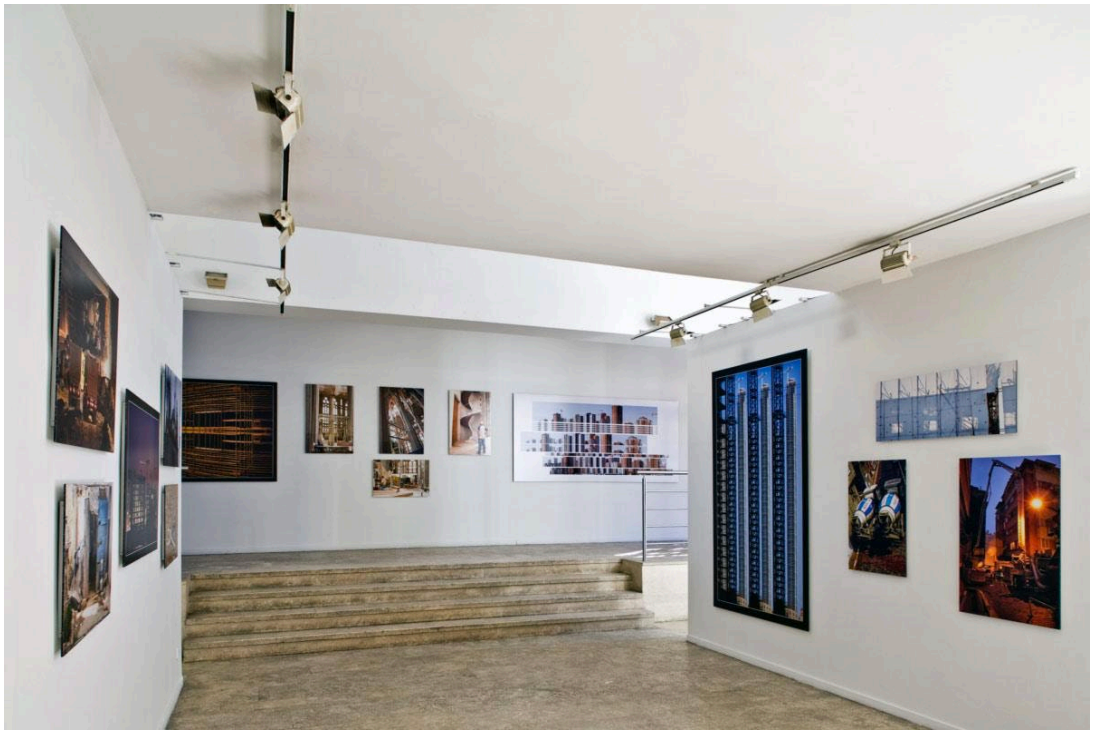

Figure 5 'İnşa'(Construct) series, exhibited at French Cultural Institute in Istanbul (Germen, 2006-2007)

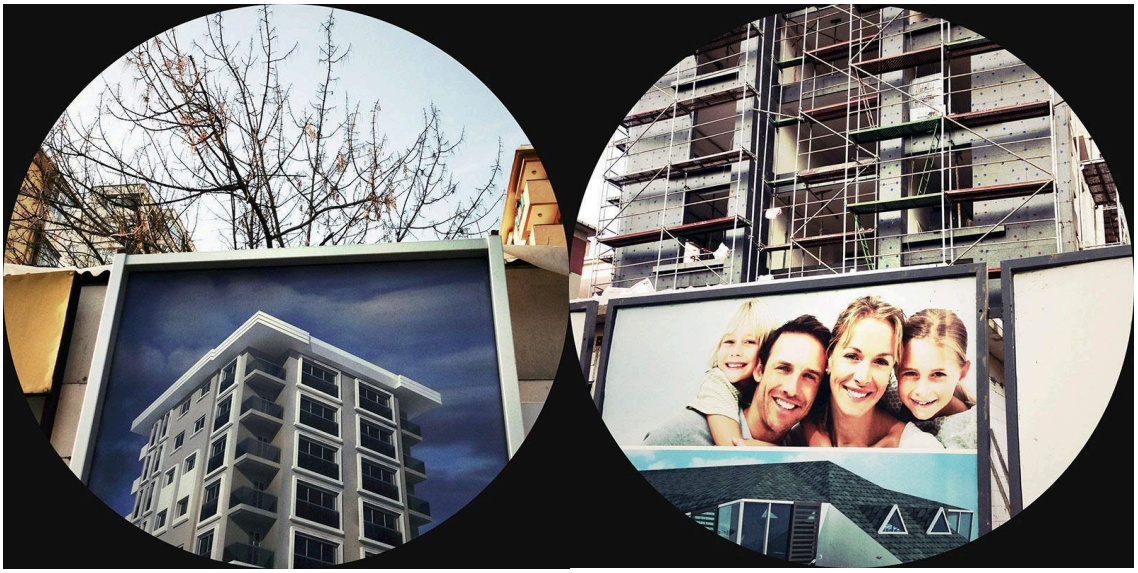

Figure 6, 7 'Transformal' series, exhibited at Diyarbakır Photo Days in 2014 (Germen, 2014b, 2014c)

5. Findings: Germen's Counter-Archival Practice at Three Sites

Production Site: The Counter-Archival Practitioner

The theoretical framework proposed that photography's potential for counter-hegemonic use must be earned from, not assumed against, its prior operation as an apparatus of power (Tagg, 1988). Germen's self-positioning reflects this awareness directly. As quoted earlier, he mentions what he is doing as "producing evidence against crime" (Germen, 2019a). This positioning maps directly onto Sekula's (1984, 1986) conceptualization of the counter-archive: a practice that refuses the terms of official representation by contesting the criteria through which certain realities are exposed and others structurally suppressed.

This is not only an ethical position but a strategic one: photography, Germen argues, is specifically suited to dissent in ways that architecture is not: *"While developing a dissident, critical attitude in architecture can lead to bankruptcy, sustaining opposition through photography is possible"* (Germen, 2023b).

Germen's documentary path - beginning with Fikirtepe in 2012 - situates the practice from its inception as a response to a process of organized invisibilization. The archive is not merely a collection of images; it is a sustained act of civic witness, aimed - in Germen's own formulation - at "*being able to build a strategy for how and what to fight, and to warn others against possible dangers"* (Germen, 2023b).

Image Site: Two Sites, Two Visual Strategies

The comparative examination of Germen's Fikirtepe and Bağdat Avenue work confirms the analytical model's central proposition. The analysis finds that the same photographer, working with the same political commitment, produces structurally different visual strategies in response to structurally different modalities of mnemonic erasure. In Fikirtepe, Germen's strategy is organized around the concept of the threshold - the moment at which anamnesis is still possible but already threatened by imminent destruction. In Bağdat Avenue, the photographic problem is different: aesthetic recoding operates by ensuring that there is no catastrophic moment to photograph. The visual strategy of the '*Transformal*' series (2014–ongoing) responds by redirecting attention from the built environment itself to the representations circulating before and around it.

These two strategies are stages of a single practice. Drawing on Tello's (2019) 'and–and' formula, Germen's ongoing documentation functions as an archive gathering fragments of demolished neighbourhoods, construction sites, and their lived residues in proximity, placing incompatible time periods side by side in ways hegemonic memory is designed to prevent.

What separates the two sites at the level of the image is therefore not the intensity of the response but its temporal structure. Aggressive erasure yields a datable rupture that a single frame can hold; aesthetic recoding distributes its losses across a duration too diffuse for any single frame to register, so that the critical content of the image has to be assembled by the viewer across time. Whether that assembly actually takes place is a question the image site cannot answer on its own, and it is to the conditions of reception that the analysis now turns.

Audiencing Site: Circulation, Discourse, and the Asymmetry of Visibility

The analysis at the audiencing site draws on 7 documented reception contexts: the initial exhibition at Alan İstanbul (2013); '*Sarmal*' (Helix) mixed exhibition at Yapı Kredi Culture Center (2017) (Figure 8); '*Fikirtepe: A Black Dot in Istanbul's History of Urbanization*' (Germen et al., 2021); the photo-essay '*Şimdilerde Şehir: Hayal Kırıklığı*' (Germen, 2020b); '*Zemin-siz İstanbul*' at Collect Gallery (2025–2026); and Germen's published interviews (*coverage by ARTE* and *Ahvalnews* alongside Turkish press).

Figure 8 Work titled "Rupture" on display at the collection exhibition 'Sarmal' (Helix) at Yapi Kredi Bank Arts & Culture, curated by Necmi Sönmez, 2017 (Germen, 2017)

The discourse yields a finding that an image-centred approach alone would miss: the two bodies of work generate significantly asymmetric discursive profiles. Germen's Fikirtepe documentation circulates most densely in contexts of urban activism, political opposition, and journalistic criticism. His work on Bağdat Avenue, by contrast, finds its primary reception in architecture journals, design criticism, and art press. This asymmetry is not a failure of Germen's practice: it is a structural reflection of the two erasure modalities he documents. Aggressive erasure tends to produce resistance and therefore a counter-discourse; aesthetic recoding produces desire, and desire tends to read itself as freedom rather than as loss. (cf. Leach (1999), on the anaesthetic function of aesthetic pleasure; Bourdieu (1984), on the misrecognition inherent in taste).

In conditions of constrained political pluralism, Germen characterizes the political conditions of the period in explicitly critical terms: *"If you try to oppose hardness with hardness, you will lose in the end; those who can deploy force - ignoring existing laws or adapting them to violence - are stronger than you. In times like these, one must use the methods they do not know: peaceful,*

creative, productive, warm-faced, unifying ones" (Germen, 2019b). This is not apolitical accommodation; it is a calculated strategy of counter-hegemonic practice - one that deploys the very aesthetic and civic legitimacy of photography against a hegemonic order that would prefer to remain invisible.

Strasser's (2020) Deptford is Changing project shows that a counter-archive can reach and mobilize the affected community. But this mobilizing function was possible because Strasser's practice targeted aggressive, event-centred displacement: residents knew they were losing something, could identify institutional actors responsible for, implementing, or benefiting from the transformation, and had clear stakes in the outcome. There are partial parallels with Germen's Fikirtepe work: his images circulated within activist and opposition networks during the period of peak displacement pressure (2012–2015), and their presence in local media and urban rights campaigns suggests some degree of mobilizing function - even if the speed of demolition limited the time available for counter-memory to consolidate. Aesthetic recoding does not create this kind of clearly affected community. In Bağdat Avenue, what is erased is the kind of harm that Leach's aesthetic anaesthesia renders imperceptible to those whose sensory pleasure the new environment is designed to sustain.

Table 2 sets the three sites side by side, comparing Fikirtepe and Bağdat Avenue across five categories: the legal and temporal mode of transformation, the relationship to collective memory each produces, Germen's visual response, the discursive circuits the resulting images travel, and the resilience potential each configuration sustains. Taken together, the rows show that the two sites differ in kind rather than degree, and that this difference carries through from the legal mechanism of transformation to the audiences the images are finally able to reach. Both bodies of work testify. What does not travel equally is their capacity to mobilize, and it is that asymmetry the next section takes up as a question of counter-memorial efficacy.

Table 2 Comparative Analysis of Two Modalities of Mnemonic Erasure in Post-2000 Istanbul, Evaluated Across Five Analytical Categories at the Sites of Production, Image, and Audiencing

Analytical Category	Fikirtepe (Aggressive Erasure)	Bağdat Avenue (Aesthetic Recoding)
(1) Mode of Transformation	Legally declared risk-zone designation and compulsory acquisition - visible, concentrated, and temporally bounded.	Incremental parcel-by-parcel redevelopment driven by market incentives - gradual, dispersed, and legally unchallenged.
(2) Relationship to Collective Memory	Abrupt erasure producing identifiable moments of mnemonic rupture; communities lose neighbourhood as social space overnight.	Gradual erasure producing what Koylan (2018) calls *"birikememe tarihi"*
(3) Visual Strategy (Germen)	Threshold images: half-demolished walls, lone standing structures, aerial dystopian landscapes - mnemonic rupture rendered visible at a single glance.	Gap between representation and reality: construction-site renders juxtaposed with built outcomes - requires temporal and comparative reading to activate critical content.
(4) Audience Reception	Circulates primarily in activist, journalistic, and political opposition contexts.	Circulates primarily in architecture journals, design criticism, and art press.
(5) Resilience Potential	Testimonial function: robust. Mobilizing function: stronger - confrontational structure creates identifiable communities of shared experience and recognizable perpetrators.	Testimonial function: robust. Mobilizing function: weakened - aesthetic recoding dissolves the felt sense of dispossession before counter-memory can take hold.

Source: Author, drawing on Rose (2016), Koylan (2018), and Land (2023)

6. Discussion: Photography, Memory, and the Resilience Potential of the Counter-Archive

The comparative analysis yields a finding with consequences beyond the Istanbul case: the counter-memorial efficacy of photographic counter-archive is not a fixed property of photographic practice but depends on the relationship between the spatial logic of mnemonic erasure and the social conditions in which visual meaning is made. Photographs alone do not produce counter-memory; what matters is the fit between a photographic approach and the specific form of erasure it confronts.

In Fikirtepe, aggressive erasure produced a legible confrontational structure: a state-backed process of demolition confronting a community capable of resistance. This structure is photographable - it generates threshold moments, visible losses, identifiable institutional actors responsible for, implementing, or benefiting from the transformation, and communities whose collective suffering can be rendered as testimony. Rose's tripartite model shows that the counter-memorial function is realized - imperfectly, but demonstrably - because the modality of erasure generates the social conditions necessary for its own challenge. The coercive effects of transformation become spatially and socially legible, and legibility is the precondition of counter-memory.

In Bağdat Avenue, aesthetic recoding systematically destroys the preconditions of this legibility. The counter-archive circulates most densely in art, architecture and design publications because it documents a process that, by its nature, addresses itself to aesthetic sensibility. The critical content of the images reaches its primary audience in a discursive context that absorbs rather than activates counter-memorial potential.

Counter-Memory Without a Target: Aesthetic Recoding and the Limits of Legibility

This asymmetry has direct implications for the two functions of photographic counter-memory introduced above. The analysis shows that the testimonial function - the evidential record - remains robust across both sites. The mobilizing function - the activation of counter-hegemonic solidarity - is structurally conditioned by the modality of erasure each site instantiates.

The mobilizing function is most effectively realized where communities still experience their loss as loss - which aggressive erasure threatens but does not necessarily prevent. Aesthetic recoding undermines this more subtly: by making the very transformation pleasurable, it dissolves the felt sense of dispossession before any counter-memory can take hold.

Land (2023) provides the theoretical grounding: counter-memory, by its nature, requires an opponent - a hegemonic narrative already fixed and institutionally legible. Aggressive erasure supplies this in abundance; aesthetic recoding withholds the target. Where mnemonic infrastructure erodes through desire rather than decree, there is no moment to contest and no perpetrator to name - what Land calls a structured absence.

Price's (2023) analysis identifies the museumification risk: images of communities undergoing transformation, when received by audiences whose relationship to the photographed environment is primarily aesthetic rather than lived, tend to generate melancholic contemplation rather than political mobilization. This risk is particularly acute in the Bağdat Avenue case: the audiences that engage most consistently with Germen's 'İnşa' and 'Transformal' work are, by and large, the same professional and upper-middle classes whose aesthetic investments drive the very process of recoding that these images document. The testimonial function, however, operates on a different temporal register and is not diminished by these constraints. Land's (2023) account reframes what it achieves in the longer run: Germen's archive lays the groundwork for a future in which hegemonic memory consolidates, so that the counter-memorial record already exists, ready to be deployed - not a failed mobilization but a deposit made for a contestation that has not yet arrived.

Conditions of Efficacy: Erasure Modality and Counter-Memorial Efficacy

The comparative analysis suggests a provisional schema. Where erasure operates through coercion and speed - producing legible confrontational structures and identifiable moments of loss - photographic counter-memory has its strongest claim to mobilizing function. Where it operates through desire and gradual erosion, with no such legible structure, counter-memory faces a challenge no degree of photographic sophistication fully resolves: its testimonial function and analytical contribution remain significant, but its mobilizing function is weakened by the very success of the erasure it contests. This schema is not binary - actual transformations combine elements of both modalities - but it offers a tool for identifying which dimension of counter-memorial practice, testimonial or mobilizing, a given photographic strategy can claim to activate, and for which audiences.

7. Conclusion

This article has advanced three interconnected arguments. The first is theoretical: that mnemonic erasure is not a secondary side effect of urban transformation but one of its primary mechanisms - a deliberate dissolution of the social frameworks through which collective memory operates. The concept of hegemonic memory policy, developed through the intersection of Harvey, Gramsci, and Leach, names this dissolution as a political project rather than an unfortunate byproduct of development, and thereby reframes the question of urban resilience: what is at stake in urban transformation is not only the physical fabric of neighbourhoods or the economic security of their residents, but the capability of communities to narrate their own experience, transmit it to future generations, and mobilize it for political contestation.

The second argument is empirical: hegemonic memory policy takes at least two distinct forms - aggressive erasure (Fikirtepe) and aesthetic recoding (Bağdat Avenue) - which achieve the same mnemonic outcome through opposite means. Aggressive erasure deploys speed, coercion, and physical demolition to prevent the social processes of memory formation before they can consolidate; aesthetic recoding uses desire, pleasure, and market rationality to make the dissolution of mnemonic infrastructure not only tolerable but actively sought. These findings acquire additional weight when situated within a longer genealogy of mnemonic erasure in Turkish urban space.

Kolluoğlu Kırlı's (2002) analysis of Smyrna/İzmir's rebuilding after the 1922 fire, and the Republican-era reordering of Ankara and Taksim Square to produce a new national subject (Akpınar, 2014), show that the political rewriting of urban space has deep roots in Turkish modernity. Post-2000 Istanbul is not a rupture but the sharpest contemporary expression of this structural tendency.

A third and methodological thread runs through both cases: Rose's (2016) tripartite framework, applied to Murat Germen's work across both cases, reveals that the resilience value of photographic counter-memory is not a property of images but a relational achievement, one that takes shape in the interaction between the conditions of photographic production, the visual strategies through which counter-memorial narratives are constructed, and the social constitution of their meaning in reception. The asymmetric discursive profiles of Germen's two bodies of work - activist and political in the Fikirtepe case, aesthetic and critical in the Bağdat Avenue case - are not a failure of photographic practice but a structural reflection of the different erasure modalities they document.

The findings carry practical implications in three areas. In heritage conservation, documentation must be calibrated to the transformation's temporal logic: rapid coercive displacement calls for urgent threshold photography, while gradual aesthetic recoding calls for longitudinal, comparative work tracking the gap between promise and outcome. Community archiving and participatory planning benefit most where the affected community still holds a shared sense of loss, which policy frameworks for community archives can help sustain. In memory-sensitive urban design, the

concept of mnemonic infrastructure argues for impact assessments that weigh the loss of the spatial conditions through which collective memory forms, not only physical displacement.

The framework itself, distinguishing modalities of mnemonic erasure from functions of photographic counter-memory, is not specific to Istanbul. Shanghai (Shao, 2013) and Dubai (Elsheshtawy, 2010) suggest that aggressive erasure and aesthetic recoding are structural tendencies, surfacing wherever neoliberal urban development combines direct state coercion with market-driven aestheticization. Germen's practice finds counterparts elsewhere in the Global South, where photographic and artistic resistance similarly contests demolition-led amnesia: in urban China, collage, rephotography, and documentary work recover fleeting urban memory against hyper-accelerated redevelopment (Sterling, 2016; Mugica & Whyke, 2024; Pawlik, 2024; Li, 2025); in South Africa, artistic documentation, oral history, and public intervention make forced removals and apartheid spatial afterlives visible (Siegenthaler, 2021; Anderson & Daya, 2022; Roux, 2018; Makhubu & Ruiters, 2020); and across Latin America, archival and participatory image-making reactivate suppressed histories of dictatorship and displacement (Corrigan, 2022; Guerra, 2025; Gamboa-Morales, 2025; Trujillo-Losada et al., 2025). As with Germen's counter-archive, this global pattern rarely restores a stable past; rather, it uses visual practice to expose contested space and reopen political claims on places being overwritten (Huyssen, 2025).

Several lines of future research follow: a comparative study of multiple photographers, including community-based practitioners, to test these modality-specific visual strategies against a broader corpus; work on audience and community response, rather than institutional reception, to reach the mobilizing function more directly; and, most promisingly, participatory photography, in which affected communities produce their own documentation and combine testimonial and mobilizing functions in ways a single-author counter-archive cannot. Within Istanbul, the framework could extend to Republican-era urban areas that are now under increasing development pressure.

The article's contribution to urban resilience research is a distinction, not a verdict. The testimonial and mobilizing functions of counter-archival practice can be told apart, and telling them apart stops documentation from being counted as resistance by default. It also makes it possible to specify the conditions under which a photographic counter-archive can claim counter-memorial efficacy, and those conditions begin with the legal structure that authorises erasure in the first place. Germen's archive, read this way, is less a visual chronicle of Istanbul's transformation than a political act - the systematic production of visibility for processes having the effect of reducing or eliminating the visible traces of the displaced urban environment of what they displace. It exists, it circulates, and it keeps generating discursive contestation. In the terms developed throughout this article, that is already a form of urban resilience: imperfect, incomplete, but irreplaceable.

CRediT Authorship Contribution Statement

Sena Özfiliz: Writing – review & editing, Writing – original draft, Methodology, Investigation, Resources, Analysis, Data curation, Conceptualization, Data visualization. İpek Akpınar: Writing – review & editing, Methodology, Supervision.

Declaration of Competing 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 paper.

Data Availability

Data will be made available on request.

Ethics Committee Approval

This study is based on publicly available photographs, published interviews, exhibition materials, academic publications, and institutional documents. No interviews, surveys, or other forms of research involving human participants were conducted, and no personal or sensitive data were collected. Therefore, institutional ethics committee approval was not required. Written permission was obtained from the copyright holder for the reproduction of the photographic works included in the article.

Notes

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References

Akpınar, İ. (2014). The rebuilding of İstanbul revisited: Foreign planners in the early Republican years. *New Perspectives on Turkey*, *50*, 59-92. https://doi.org/10.1017/S0896634600006580

Aksoy, A. (2012). Riding the storm: New Istanbul'. *City, 16*(1_2), 93_111. https://doi.org/10.1080/13604813.2012.662373

Aksoy, A. (2014). İstanbul'un neoliberalizmle imtihanı. In A. B. Candan and C. Özbay (Eds.), *Yeni İstanbul çalışmaları: Sınırlar, mücadeleler, açılımlar,* (p. 27-46). Metis Yayınları.

Anderson, M., & Daya, S. (2022). Memory justice in ordinary urban spaces: The politics of remembering and forgetting in a post_apartheid neighbourhood. *Antipode*, *54*(6), 1673_1693. https://doi.org/10.1111/anti.12863

Azoulay, A. (2008). *The civil contract of photography*. Zone Books.

Batuman, B. (2018). *New islamist architecture and urbanism: Negotiating nation and islam through built environment in Turkey.* Routledge.

Batuman, B. (2022a). *Milletin mimarisi*, (Ş. Tokel, Çev.; 2. bas.). Metis Yayınları.

Batuman, B. (2022b, June 30). *Millet bahçeleri: Kamusal mekanın sömürgeleştirilmesi*. Gazete Duvar. https://www.gazeteduvar.com.tr/millet-bahceleri-kamusal-mekanin-somurgelestirilmesi-makale- 1571414

Batuman, B. (2025, February 6). *Depremin ikinci yıl dönümü: Kahramanmaraş'ta bellek, mekân ve iktidar*. Gazete Duvar. https://www.gazeteduvar.com.tr/depremin-ikinci-yil-donumu-kahramanmarasta-bellek-mekan-ve-iktidar-makale-1754912

Bourdieu, P. (1984). *Distinction: A social critique of the judgement of taste.* Harvard University Press.

Bülbül Akın, B., & Türkün, A. (2019). Dar gelirli konut alanlarının dönüşümünde sosyal karma politikası: Fikirtepe örneği (Social mixed policy in the transformation of low- income housing areas: The case of Fikirtepe). *MEGARON*, *14*(SUPPL. 1), 192-202 https://dx.doi.org/10.14744/megaron.2019.85047

Connerton, P. (1989). *How societies remember.* Cambridge University Press.

Corrigan, A. (2022). Photographic assembly in post-dictatorial Argentina and Uruguay. *Journal of Latin American Cultural Studies*, *31*(2), 201-221. https://doi.org/10.1080/13569325.2022.2092084

Cretney, R. (2014). Resilience for whom? Emerging critical geographies of socio-ecological resilience. *Geography Compass*, *8(9)*, 627-640. https://doi.org/10.1111/gec3.12154

Çavuşoğlu, E., & Strutz, J. (2014). Producing force and consent: Urban transformation and corporatism in Turkey. *City, 18(2)*, 134-148. https://doi.org/10.1080/13604813.2014.896643

Çoban Çınar, M., & Özkan Töre, E. (2023). Bağdat Caddesi-Erenköy Mahallesinde kentsel dönüşüm uygulamaları: Aktörlerin rolü ve karşılaşılan sorunlar. *Kent Akademisi Dergisi*, *16*(3), 2070-2090. https://doi.org/10.35674/kent.1106510

Davoudi, S. (2012). Resilience: A bridging concept or a dead end? *Planning Theory & Practice*, *13(2)*, 299-333. https://doi.org/10.1080/14649357.2012.677124

Elsheshtawy, Y. (2010). *Dubai: Behind an urban spectacle.* Routledge.

Gamboa-Morales, D. (2025). Lost places: Mental images as an expanded form of visuality in Chile's popular revolt. *Visual Studies, 41*, 308-318. https://doi.org/10.1080/1472586x.2025.2537735

Germen, M. (2007). *İnşa* [Construction] [image-2] [Online exhibition / Artwork]. Murat Germen. (Date retrieved: 15.05.2026) https://muratgermen.com/artworks/insa/#image-2

Germen, M. (2013). *Grup sergilerindeki işler / Works at group exhibits* [#image-492] [Online exhibition / Artwork]. Murat Germen. (Date retrieved: 15.05.2026) https://muratgermen.com/artworks/grup-sergilerindeki-isler-works-at-group-exhibits/#image-492

Germen, M. (2014a). *Erasing memory: Shanghai – İstanbul belleği silmek* [Erasing memory: Shanghai – Istanbul erasing memory] [#image-45] [Online exhibition / Artwork]. Murat Germen. (Date retrieved: 15.05.2026) https://muratgermen.com/artworks/erasing-memory-shanghai-istanbul-bellegi-silmek/#image-45

Germen, M. (2014b). *Grup sergilerindeki işler / Works at group exhibits* [#image-457] [Online exhibition / Artwork]. Murat Germen. (Date retrieved: 15.05.2026) https://muratgermen.com/artworks/grup-sergilerindeki-isler-works-at-group-exhibits/#image-463

Germen, M. (2014c). *Grup sergilerindeki işler / Works at group exhibits* [#image-463] [Online exhibition / Artwork]. Murat Germen. (Date retrieved: 15.05.2026) https://muratgermen.com/artworks/grup-sergilerindeki-isler-works-at-group-exhibits/#image-457

Germen, M. (2017). *Grup sergilerindeki işler / Works at group exhibits* [#image-342] [Online exhibition / Artwork]. Murat Germen. (Date retrieved: 15.05.2026) https://muratgermen.com/artworks/grup-sergilerindeki-isler-works-at-group-exhibits/#image-342

Germen, M. (2019a, October 8). *Murat Germen'le görünenin ötesinde* [Interview by H. E. Özçelik]. IFSAK Bülten. https://www.ifsakblog.org/murat-germenle-gorunenin-otesinde/

Germen, M. (2019b, June 1). *Kimlikli yer teşekkülü* [Interview by A. Olcan]. 1+1 Express. https://birartibir.org/kimlikli-yer-tesekkulu/

Germen, M. (2019c). *İnşa* [Exhibition text]. https://muratgermen.com/artworks/insa/

Germen, M. (2020a, 12 August). *Kent planlamasında kara bir leke* [Interview by E. Demirtaş]. Gazete Kadıköy. https://www.gazetekadikoy.com.tr/gundem/kent-planlamasinda-kara-bir-leke

Germen, M. (2020b). Şimdilerde şehir: Hayal kırıklığı. *YILLIK: Annual of Istanbul Studies, 2,* 157-163. https://doi.org/10.53979/yillik.2020.12

Germen, M. (2023a). *Grup sergilerindeki işler / Works at group exhibits* [#image-179] [Online exhibition / Artwork]. Murat Germen. (Date retrieved: 15.05.2026) https://muratgermen.com/artworks/grup-sergilerindeki-isler-works-at-group-exhibits/#image-179

Germen, M. (2023b, January 3). *Kenti izlemek, insanı izlemek demek benim için* [Interview by Y. Şener]. Yapı Dergisi. https://yapidergisi.com/murat-germen-kenti-izlemek-insani-izlemek-demek-benim-icin/

Germen, M., Tülek, M., & Diriker, H. (2021, 13 April). *Fikirtepe: A black dot in Istanbul's history of urbanization*, [Video]. YouTube. https://www.youtube.com/watch?v=rAJHTnk9noQ

Guerra, L. (2025). Photography and post-dictatorship memory in Hnar's 'Missing Time'. *Axon: Creative Explorations*. https://doi.org/10.54375/001/axtem35sy2

Halbwachs, M. (1980). *The collective memory* (F. J. Ditter Jr. & V. Y. Ditter, Trans.). Harper & Row. (Original work published 1950)

Harvey, D. (2003). *The new imperialism.* Oxford University Press.

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, *4*, 1-23. https://doi.org/10.1146/annurev.es.04.110173.000245

Huyssen, A. (2003). *Present pasts: Urban palimpsests and the politics of memory.* Stanford University Press.

Huyssen, A. (2025). The art of memory activism in the global South. *Memory Studies, 18*, 564-573. https://doi.org/10.1177/17506980251320499

İstanbul Planlama Ajansı. (2024). *Kentsel dönüşümde rezerv alan ve riskli alan kavramlarına dair değerlendirme*. [Evaluation on the concepts of reserve area and risky area in urban transformation] [Report] (Date retrieved: 04.06.2026) https://www.google.com/search?q=https://ipa.istanbul/pdf-flipbook-main/index.html%3Fkey%3D/images/Calismalar/kentsel-do%25CC%2588nu%25CC%2588s%25CC%25A7u%25CC%2588mde-rezerv-alan-ve-riskli-alan-kavramlarina-dair-deg%25CC%2586erlendirme-33382.pdf

Kolluoğlu Kırlı, B. (2002). The play of memory, counter-memory: Building Izmir on Smyrna's ashes. *New Perspectives on Turkey, 26,* 1-28. https://doi.org/10.1017/S0896634600003691

Koylan, D. (2018). *İstanbul Bağdat Caddesi ve yakın çevresinde kentsel dönüşüm: 2012-2018 dönemi.* [Unpublished doctoral dissertation, Mimar Sinan Güzel Sanatlar Üniversitesi].

Kuyucu, T. (2014). Law, property and ambiguity: The uses and abuses of legal ambiguity in remaking Istanbul's informal settlements. *International Journal of Urban and Regional Research, 38(2)*, 609-627. https://doi.org/10.1111/1468-2427.12026

Kuyucu, T., & Ünsal, Ö. (2010). 'Urban transformation' as state-led property transfer: An analysis of two cases of urban renewal in Istanbul. *Urban Studies, 47(7)*, 1479_1499. https://doi.org/10.1177/0042098009353629

Küper-Büsch, S. (2019). Destruction for profit: the silhouette of "New Turkey", *Ahvalnews*, https://ahvalnews.com/turkey-construction/destruction-profit-silhouette-new-turkey (Date retrieved: 01.05.2022, 17:44)

Land, J. (2023). Synthesizing collective memory and counter-memory in urban space. *Urban Geography, 44*(5), 1011-1020. https://doi.org/10.1080/02723638.2023.2205261

Leach, N. (1999). *The anaesthetics of architecture*. MIT Press.

Lefebvre, H. (1991). *The production of space.* Blackwell, Oxford.

Li, M. (2025). Mediating forgetting as memory activism: The Hedao community's independent documentary and online activism in contemporary China. *Memory Studies, 18*, 456_474. https://doi.org/10.1177/17506980251320916

Lovering, J., & Türkmen, H. (2011). Bulldozer neo-liberalism in Istanbul: The state-led construction of property markets, and the displacement of the urban poor. *International Planning Studies, 16(1)*, 73-96. https://doi.org/10.1080/13563475.2011.552477

MacKinnon, D., & Derickson, K. D. (2013). From resilience to resourcefulness: A critique of resilience policy and activism. *Progress in Human Geography*, *37(2)*, 253_270. https://doi.org/10.1177/0309132512454775

Makhubu, N., & Ruiters, G. (2020). 'This land is not for sale': Post-1994 resistance art and interventionism in Cape Town's precarious publics. *City, Culture and Society, 23,* 100368. https://doi.org/10.1016/j.ccs.2020.100368

Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. *Landscape and Urban Planning*, *147*, 38-49. https://doi.org/10.1016/j.landurbplan.2015.11.011

Mugica, J. L., & Whyke, T. W. (2024). Representations of post-industrial Shanghai. *Asian Studies*, *12*(1), 355-387. https://doi.org/10.4312/as.2024.12.1.355-387

Nora, P. (1989). Between memory and history: Les lieux de mémoire. *Representations, 26*, 7-24.

Pawlik, K. (2024). Shanghai and the surreal: Urban renewal as an inception. *Journal of Contemporary Chinese Art*, *11*(1), 107-124. https://doi.org/10.1386/jcca_00107_1

Price, Z. (2023). Missing the present: Nostalgia and the archival impulse in gentrification photography. *Arts*, *12*(3), Article 85. https://doi.org/10.3390/arts12030085

Rose, G. (2016). *Visual methodologies: An introduction to researching with visual Materials (4th ed.)*. SAGE.

Roux, N. (2018). 'A house for dead people': memory and spatial transformation in Red Location, South Africa. *Social & Cultural Geography, 1*9, 407-428. https://doi.org/10.1080/14649365.2017.1280614

Saraçoğlu, C., & Demirtaş-Milz, N. (2014). Disasters as an ideological strategy for governing neoliberal urban transformation in Turkey: Insights from Izmir/Kadifekale. *Disasters, 38(2)*, 300_327. https://doi.org/10.1111/disa.12038

Sekula, A. (1984). *Photography against the grain: Essays and photo works 1973–1983.* Press of the Nova Scotia College of Art and Design.

Sekula, A. (1986). The body and the archive. *October, 39,* 3-64.

Shao, Q. (2013). *Shanghai gone: Domicide and defiance in a Chinese megacity.* Rowman & Littlefield.

Siegenthaler, F. (2021). Representing Johannesburg in transformation: Urban experience, imageries, and the work of art by David Koloane, Jo Ractliffe and Anthea Moys. *Critical African Studies, 13*, 286-304. https://doi.org/10.1080/21681392.2021.1999833

Sterling, C. (2016). An era without memories: Chinese contemporary photography on urban transformation. *The Journal of Architecture*, *21*(7), 1159-1164. https://doi.org/10.1080/13602365.2016.1233625

Strasser, A. (2020). *Deptford is changing: A creative exploration of the impact of gentrification.* Self-published.

Tagg, J. (1988). *The burden of representation: Essays on photographies and histories.* Macmillan.

Tello, V. (2019). *Counter-memorial aesthetics: Refugee histories and the politics of contemporary art.* Bloomsbury.

Trujillo-Losada, M. F., Villamarín, E. C., & García, N. (2025). Appropriation of space: El Arbol settlement as a space of resistance in the city of Santiago de Cali, Colombia. *City*, *29*, 1141-1154. https://doi.org/10.1080/13604813.2025.2562780

Türkün, A. (2011). Urban regeneration and hegemonic power relationships. *International Planning Studies, 16 (1)*, 61-72. https://doi.org/10.1080/13563475.2011.552473

Türkün, A. (2014). İstanbul'da 1980'ler sonrasında kentsel dönüşüm: Mevzuat, söylem, aktörler ve dönüşümün hedefindeki alanlar. In A. Türkün (Ed.), *Mülk, mahal, insan: İstanbul'da kentsel dönüşüm* içinde (p. 1-68). İstanbul Bilgi Üniversitesi Yayınları.

Ünver, M., & Suri, L. (2020). Kentsel dönüşümün Fikirtepe'ye yansıması. *İstanbul Ticaret Üniversitesi Teknoloji ve Uygulamalı Bilimler Dergisi*, *2*(2), 11-23. https://izlik.org/JA96NE63NH

Resume

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Climate-induced flooding and coastal transportation vulnerability: Implications for urban resilience in Izmir, Türkiye

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Abstract

Climate-related sea-level rise and storm surges are progressively impacting coastal cities and their transportation infrastructure, placing increasing strain on mobility in these areas. Since major transportation routes are often located in low-lying coastal areas, assessing their susceptibility to flood-related hazards has become a critical aspect of urban resilience and climate adaptation planning. This research examines the relationship between sea level variability and traffic performance under flood-prone conditions through a case study of a coastal transportation corridor in Izmir, Türkiye. The analytical framework integrates long-term relative sea level observations (1999–2024) with high-frequency traffic volume data collected during rainfall and flood-prone periods in 2023. Long-term sea level variability and seasonal patterns were examined using time-series analysis, while the empirical relationship between sea level variability and traffic flow was analysed using regression and correlation analyses. In addition, exploratory future scenarios were developed to illustrate potential exposure pathways under continued sea level rise. The findings indicate that higher sea level values are associated with modest but statistically significant reductions in traffic volumes along coastal routes. The strength of these associations varies spatially and temporally, with stronger relationships observed at specific locations and during peak traffic periods. The analysis further highlights the vulnerability of coastal transport corridors to flood-induced disruptions and illustrates how corridor-scale analyses can identify localized vulnerabilities that may be masked at broader regional scales. By linking observed traffic responses to sea level variability under flood-prone conditions, the study contributes empirical evidence to the growing literature on climate-resilient transportation systems. These insights provide valuable insights for assessing transportation vulnerability and resilience in urban growth, infrastructure management, and climate adaptation interventions in coastal cities.

Keywords: climate-induced flooding, coastal transportation, sea level variability, transportation vulnerability, urban resilience

1. Introduction and Literature Review

Climate change has enhanced both the long-term risks of sea level rise and the short-term flood hazards to which coastal urban systems are exposed. Because it underpins mobility, economic activity, and emergency response, transportation infrastructure is especially at risk. Coastal areas are highly exposed because their mobility corridors and critical infrastructure are densely clustered in low-elevation zones vulnerable to tidal and storm surges, and high-intensity precipitation events (Hallegatte et al., 2019; Nawarat et al., 2026). When floods force the closure of roads and rail lines for repair, they trigger a series of transport service disruptions that can restrict accessibility, aggravate congestion, and produce cascading socio-economic effects; hence the resilience of transportation systems is considered a crucial element for climate adaptation (Koetse & Rietveld, 2009; Jaroszweski et al., 2010). Recent empirical analyses also suggest that flood-induced road infrastructure disruptions can significantly increase travel times and result in major economic losses through delays and inefficiencies in the road network (Saiz & Wang, 2022; Shan et al., 2025).

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A large number of studies have investigated the impact of weather and climate hazards on transport systems. Evidence-based research has shown that precipitation and severe weather conditions exert a substantial effect on traffic volume, road safety, and network operations (Brodsky & Hakkert, 1988; Changnon, 1996; Al Hassan & Barker, 1999). Recent studies indicate that precipitation, extreme weather events, and other weather-related phenomena continue to strongly impact flow, safety and transport efficiency often resulting in disruptions and or impairment of traffic performance and increased operation and maintenance costs (Touloumidis et al., 2025; Liu et al., 2026). Along with these usual weather effects, numerous studies have focused on the impacts of heavy rainfall and urban flooding. The studies demonstrate that flooding can significantly reduce road capacity, disrupt traffic flow and degrade network performance, particularly in densely populated urban areas (Chang et al., 2010; Cools et al., 2010; Mitsakis et al., 2014; Diakakis et al., 2020). Moreover, due to network interdependencies, such disruptions often propagate far beyond directly flooded zones, cascading into system-wide delays and reduced accessibility across broader transportation networks (Jenelius et al., 2006; Coles et al., 2017; Kasmalkar et al., 2020).

In addition to short-term flood impacts, extensive literature links sea level rise to long-term transportation vulnerabilities. Rising sea-levels can also change land-use patterns, impair roadway performance, and exacerbate congestion risks along coastal routes (Papakonstantinou et al., 2020). Regional-scale studies further argue that substantial populations, along with large stretches of transportation infrastructure, could increasingly face the risk of sea level rise, highlighting the urgency of anticipatory adaptation planning (Hauer et al., 2016; Pregnolato et al., 2016; Jacobs et al., 2018). Many of these analyses rely on sophisticated modeling techniques such as hydrodynamic flood models and resilience measures at the level of networks (Pregnolato et al., 2016; Arrighi et al., 2019; Boeing & Ha, 2024).

Despite these advances, important gaps remain in the literature. Much of the existing research focuses either on large-scale flood risk assessments or on model-based analyses of transportation systems. While these studies provide valuable insights, relatively little attention has been paid to corridor-scale empirical assessments that directly examine the relationship between observed sea level variability and transportation performance under flood-prone conditions. This limitation is particularly critical for coastal cities, which can be overlooked by regional evaluations of vulnerabilities. Understanding these place-specific dynamics is essential for embedding resilience into transportation planning and climate adaptation measures.

Izmir provides a particularly relevant case for examining these questions. As one of the major coastal cities of Türkiye, it has extensive transportation infrastructure along the coast. Numerous, critical transportation corridors are exposed to tidal flooding, storm surges, and intense precipitation, posing potential threats to transportation, accessibility, and infrastructure functionality. These characteristics make Izmir an appropriate setting for investigating the interactions between flood-related hazards and coastal transportation systems within a broader urban resilience context.

Local climate risk assessment is considered a key element of urban climate planning, specifically addressing the exposure of critical infrastructure, such as transport systems, to local climate risks. Municipal vulnerability assessments and risk analyses - such as those which may be conducted within the context of the Sustainable Energy and Climate Action Plan (SECAP) - need to explicitly address climate hazards (e.g. sea-level rise, flooding, etc.), as well as their impacts on urban infrastructure and mobility systems (Davide et al., 2025). Although the SECAP guidelines provide a general methodological framework rather than city-specific analyses, their focus on local risk assessment is consistent with the climate adaptation priorities in Izmir, where coastal districts, infrastructure and seaports are susceptible to sea level variability and coastal flooding. Transportation strategy development also highlights the sensitivity of coastal transport systems and the need to incorporate adaptation to climate change in transportation planning activities in the Izmir Sustainable Urban Transportation Plan (SKUP) (Izmir Metropolitan Municipality, 2025).

Supplementary environmental planning systems have also recognized transportation infrastructure as a critical climate risk-vulnerable sector; e.g., the Izmir Green City Action Plan (GCAP) highlights the requirement for integrated resilience approaches that connect infrastructure planning, environmental management and sustainable mobility (Izmir Metropolitan Municipality, 2020). The city's recent climate-neutrality plans also emphasize the need to consider sea level rise in long-term city and infrastructure planning (Izmir Metropolitan Municipality, 2021). Moreover, global coastal risk screening tools suggest that large swathes of Izmir's coastal urban areas could be at risk of flooding in the future even in moderate sea level rise scenarios (Climate Central, 2021).

The scholarly literature dedicated specifically on Izmir primarily addresses the risk of sea level rise particularly from the standpoints of planning and policy. Studies on city climate plans indicate differences in the capacity to adapt to risks and to assess them among cities on the Turkish coast (Iavarone & Kaya, 2021). Studies on urban design and spatial planning have highlighted the importance of water-sensitive urban morphology, blue–green infrastructure, and sustainable stormwater management to improve climate resilience and mitigate flood risks in coastal areas (Barbosa et al., 2012; Akdeniz, 2022; Özeren Alkan & Hepcan, 2023). Various other reviews of the literatures have also focused on the flood hazard mapping with GIS applications (Ozkan & Tarhan,2016), adaptation measures for coastal areas under threat through sea level rise and flooding (Ercanlı & Savaşır, 2022a), vulnerability of ecosystems to climate change (Arslan, 2023), and historical major flood events in Izmir (Karataş, 2024; Mutluer & Işık, 2025). Further planning research also focuses on mainstreaming the climate adaptation aspects in the urban transformation policies and governance arrangements (Allarané et al., 2024). However, despite the growing emphasis on resilience-oriented planning and climate adaptation, empirical evidence linking observed environmental variability to transportation system performance remains limited. As a result, the transportation aspect of urban resilience remains underrepresented in local climate adaptation assessments. However, there are still few empirical studies that directly examine the relationship between observed sea level variability and transportation performance.

In addition, the thematic analysis of the literature related to coastal transport planning revealed gaps, including a lack of empirical studies at the scale of a corridor, limited focus on contexts where data is scarce, and poor linkage between concepts of climate adaption and measured transport performance (Lennon et al., 2014; Mushtaq et al., 2024). Recent reviews highlight that the majority of transportation studies in flood have a strong dependence on modeling techniques and data availability, while empirical studies founded on observational data of real events remain limited in number (Boeing & Ha, 2024; Dharmarathne et al., 2024; Chen & Lo, 2026). Consequently, transportation planning in many coastal cities continues to rely on generalized risk assessments rather than on site-specific empirical data.

Within this context, the present study examines the vulnerability of a coastal transportation corridor in Izmir by investigating the relationship between sea level variability and transportation performance under flood-prone conditions. Long-term sea level data were combined with traffic flow data gathered during rainfall and flood-prone periods to provide an empirical analysis of the sensitivity of coastal transportation systems to environmental perturbations. The study is thus expected to add value to resilience-focused transportation planning by assessing localized transportation vulnerabilities associated with sea level variability and illustrating how such analyses can inform corridor-based climate adaptation strategies in coastal urban areas.

1.1. Contribution and Limitations

This paper contributes to the growing literature on climate resilience and transportation by examining the relationship between sea level variability and transportation performance under flood-prone conditions in a Mediterranean coastal city. The study provides empirical evidence of the relationship between sea level variability and transportation performance under flood-prone conditions at the corridor scale, an area that remains relatively underexplored within climate adaptation and resilience research.

The scale of the study at the corridor level allows for a direct evaluation of the relationship between observed sea level variability and disruptions to traffic flow during rainfall and flood-prone periods. Focusing on a single coastal transport corridor in Izmir, the study reveals local effects that may be masked in analyses at the network level or by the model-based research alone. This high-resolution view reveals how low-lying coastal highways respond to periods of elevated sea levels and identifies critical points of exposure in urban transportation grids.

The study proposes a corridor-scale empirical assessment framework for examining relationships between sea level variability and transportation performance under flood-prone conditions. Rather than replacing advanced climate or transportation models, the framework complements existing planning approaches by identifying localized vulnerabilities and potential exposure pathways under future sea level rise conditions. Its application demonstrates how empirical observations can support resilience-oriented transportation planning and climate adaptation in coastal urban environments.

In addition to methodological contributions, these results also inform discussions on policy and planning by grounding adaptation concerns in empirical observations of traffic behavior. The combination of traffic performance measures with an analysis of exposure to flooding provides a linkage between climate risk analyses and transportation planning that can offer decision-relevant insights to enhance the resilience of coastal mobility systems.

Despite these contributions, several limitations should be acknowledged. The analysis is based on a relatively short period of overlap between sea-level observations and traffic counts. Traffic data are only available for selected flood-prone periods within a year, whereas long-term sea level records are available. Moreover, the two datasets have different temporal resolutions: sea level data are represented by monthly averages, while traffic volumes are recorded hourly. This temporal misalignment prevents exact synchronization between the two datasets and therefore limits the interpretation of the resulting statistical relationships. Therefore, the statistical relationships identified in the study should be interpreted as exploratory associations rather than casual effects. Studies in the future that include longer durations of both concurrent traffic and sea level observations, as well as other potential explanatory variables (such as rainfall intensity, traffic demand, road conditions, and traffic incidents), may make it possible to conduct more robust multivariate analyses and provide stronger evidence for causation.

The methodological framework consistently relies on a few basic statistical tools such as regression and correlation analysis. While these techniques suit exploratory analyses given data limitations, they do not capture the complexity of climate–transport system interactions. More sophisticated methods reflecting hydrodynamic flood modeling on the one hand and network-level analysis or climate model–based projections on the other could shed light on prospective transportation effects.

The future scenarios are based on a trend-continuation assumption rather than on downscaled global or regional climate model outputs and should therefore be interpreted as a what-if sensitivity analysis rather than as a predictive model. They are used to examine how potential rises in sea level might change the spatial exposure of low-lying coastal transportation segments, not to estimate particular future traffic volumes. Therefore, the scenarios can be considered as representative exposure pathways for potential future sea level conditions.

This research is concerned mainly with road traffic on one coastal route. Effects on public transit, active modes and wider socio-economic aspects are not explicitly monetised. Addressing these issues would require further data and methodological tools, marking them as the main challenges in forthcoming research.

2. Methodology

An empirical approach was adopted to investigate the connection between sea level variability and transportation performance under flood-prone conditions in a coastal city. The approach integrates long-term sea level observations with traffic volume data to examine how sea level variability is associated with transportation performance along a coastal corridor during rainfall and flood-prone periods. Rather than aiming for exact predictive forecasting or strict causal attribution, the purpose of the analysis is to identify empirical regularities, spatial sensitivities, and possible risk transference mechanisms related to flood- associated hazards. By concentrating on observed interactions of environmental variables with traffic performance, the framework delivers a corridor-scale view that can be used for transportation resilience quantification and climate risk management in coastal urban areas. The overall methodological process is illustrated in Figure 1.

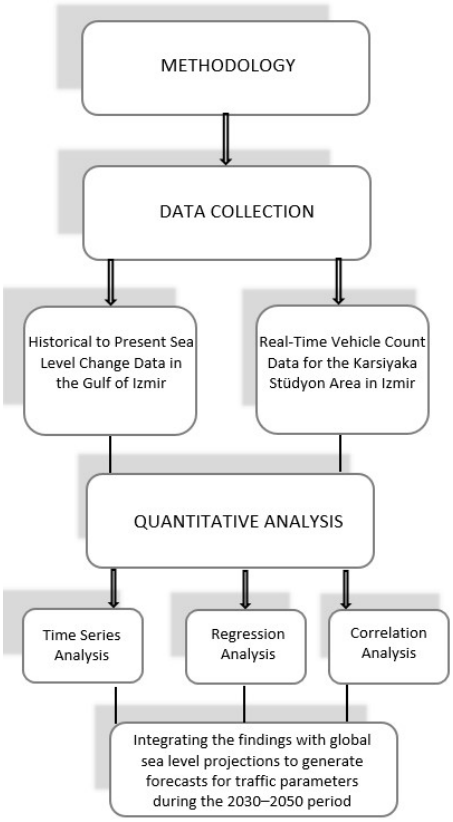

Figure 1 Methodological framework of the study

2.1. Research Design and Study Context

A case study approach was used to investigate the correlation between sea level variability and transportation performance under flood-prone conditions in a coastal city. The methodological approach combines observational sea level and traffic data to evaluate the susceptibility of a coastal transportation corridor to flood-induced disturbances. Rather than constructing predictive climate–transport simulation models, the methodological framework seeks to identify empirical relations and site-specific vulnerability patterns that can be used to inform transportation resilience assessment and climate adaptation planning.

The case study focuses on the Yali Boulevard which is one of the main coastal transportation arterys in Karsiyaka district found in the city of Izmir, Türkiye. This corridor was chosen both for its importance to transportation and its documented exposure to coastal flood hazards. Following the general direction of the Aegean coastline, the corridor is a major artery between its clustered residential, commercial and recreational areas. Previous studies have identified the Karsiyaka coastline as one of the most vulnerable coastal zones in Izmir due to its low elevation, and exposure to sea level rise, storm surge, and extreme precipitation events (Özkan & Tarhan, 2016; Ercanlı &

Savaşır, 2022a; Ercanlı & Savaşır, 2022b; Climate Central, 2021). Because of its low-lying nature and proximity to the coast, the corridor is vulnerable to tidal flooding, storm surges, and heavy precipitation events. Moreover, the availability of continuous traffic monitoring data from multiple camera locations makes this corridor particularly well suited for studying the relationship between sea level variability and transportation performance. It therefore provides a suitable context for analyzing the effects of flood-induced hazards on transport performance in coastal urban areas. The study area also represents a general problem faced by many Mediterranean coastal cities, where critical mobility infrastructure is becoming increasingly exposed to climate-induced flood hazards and associated resilience challenges.

2.2. Data Sources and Preparation

The analyses draws on two primary datasets: long-term sea level observations and traffic volume data. Sourced from official monitoring networks, these datasets were integrated to analyze the relationship between sea level variability and transportation performance under flood-prone conditions. Tide data for Izmir Bay were obtained from the Turkish National Sea Level Monitoring System (TUDES), established by the General Command of Mapping. The time series extends from April 1999 to September 2024 and is the longest continuous sea level record ever obtained in the study region. Daily sea-level observations were combined to produce monthly averages in order to minimize the impact of short-term variations and to give an overview of possible long-term trends and seasonal variations. Although the time series principally represent relative sea level variability resulting from local tectonic and oceanographic processes, it is a solid empirical basis for analyzing coastal flood exposure in the coastal zone.

Traffic volume data were obtained from traffic-counting detectors and cameras managed by Izmir Transportation Center (IZUM). Data on traffic volumes were obtained for specific intervals between April and December 2023, covering periods with rainfall and other flood-prone. The data comprises hourly vehicle counts recorded by several camera locations along Yali Boulevard, enabling a high-frequency traffic flow analysis at the corridor-level under flood-prone conditions. For the purpose of interpretation, meteorological data (hourly line precipitation) was acquired from the Turkish State Meteorological Service (MGM) and synchronized in time to the sea level and traffic data. It should be noted that the sea level and traffic datasets have different temporal resolutions. Although traffic counts are available as hourly observations, sea level data were compiled as monthly averages for the purposes of this study. Therefore, accurate temporal synchronization on an hour-to-hour basis between the two datasets was not feasible. Hence, the monthly sea level values were used to represent wider environmental conditions during the corresponding traffic observation periods, rather than to represent sea level conditions at the exact time of individual traffic observations. This difference in the temporal resolution is a significant limitation of the analysis and has to be taken into account in the interpretation of the observed statistical associations.

2.3. Analytical Approach and Exploratory Scenarios

The analytical framework consists of three interrelated parts: (i) a time-series analysis to investigate long-term and seasonal fluctuations of sea level variability; (ii) regression and correlation studies to analyze empirical connections between sea level variability and traffic performance under flood-prone conditions; and (iii) an exploratory scenario analysis to illustrate potential future exposure under continued sea level rise.

The sea level data were analyzed using time-series analysis to evaluate trend persistence and seasonal behavior, and historical patterns were assessed through conventional stationarity tests to determine whether these patterns could be applied for exploratory scenario development. Regression and correlation analyses were subsequently conducted to investigate whether sea level variability is significantly correlated with traffic volume at specific locations and times of the day.

These analyses are not expected to be causal, but rather to capture signals in a complex urban traffic environment, driven by a variety of interplaying factors.

To consider potential future conditions, simplified scenarios for 2030 and 2050 were developed using observed local trends and regional sea level rise projections from the literature. These scenarios are presented as an exploratory sensitivity analysis rather than a predictive forecasting model. They are designed to investigate the effects on the spatial exposure of the low-lying parts of the coastal transportation corridor to plausible increments in sea level. Thus, the scenario analysis focuses on the spatial overlap between potential future sea level conditions and at-risk road segments, rather than extending the 2023 regression relationships to estimate future traffic volumes. These scenarios therefore demonstrate possible exposure pathways and should not be interpreted as forecasts of the magnitude or timing of future transportation impacts.

The overall methodological design is to allow for an empirical evaluation of transportation susceptibility to sea level variability under flood-prone conditions at the transportation corridor level. The method facilitates detection of regional exposure and potential system-level vulnerabilities in the coastal transportation system by using observational datasets and a relatively straightforward analytical procedure. The framework is designed to support early-stage assessments of risk and processes for considering options for adaptation, while acknowledging that more sophisticated modeling techniques may be needed for detailed engineering and long-term investment decisions.

3. Results

Empirical results demonstrate that both sea level variability and traffic responses under flood-prone conditions are characterized by specific spatial and temporal patterns. The results are organized to progress from the physical environment context (long-term sea level behavior) to the observed relationships with transportation performance and their spatial and temporal patterns. The final stage explores the robustness of these results to different statistical specifications and to simple foresight sensitivity cases.

3.1. Sea Level Variability and Long-Term Trends

Analysis of relative sea level data for Izmir Bay from 1999 to 2024 shows a slow increasing trend with obvious seasonal variations. The time series analysis demonstrated that the sea level variability remains within a relatively stable range during the period of time observation, which means that the observed relationships support the hypothesis that long-term behavior is stable and free of abrupt behaviors. As illustrated in Figure 2, higher sea level values in recent years reflect the long-term variation (the cumulative effect) in the coastal system.

Apart from the long-term patterns, sea levels in Izmir Bay has strong seasonal oscillations. Mean sea levels are higher during late winter and spring, whereas it is relatively lower in summer. These seasonal cycles, depicted in Figure 3, are important in the context of flood-risk because they take place during the period of maximal activity in precipitation and storms. Although these patterns do not provide definitive forecasts of future sea levels, they provide an important context for assessing the long-term exposure of coastal transportation infrastructure and guiding resilience-oriented planning strategies.

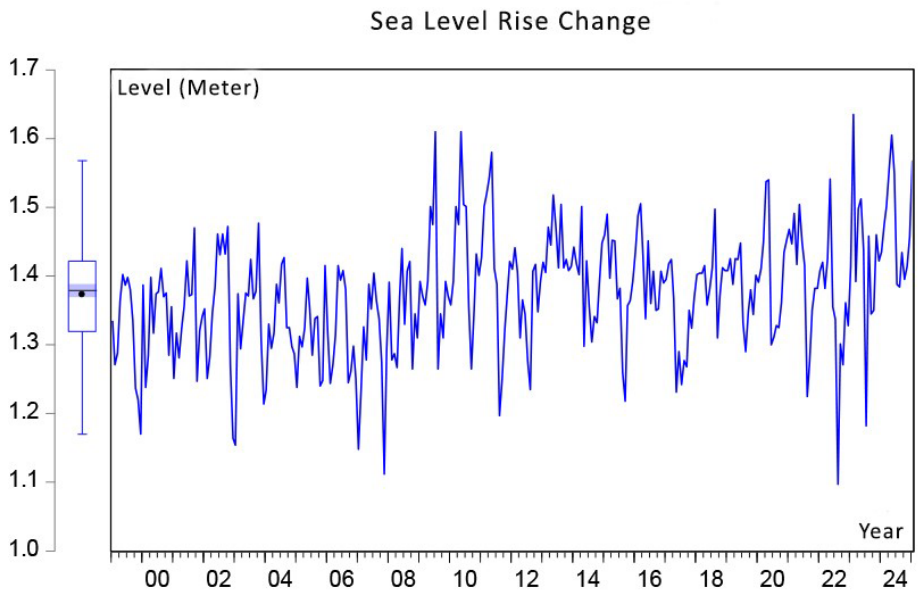

Figure 2 Long-term relative sea level variability in Izmir Bay (1999–2024)

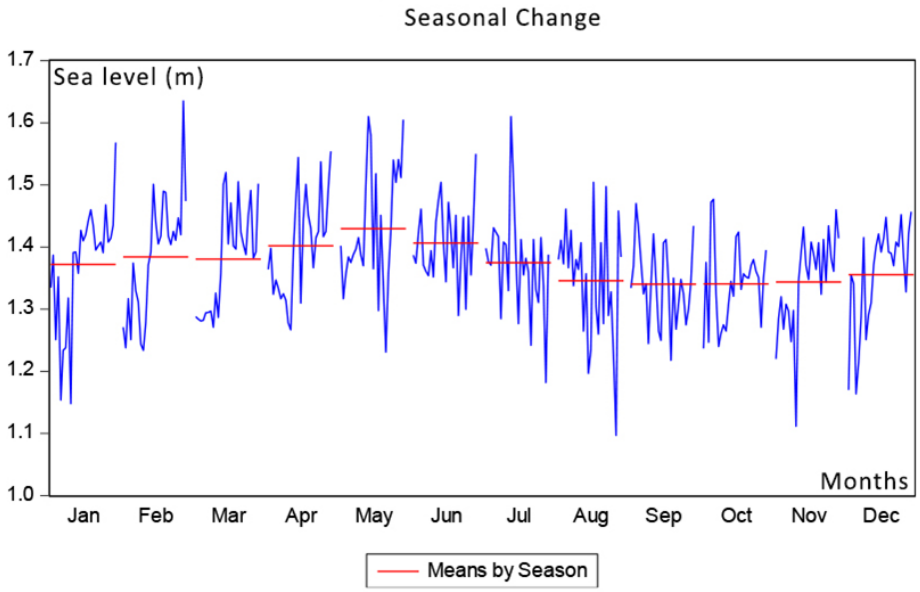

Figure 3 Seasonal variation in relative sea level values

3.2. Traffic Responses Under Flood-Prone Conditions

Traffic volume observations collected along Yali Boulevard during rainfall and flood-prone periods in 2023 indicate discernible changes in traffic volume during periods of elevated sea levels. At several camera locations, traffic volumes appear to decline during periods of elevated sea levels and heavy rainfall, notably along roadway segments adjacent to the coastline. The geographical layout of the study corridor and traffic cameras are depicted in Figure 4 to underlie the differences of traffic responses along the corridor.

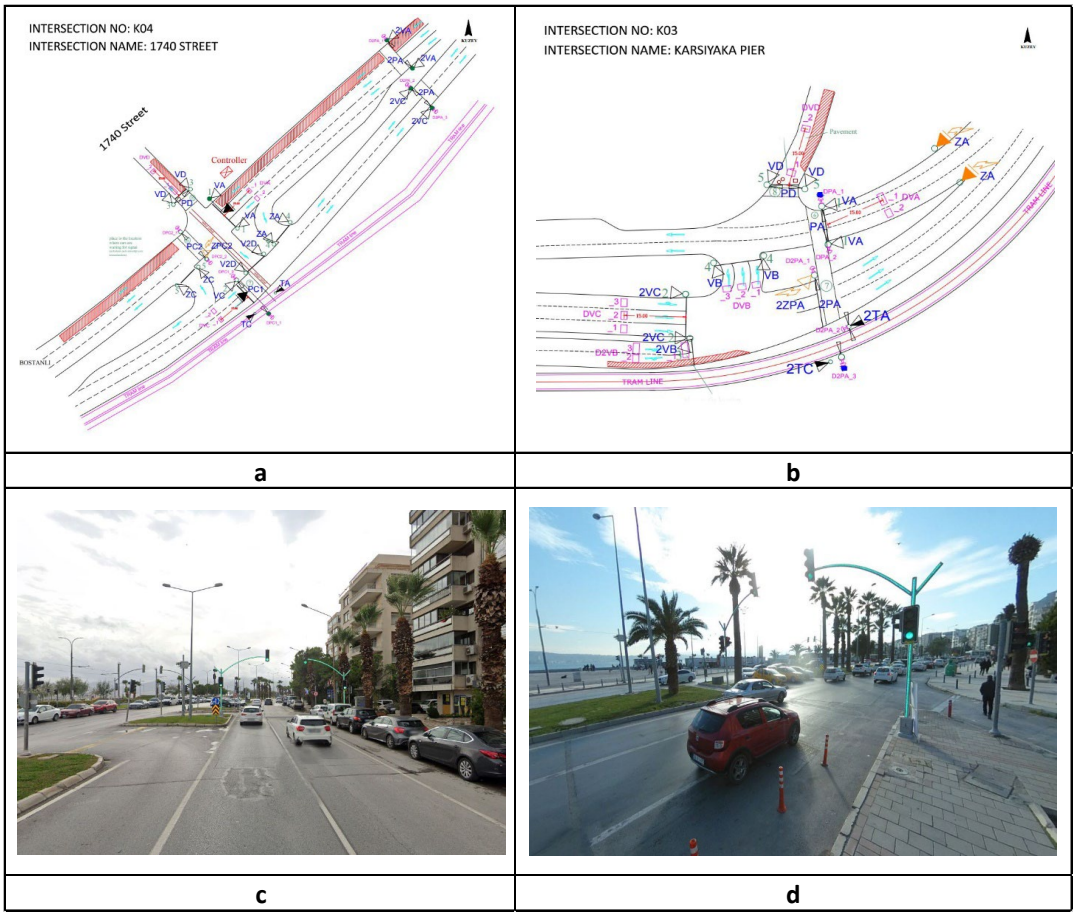

Figure 4 Study corridor and camera locations

Based on the spatial context described above, the analyses were conducted separately for each camera location to investigate empirical relationships between sea level variation and traffic volume along the study corridor. Findings suggest that these relationships are weak to moderate, with higher sea levels are typically associated with minor decreases in hourly vehicle counts at certain sites, while other site-specific responses are less definitive. Figure 5 provides a representative example of these relations, showing the general sign and order of magnitude of the observed relation without implying causality.

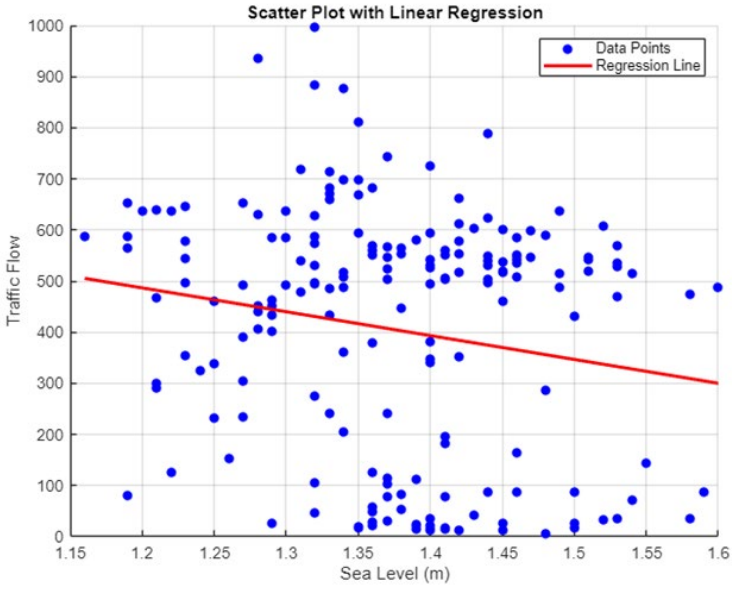

Figure 5 Representative regression result between sea level variability and traffic flow

The regression results should therefore be interpreted as descriptive associations, rather than causal effects. Multiple interacting processes, such as rain intensity, day-to-day travel demand variation, incidents on-route, and driver behavior, shape urban traffic dynamics. Hence, the representative regression result is presented to illustrate the direction and magnitude of the observed empirical relationship. Due to the complexity of urban traffic dynamics and the influence of multiple interacting factors, the figure should be interpreted as descriptive corroboration rather than evidence of a strong predictive or causal relationship between sea level variability and traffic flow.

In addition to spatial heterogeneity, traffic responses to high sea levels have clear temporal patterns. The correlation analysis suggests that the intensity and direction of the relationship between sea level variability and traffic flow are dependent on the time of day. As illustrated in Table 1, the negative correlations are stronger at specific morning and afternoon intervals, while there is a weak or no association during non-rush hours. These observations suggest that transportation vulnerability is not spatially uniform but varies according to corridor characteristics and temporal demand patterns. These temporal variations indicate that the observed relationships between sea level variability and traffic performance is not temporally uniform. During peak or transition periods, small reductions in effective road capacity can cause large drops in observed traffic volumes, while traffic during off-peak periods appears to be more resilient to changes associated with elevated sea levels. This time-varying susceptibility is especially of practical concern for traffic control and emergency response strategies in coastal cities.

Table 1 Correlation Between Monthly Average Sea Level Conditions and Traffic Volume

Hour				Traffic Volume
3:00	DVB_1	Sea Level (m)	Pearson Correlation	-0.871**
			Sig. (2-tailed)	0.002
4:00	DVB_1	Sea Level (m)	Pearson Correlation	-0.822**
			Sig. (2-tailed)	0.007
9:00	DVB_1	Sea Level (m)	Pearson Correlation	-0.804**
			Sig. (2-tailed)	0.009
10:00	DVB_1	Sea Level (m)	Pearson Correlation	-0.790*
			Sig. (2-tailed)	0.011
11:00	DVB_1	Sea Level (m)	Pearson Correlation	-0.692*
			Sig. (2-tailed)	0.039
16:00	DVB_1	Sea Level (m)	Pearson Correlation	-0.920**
			Sig. (2-tailed)	0.000
17:00	DVB_1	Sea Level (m)	Pearson Correlation	-0.672*
			Sig. (2-tailed)	0.047

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

3.3. Exploratory Future Sensitivity and Robustness of Findings

Using the observed patterns of long-term sea level variability and the empirically identified relationships between sea level variability and traffic flow, simplified future sensitivity scenarios were developed for the years 2030 and 2050 under a trend-continuation assumption. By applying the observed long-term sea level patterns and anticipated future increments, an exploratory sensitivity analysis was conducted for 2030 and 2050 under a trend-continuation scenario. Instead of predicting future traffic volumes, the analysis assesses how potential sea level rise scenarios could change the spatial exposure of low-lying sections of the coastal transportation corridor. As illustrated in Figure 6, low-lying parts of the Karsiyaka coastline appear particularly sensitive to incremental increases in sea level, indicating that future exposure may become spatially concentrated along specific coastal road segments. This spatial clustering identifies priority areas where adaptation measures could be especially relevant for sustaining transportation resilience.

These are examples of potential interactions between infrastructure and flood exposure for illustrative purposes and are not intended to provide estimates of magnitude or timing of impacts. Therefore, the spatial patterns in Figure 6 can serve a relative sensitivity to provide background with the empirical findings already presented above.

Figure 6 Illustrative flood exposure along the Karsiyaka coastline under a trend-continuation scenario (2030-2050)

To assess the sensitivity of the found relationships, further sensitivity analyses were conducted with other statistical methods and data partitions. The sign and relative size of the correlations between sea level variability and traffic flow were robust to using other correlation measures, excluding extreme values from the sample, and splitting samples between rainy and dry periods. In particular, the negative correlations between sea level variability and traffic-flow were stronger during rainy periods, which further supports the notion that the detected traffic drop-offs are related to flood-prone conditions, not just to inherent traffic variability.

The analyses indicate that sea level variability is associated with variations in transportation performance under flood-prone conditions and reveal localized patterns of vulnerability across space and time. Although the strength of the observed associations is moderate, their consistency across multiple analytical specifications suggests that flood-related disruptions represent a relevant consideration for resilience-oriented transportation planning and climate adaptation in coastal urban environments.

4. Discussion

The empirical evidence presented here demonstrates a relationship between sea level variability and transportation performance under flood-prone conditions within a coastal transportation corridor. The findings indicate that even moderate sea level variability under flood-prone conditions can be associated with changes in traffic flow and localized patterns of transportation vulnerability. These results add to an expanding literature on the vulnerability of urban mobility to climate-related hazards.

These findings are consistent with previous research on transportation disruption due to floods in other coastal cities. Research conducted on urban areas in San Francisco, Athens, and Portland shows that temporary flooding and modest sea level rise can bring about measurable deterioration in traffic flow, particularly on roads near the coast and in low-lying zones (Chang et al., 2010; Mitsakis et al., 2014; Kasmalkar et al., 2020). Contrary to numerous extant work that predominantly employs simulation methods, this paper showcases the insights from real world observations at the corridor level, with implications for resilience-based transport system planning. The analyses for Izmir reveal that the relationship between sea level variability and traffic performance varies both temporally and spatially. The findings also complement previous studies conducted in Izmir, which have primarily focused on flood hazard mapping (Özkan & Tarhan, 2016), coastal adaptation strategies (Ercanlı & Savaşır, 2022a), and ecosystem vulnerability under climate change (Arslan, 2023). These observations are consistent with prior planning-oriented evaluations of the Karsiyaka shore, highlighting the importance of integrated adaptation measures for managing such growing flood hazards in low-altitude coastal lands (Ercanlı & Savaşır, 2022b). While that study was centered on the analysis of adaptation options from planning level of detail, the current study draws on empirical data to examine the observed relationship between sea level variability and transportation performance under flood-prone conditions. However, in contrast to numerous model-based studies, where the vulnerability analysis is grounded on hydrodynamic modelling outcomes or on network-level performance measures, the present study demonstrates that similar patterns of vulnerability can be derived from sparse observational data. This indicates that patterns of transportation vulnerability associated with flood-prone conditions can be identified even through relatively simple corridor-scale empirical analyses. The present results are consistent with wider urban water management research arguing that the effects of flooding on urban infrastructure are not adequately mitigated by traditional drainage systems. Barbosa et al. (2012) argue that sustainable stormwater management is only attainable through integrated planning approaches that account for hydrological processes in the context of urban infrastructure and land use systems. The localized traffic disruptions identified in this study provide further empirical support for the argument that flood management and transportation planning should be coordinated as part of climate adaptation.

For planning purposes, this underscores the need for corridor-based analyses to detect spatially dependent transportation vulnerabilities. Results also show that relatively small increases in observed sea level can degrade traffic performance during critical periods, indicating that coastal transportation planning should explicitly consider flood-sensitivity of low-lying routes. Monitoring of traffic-flow through flood-prone corridors can also be incorporated into or form part of standard monitoring precaution and short-term traffic control. In this context, the integration of real-time traffic data with elementary hydrological forecasting could offer a feasible basis for the coordination of traffic management under future climate scenarios. This method can be especially applicable to cities lacking in climate–transport modeling capabilities.

From an urban resilience perspective, the observed patterns suggest that transportation corridors should be considered critical components of climate adaptation strategies in coastal cities. Corridor-scale vulnerability assessments can support the identification of priority areas for intervention, including drainage improvements, nature-based solutions, protective infrastructure, and adaptive mobility management measures. These findings align with water-sensitive planning

perspectives that promote the integrated management of stormwater, the use of blue–green infrastructure and nature-based solutions to mitigate flood risks and contribute to building urban resilience (Barbosa et al., 2012; Özeren Alkan & Hepcan, 2023). The empirical observations emphasize the value of incorporating corridor-scale risk assessments into strategic transportation planning processes (e.g., sustainable urban mobility plans) where climate adaptation actions can be addressed as part of the consideration of long-term infrastructure investments. Integrating such assessments into urban planning processes may help reduce future disruption risks and strengthen the resilience of coastal transportation networks. In the case of Izmir, these results contribute also to the integration of corridor-scale flood vulnerability in the Izmir Sustainable Urban Transport Plan (SKUP), where climate adaptation options for coastal transport corridors may be more clearly reflected in long-term transport investment and management decisions. Integrating flood-vulnerable coastal corridors into long-term transportation investment plans, traffic management systems, early warning systems and adaptive routing would enhance the transportation system's resilience to future sea level rise and related flood hazards.

The observed patterns suggest a number of other avenues for further research. The analytic framework can be expanded to account for some public transport systems, active modes of travel, and an accessibility measure, to capture a broader picture of disruptions to mobility related to flooding. More spatially and temporally extended traffic data sets may further allow for the use of more sophisticated statistical and simulation-based techniques, e.g., network-level resilience assessments and climate model–informed scenarios. Finally, a better integration of socio-economic and equity issues in flood–transport analyses could improve understanding of how climate-related disruptions may disproportionately affect particular population groups, allowing for more inclusive and context-sensitive strategies for adaptation.

5. Conclusion

This study examined the relationship between sea level variability and transportation performance under flood-prone conditions along a coastal corridor Izmir, Türkiye, with particular focus on the implications for transportation resilience and climate adaptation planning. By combining long-term sea level observations with traffic data collected during flood-prone periods, the present study provides empirical evidence on the relationship between observed environmental conditions and transportation performance.

Collectively, these results demonstrate the susceptibility of coastal transportation corridors to sea level variations and highlight the usefulness of corridor-scale analyses in uncovering spatially concentrated exposure within city-scale transportation systems. Relatively small increases in observed sea levels are also associated with variations in traffic performance during specific time intervals, indicating that transport planning in coastal cities would benefit from a formal consideration of flood sensitivity of routes in the low-lying areas. Meaningful vulnerability analyses can be conducted even with limited observational capabilities, providing a feasible analysis pathway for cities with limited access to advanced climate–transport modeling tools. These findings underscore the importance of incorporating transportation vulnerability assessments into broader urban resilience and climate adaptation frameworks.

From a planning and operational perspective, the observed relationships support the systematic consideration of flood-prone transportation corridors within resilience-oriented infrastructure management and urban adaptation strategies. Integrating real-time traffic observations with hydrological information may improve situational awareness during flood events and assist decision-makers in prioritizing adaptive interventions aimed at maintaining mobility and accessibility under changing climate conditions.

In prospective studies, the scope of analysis could be expanded to include public transport systems, active mobility infrastructures, and broader accessibility measures to foster a better understanding of climate-induced disruptions of mobility. Incorporating the socio-economic aspects and equity concerns in the evaluation of flood–transport interactions is thus expected to

provide an even more robust basis for urban planners and policy-makers to develop inclusive adaptation options. Ultimately, the study demonstrates the importance of corridor-scale empirical evaluations for supporting urban resilience and climate adaptation in at-risk coastal cities.

CRediT Authorship Contribution Statement

Çağla Ercanlı: Data collection from relevant institutions, Data classification, Conducting analyses, and Manuscript writing. Ahmet Karakurt: Conducting analyses and Preparing figures.

Declaration of Competing 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 paper.

Data Availability

Data will be made available on request.

Ethics Committee Approval

Ethics committee permission is not required.

References

Akdeniz, A. G. (2022). Kentsel morfoloji yaklaşımlarında alternatif ufuk: Kentsel ve mimari tasarım stratejisi olarak iklim- dirençli su yerleşmeleri [An alternative horizon in urban morphology approaches: Climate-resilient water settlements as an urban and architectural design strategy]. In C. Birsel, & O. Çalışkan (Eds.), *Türkiye Kentsel Morfoloji Ağı-III. Kentsel Morfoloji Sempozyumu Bildiriler Kitabı, Kent Morfolojileri Kentsel Form Araştırmalarında Çok Boyutlu Yaklaşımlar* (pp.627-648). Odtü Geliştirme Vakfı. https://tnum.org.tr/index.php/tnum/article/view/155

Al Hassan, Y., & Barker, D.J. (1999). The impact of unseasonable or extreme weather on traffic activity within Lothian region, Scotland. *Journal of Transport Geography*, *7*(3), 209_213. https://doi.org/10.1016/S0966-6923(98)00047-7

Allarané, N., Atchadé, A. J., N'Dilbé, T. R., Azagoun, V. V. A., & Hetcheli, F. (2024). Integrating climate change adaptation strategies into urban policies for sustainable city resilience: Barriers and solutions in the Central African city of N'Djaména. *Sustainability*, *16*(13), 5309. https://doi.org/10.3390/su16135309

Arrighi, C., Pregnolato, M., Dawson, R. J., & Castelli, F. (2019). Preparedness against mobility disruption by floods. *Science of the Total Environment*, *654*, 1010_1022. https://doi.org/10.1016/j.scitotenv.2018.11.191

Arslan, B. (2023). How to adapt to climate change? An analysis of ecosystem vulnerability in Izmir (Türkiye). [Master's thesis, Izmir Institute of Technology].

Barbosa, A. E., Fernandes, J. N., & David, L. M. (2012). Key issues for sustainable urban stormwater management. *Water Research*, *46*(20), 6787-6798.

Boeing, G., & Ha, J. (2024). Resilient by design: Simulating street network disruptions across every urban area in the World. *Transportation Research Part A: Policy and Practice, 182*, 104016. https://doi.org/10.1016/j.tra.2024.104016

Brodsky, H., & Hakkert, A. S. (1988). Risk of a road accident in rainy weather. *Accident Analysis & Prevention*, *20*(3), 161-176. https://doi.org/10.1016/0001-4575(88)90001-2

Chang, H., Lafrenz, M., Jung, I. W., Figliozzi, M., Platman, D., & Pederson, C. (2010). Potential impacts of climate change on flood-induced travel disruptions: A case study of Portland, Oregon, USA. *Annals of the Association of American Geographers*, *100*(4), 938_952. https://doi.org/10.1080/00045608.2010.497110

Changnon, S. A. (1996). Effects of summer precipitation on urban transportation. *Climatic Change*, *32*(4), 481-494. https://doi.org/10.1007/BF00140357

Chen, H., & Lo, J. T. Y. (2026). Impact of urban gray infrastructure on urban flooding: A city-scale drainage and surface water modeling framework. *International Journal of Disaster Risk Reduction*, *133*, 105907. https://doi.org/10.1016/j.ijdrr.2025.105907

Climate Central. (2021). *Coastal risk screening tool*. https://coastal.climatecentral.org/map/8/100.6166/13.2746/?theme=water_level&map_type=water_level_above_mhhw&basemap=roadmap&contiguous=true&elevation_model=best_available&refresh=true&water_level=1.0&water_unit=m

Coles, D., Yu, D., Wilby, R. L., Green, D., & Herring, Z. (2017). Beyond 'flood hotspots': Modelling emergency service accessibility during flooding in York, UK. *Journal of Hydrology*, *546*, 419-436, https://doi.org/10.1016/j.jhydrol.2016.12.013

Cools, M., Moons, E., & Geert, W. (2010). Assessing the impact of weather on traffic intensity. *Weather, Climate, and Society*, 60-68, (2010), https://doi.org/10.1175/2009WCAS1014.1

Davide, M., Bastos, J., Bezerra, P., Hernandez Moral, G., Palermo, V., Pittalis, M., Todeschi, V., Treville, A., Barbosa, P., & Melica, G. (2025). How to develop a sustainable energy and climate action plan (SECAP)-Covenant of Mayors Guidebook, Main document, Publications Office of the European Union, Luxembourg. https://publications.jrc.ec.europa.eu/repository/handle/JRC142148

Dharmarathne, G., Waduge, A. O., Bogahawaththa, M., Rathnayake, U., & Meddage, D. P. P. (2024). Adapting cities to the surge: A comprehensive review of climate-induced urban flooding. *Results in Engineering*, 22, 102123. https://doi.org/10.1016/j.rineng.2024.102123

Diakakis, M., Boufidis, N., Grau, J. M. S., Andreadakis, E., & Stamos, I. (2020). A systematic assessment of the effects of extreme flash floods on transportation infrastructure and circulation: The example of the 2017 Mandra flood. *International Journal of Disaster Risk Reduction*, *47*. https://doi.org/10.1016/j.ijdrr.2020.101542

Ercanlı, C., & Savaşır, G. (2022a). An approach for the analysis of urban coastal areas and adaptation strategies against the sea level rise and flooding: The case of Izmir. *The Journal of Planning*, *32*(3), 361-383.

Ercanlı, C., & Savaşır, G. (2022b). Kentsel kıyı alanlarında taşkın riskine yönelik uyum stratejilerini İzmir Karşıyaka kıyı bandı örneği ile değerlendirmek [Assessing adaptation strategies against flood risk ın urban coastal areas through Izmir Karsıyaka coastline case]. *Megaron*, *17*(2), 274.

Hallegatte, S., Rentschler, J., & Rozenberg, J. (2019). *Lifelines: The resilient infrastructure opportunity*. World Bank Publications.

Hauer, M. E., Evans, J. M., & Mishra, D. (2016). Millions projected to be at risk from sea-level rise in the continental United States. *Nature Climate Change*, *6*, 691-695. https://doi.org/10.1038/nclimate2961

Iavarone, A. H., & Kaya, İ. (2021). Deniz seviyesinde yükselme riskleri odağında kentlerin iklim eylem planı söylemlerinin incelenmesi [Examination of urban climate action plan discourses with a focus on sea level rise risks], *Resilience*, *5*(1), 51-66. https://doi.org/10.32569/resilience.824576

Izmir Metropolitan Municipality. (2020). *Izmir yesil sehir eylem plani [Izmir green city action plan]*. Izmir Metropolitan Municipality.

Izmir Metropolitan Municipality. (2021). *Climate neutrality action plan 2030*. Izmir Metropolitan Municipality.

Izmir Metropolitan Municipality. (2025). *Izmir sustainable urban transportation plan (Skup)*. Izmir Metropolitan Municipality.

Jacobs, J. M., Culp, M., Cattaneo, L., Chinowsky, P., Choate, A., DesRoches, S., Douglass, S., & Miller, R. (2018). Transportation. In D. R. Reidmiller, C. W. Avery, D. R. Easterling, K. E. Kunkel, K. L. M. Lewis, T. K. Maycock, & B. C. Stewart (Eds.), *Impacts, risks, and adaptation in the United States: Fourth National Climate Assessment, Volume II* (pp. 479-511). U.S. Global Change Research Program. https://doi.org/10.7930/NCA4.2018.CH12

Jaroszweski, D., Chapman, L., & Petts, J. (2010). Assessing the potential impact of climate change on transportation: The need for an interdisciplinary approach. *Journal of Transport Geography*, *18*(2), 331-335. https://doi.org/10.1016/j.jtrangeo.2009.07.005

Jenelius, E., Petersen, T., & Mattsson, L. G. (2006). Importance and exposure in road network vulnerability analysis. *Transportation Research Part A: Policy and Practice*, *40*(7), 537_560. https://doi.org/10.1016/j.tra.2005.11.003

Karataş, İ. (2024). 1930 Izmir sel afeti [1930 Izmir flood disaster]. *Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *26*(3), 1006-1036.

Kasmalkar, I. G., Serafin, K. A., Miao, Y., Bick, I. A., Ortolano, L., Ouyang, D., & Suckale, J. (2020). When floods hit the road: Resilience to flood-related traffic disruption in the San Francisco bay area and beyond. *Science Advances, 6*(32), eaba2423. https://doi.org/10.1126/sciadv.aba2423

Koetse, M. J., & Rietveld, P. (2009). The impact of climate change and weather on transport: An overview of empirical findings. *Transportation Research Part D: Transport and Environment*, *14*(3), 205-221. https://doi.org/10.1016/j.trd.2008.12.004

Lennon, M., Scott, M., & O'Neill, E. (2014). Urban design and adapting to flood risk: The role of green infrastructure. *Journal of Urban Design*, *19*(5), 745_758. https://doi.org/10.1080/13574809.2014.944113

Liu, J., Xu, Z., Wan, L., & MacAskill, K. (2026). Road transport resilience under extreme rainfall: Integrating multiple impact factors and delay propagation. *International Journal of Disaster Risk Reduction*, 106024. https://doi.org/10.1016/j.ijdrr.2026.106024

Mitsakis, E., Stamos, I., Diakakis, M., & Grau, J. M. S. (2014). Impacts of high-intensity storms on urban transportation: Applying traffic flow control methodologies for quantifying the effects. *International*

Journal of Environmental Science and Technology, 11(8), 2145-2154. https://doi.org/10.1007/s13762-014-0573-4

Mushtaq, M., Corradi, M., & Sikdar, S. (2024). Climate adaptation of roads to flooding hazards - A review. *Construction Materials*, *4*(4), 748-776. https://doi.org/10.3390/constrmater4040041

Mutluer, M., & Işık, S. (2025). Kasım 1995 Karsiyaka-Cigli sel felaketi sonrasında yapılan çalışmalar üzerine bazı gözlemler [Some observations on the studies conducted following the November 1995 Karsiyaka-Cigli flood]. *Ege Coğrafya Dergisi*, *11*(1), 57-74. https://izlik.org/JA57YM82FE

Nawarat, K., Reyns, J., Vousdoukas, M. I., Mulholland, E., van Ginkel, K., Feyen, L., & Ranasinghe, R. (2026). Coastal flood risk to European surface transport infrastructure at different global warming levels. *Nature Climate Change*, 1-7. https://doi.org/10.24433/CO.9918929.v1

Özeren Alkan, M., & Hepcan, S. (2023). Water sensitive spatial planning in terms of sustainable stormwater management: The case of Bornova stream catchment (Izmir), Turkey. *Urban Water Journal*, *20*(10), 1317-1330.

Özkan, S. P., & Tarhan, C. (2016). Detection of flood hazard in urban areas using GIS: Izmir case. *Procedia Technology*, 22, 373-381.

Papakonstantinou, I., Madanat, S., & Siwe, A. T. (2020). Effects of sea level rise induced land use changes on traffic congestion. *Transportation Research Part D: Transport and Environment*, *87*(2), 102515. https://doi.org/10.1016/j.trd.2020.102515

Pregnolato, M., Ford, A. C., Glenis, V., Wilkinson, S., & Dawson, R. J. (2016). Impact of climate change on disruption to urban transport networks from pluvial flooding. *Journal of Infrastructure Systems, 23*(4), 04017015. https://doi.org/10.1061/(ASCE)IS.1943-555X.0000372

Saiz, A., & Wang, L. (2022). Physical geography and traffic delays: Evidence from a major coastal city. *Environment and Planning B*, *50*(1), 218-243. https://doi.org/10.1177/23998083221108406

Shan, X., Yao, Q., Wang, J., Wen, J., Li, M., Scussolini, P., Wei, X., & Gao, S. (2025). The economic impacts of flood-driven transportation delays. *Journal of Transport Geography*, *129*, 104436. https://doi.org/10.1016/j.jtrangeo.2025.104436

Touloumidis, D., Madas, M., Zeimpekis, V., & Ayfantopoulou, G. (2025). Weather-related disruptions in transportation and logistics: A systematic literature review and a policy implementation roadmap. *Logistics*, *9*(1), 32. https://doi.org/10.3390/logistics9010032

Resume

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Impact of form factor variability on building energy assessment: A computational and empirical analysis for early-stage design

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Abstract

While energy efficiency is increasingly recognised as an integral factor in building design, form-related considerations in Nigeria remain underexplored. This study explores the influence of compactness on building energy demand and carbon emissions using computational simulations tailored for early-stage residential design. Ten distinct building forms consisting of six one-storey, three two-storey and one three-storey building were modelled in SketchUp to collect building entity data and systematically transformed for compactness assessment while maintaining the same volume and floor area. A weather file for location-based energy requirements was generated using Meteonorm, while dynamic thermal modelling, energy performance and carbon emissions were evaluated using EnergyPlus. Python programming was utilised for advanced statistical evaluation, pattern recognition and data visualisation. Findings revealed that single-storey buildings have higher surface-to-volume (SV) ratios and are more energy efficient than more compact, multi-storey counterparts. Principal Component Analysis (PCA) confirmed that building volume accounts for more than 97% of form factor variability, establishing it as the most dominant driver of compactness, while regression analysis reinforced its statistical significance (P-value = 0.038). However, cluster analysis demonstrated that energy efficiency is not solely a function of form factor but is informed by complex interplays between building morphology parameters and façade exposure. Unexpectedly, despite improvements in SV ratios of the transformed buildings, energy demand intensified by up to 30.27%, challenging conventional assumptions that compactness universally enhances energy efficiency. These findings highlight the limitations of compactness as a standalone metric for evaluating energy performance in tropical climates, stressing the need for integrating passive design strategies, such as solar-responsive façades and optimised building orientation, into form optimisation. This study redefines performance assessments for early-stage design by advocating for a more context-sensitive approach to building form in tropical climates.

Keywords: building compactness, building energy efficiency, early-stage design, form factor, tropical buildings

1. Introduction

Global temperatures have been on the increase due to anthropogenic activities since the industrial age, posing severe risks to both buildings and their occupants (Driga & Drigas, 2019). These challenges manifest as thermal discomfort and increased cooling demand, and in extreme scenarios, heightened mortality rates (Hong et al., 2023). Buildings experience degradation and façade overheating, resulting in diminished energy efficiency. Addressing these challenges requires urgent sustainability actions, a central focus of contemporary built environment research (Noah & Çağnan, 2021). One of the key determinants of a building's energy performance is its form, as its geometry directly influences thermal behaviour and heat gain (Algburi & Ferah, 2021). Rapid urbanisation, especially in hot climates, has intensified the demand for cooling, exacerbating the

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vulnerability of buildings to extreme temperatures, but modern developments often fail to harmonise with prevailing climatic conditions (Djeddou et al., 2024). Historically, local architectural styles were largely overshadowed by foreign influences, leading to the neglect of indigenous materials and climate-responsive designs (Adenaike & Opoko, 2024). In Nigeria, this issue is acute as architectural designs are frequently replicated without adequate adaptation for climatic differences. Aesthetic inclinations and societal influences often take precedence over environmental considerations, leading to inefficient buildings (Folorunso et al., 2017). Additionally, the persistent adoption of foreign architectural styles has contributed to a huge decline in indigenous, climate-responsive building techniques (Umar et al., 2019).

Efforts to enhance energy efficiency in the built environment have gained traction globally. For instance, countries like the UAE have promoted compact urban forms over sprawling developments to curb energy consumption (Galal Ahmed & Hossein Alipour, 2019). Nevertheless, building energy-efficiency remains a challenge, especially in developing countries, where economic expansion correlates with increased energy demand (Mohsenzadeh et al., 2021). Given that buildings contribute massively to global energy use, reducing their consumption is vital for achieving a carbon-neutral environment (Lian et al., 2023; Notodipuro & Mandala, 2022). Among the numerous factors that determine building energy performance, thermal properties, including form, material composition and microclimatic interactions, are particularly critical (Remon, 2019). Studies suggest that urban form and building geometric configurations play a significant role in determining energy demand (Mutani et al., 2020), by influencing heat stress, cooling loads and overall environmental sustainability (Alshboul & Alatrash, 2024; Freewan, 2022). Despite these known benefits, building form remains underexplored in sub-Saharan Africa's energy-efficiency discourse.

Furthermore, research have shown that building orientation exerts a considerable influence on energy demand in hot climates (Ahmed et al., 2021; Hatem & Karram, 2020), stressing the need for multi-factor assessment in building performance evaluation. The adoption of climate-responsive building design has been identified as one of the most effective strategies for reducing energy consumption (Ochedi & Taki, 2022). However, understanding the physics of buildings is critical for early-stage design performance evaluation (Kistelegdi et al., 2022), as even minor adjustments can affect energy efficiency, emissions and thermal comfort (Ahmadian et al., 2021; El-Agami et al., 2021; Lian et al., 2023; Liang et al., 2023). Optimising various building geometric configurations, including height and envelope characteristics—to achieve peak energy efficiency remains a complex task (Kheiri, 2018).

While substantial research has focused on building fabric materials and high-performance insulation to improve energy efficiency, fewer studies have isolated the explicit role of building form in shaping energy demand (Oh & Kim, 2019). Existing literature sometimes conflates form factor variations with changes in occupied floor area or total volumetric capacity, obscuring the actual thermodynamic leverage of building morphology. Although shape coefficients like surface-to-volume ratio and heat loss form factor are often employed to estimate building energy demand, they are insufficient on their own. Additional factors, including building orientation, window-to-wall ratio and solar radiation, must be considered for a more holistic assessment (Li et al., 2023; Yip et al., 2021). Moreover, the impact of building form on energy demand varies significantly across building types, reinforcing the need for context-specific evaluations (Song et al., 2020). Despite the growing body of knowledge on energy-efficient building design, research on form factor optimisation in tropical climates remains limited (Gupta & Deb, 2023; Kistelegdi et al., 2022; Li et al., 2024). This study addresses these gaps by providing a controlled, geometry-based investigation of form factor variability during early-stage residential building design in Nigeria. Its specific contributions are, first, the study isolates form factor effects by holding building volume, height and usable floor area strictly constant during morphological transformation—an approach rarely implemented in existing literature, where geometric changes are mostly confounded by scale-reliant variations. Second, the study presents simulated counter-evidence to the widely accepted

"compactness-efficiency" assumption, where despite reductions in surface-to-volume ratio, compacted forms exhibited higher cooling energy demand due to increased façade exposure and solar heat gains, exposing a tropical performance paradox. The study highlights the need for integrating orientation, solar envelope design and climate considerations into form optimisation, offering architects and designers a more reliable basis for performance-driven massing decisions.

2. Literature Review

2.1. Vernacular to Modern Architecture: Energy Efficiency Implications

The demand for energy in buildings globally is expected to rise significantly due to urbanisation, making energy efficiency a critical issue Mahmoud (2022). Modernisation and advances in technology have shifted architectural focus away from preserving locally responsive buildings, leading to over-dependence on mechanical cooling (Umaru et al., 2022). Arbabzadeh et al. (2020) argue that early Modernist movements introduced geometrically abstract designs that created a disconnect between buildings and environmental adaptation, favouring aesthetic appeal over energy efficiency. Corroborating this paradigm shift, Lucchi (2023) notes that evolving architectural movements have systematically displaced the historic role of primary building form in meeting functional and climatic comfort requirements, creating an operational misalignment between contemporary modernism and energy efficiency. This trend led to the neglect of vernacular construction methods, which were inherently suited for their environments, diminishing both occupant comfort and energy efficiency (Agbete & Frank, 2020; Lodson et al., 2018; Nwalusi et al., 2022). Vernacular architecture has long demonstrated superior adaptability through the integration of energy-saving strategies tailored to specific environmental conditions (Noah & Çağnan, 2021). These buildings, characterised by compact forms and high thermal mass, have been shown to outperform modern buildings in energy-efficiency (Dada & Alibaba, 2023). In addition, the use of locally-sourced materials further reduces their environmental impacts by minimising carbon emissions (Djeddou et al., 2024). From an economic and environmental standpoint, improving building performance is pivotal, with energy efficiency as the primary objective (Aydın & Koçlar Oral, 2024; Belussi et al., 2019) . In this context, a performance-based design framework is essential for identifying architectural forms that align with sustainability objectives (Song & Sun, 2021), noting that regardless of the envelope materials used, the geometric properties of buildings are influential in energy performance outcome (Premrov et al., 2018). Existing building energy-efficiency assessment frameworks evaluate compactness alongside material properties, cultural practices or passive cooling strategies, making it difficult to isolate the contribution of building form alone. This creates a gap in understanding whether compactness itself drives energy efficiency or whether its benefits are reliant on broader envelope-related factors.

While several studies focus on improving energy efficiency through optimised and passive design strategies (Kistelegdi et al., 2022), a critical challenge remains. For instance, when designs fail to account for local climate impacts, they depend on active cooling systems, elevating energy consumption and emissions (Offor & Emenike, 2019). With the building envelope as the primary driver of heat transfer, the need for optimised geometric indicators such as floor area, perimeter and building height to achieve sustainable energy performance must be prioritised (D'Amico et al., 2021; Gamero-Salinas et al., 2020; Koźniewski et al., 2022; Ragab, 2022). In this regard, Sokar et al. (2023) emphasise that passive measures that are driven by envelope design and passive cooling integration serve as the most effective interventions to suppress energy loads before mechanical systems are integrated. An additional complexity in sustainable design is the challenge of estimating carbon footprints at the early design stage (Yadav & Kumar, 2022) because, unlike operational energy that can be measured, embodied carbon and lifecycle energy demand require predictive modelling. Nonetheless, building form optimisation and analysis emerges as a crucial tool for architects to evaluate and estimate energy consumption from the outset (Deng et al., 2020; Keskisalo & Matveinen, 2021).

2.2. Building Form Factor and Energy Efficiency

A building's form is the primary determinant of its energy performance, as it regulates heat flow and thermal efficiency. It encompasses salient parameters, such as height, width and depth (The Archspace, n.d.; Whole Building Design Guide, n.d.). As opined by Taştemir et al. (2024), optimising building design forms, particularly during preliminary architectural interventions, is a crucial task that can enhance design performance at a minimal cost. Several factors influence a building's form, including functional, aesthetic and cultural preferences (Archi-Monarch, n.d.). However, its most crucial role lies in predicting how efficiently its envelope encloses its volume; a quality quantified by form factor metrics such as surface-to-volume (SV) ratio (Araji, 2019; D'Amico & Pomponi, 2019), shape factor (Carpio & Carrasco, 2021; Zhao et al., 2023; Zhu et al., 2024), compactness ratio (Kahraman & Köymen, 2023; Koźniewski et al., 2022; Vasilenko, 2019) and heat loss form factor (HLFF) (Burrell, n.d.; Vidmar, 2019). The SV ratio is a widely used compactness indicator, mathematically expressed as the total envelope area per unit volume (Equation 1). A lower SV ratio is indicative of a more compact structure with reduced heat exchange through its envelope, enhancing energy efficiency.

The HLFF provides a more refined measure of building compactness by accounting for the portion of the building's actual heated floor area (Equation II). Unlike the SV ratio, which considers the volume of buildings, HLFF is based on the heated floor area (HFA), making it more applicable to energy performance assessments (Vidmar, 2019). Ideally, the HFA is calculated as 75% of the building's total floor area (TFA). Areas occupied by partitions, doors, stairs and unusable spaces are excluded from the TFA (Burrell, n.d.; Vidmar, 2019). Studies suggest that the HLFF usually ranges from 0.5 to 5, with values below 3 required to meet the Passivhaus standard.

$$Surface - to - Volume\ Ratio\ (SV) = \frac{Total\ Envelope\ Area\ (TEA)(m^2)}{Volume\ (V)(m^3)} \quad \ldots Equation\ I$$

$$Heat\ Loss\ Form\ Factor\ (HLFF) = \frac{Total\ Envelope\ Area\ (TEA)(m^2)}{Heated\ Floor\ Area\ (HFA)(m^2)} \quad \ldots Equation\ II$$

The compactness of a building plays a significant role in determining its thermal performance throughout its lifecycle (Alshboul & Alatrash, 2024; Li et al., 2024; Marincu et al., 2024; Zhu et al., 2024). Increasing surface areas reduces the compactness ratio, particularly for buildings with smaller floor areas (Kahraman & Köymen, 2023), but compactness alone does not always ensure buildings energy efficiency. While a higher SV ratio results in increased solar energy absorption and heat gains, it also elevates cooling demands, making form optimisation context-specific (Araji, 2019). The SV ratio consists of two components: a scale-dependent size factor and a scale-independent term shape factor (D'Amico & Pomponi, 2019). While the size factor relates to absolute building dimensions, the shape factor focuses on the building's proportionality, allowing for a standardised measure for comparing different building shapes independent of size. This distinction is essential for optimising energy performance, as buildings with similar volumes but different geometric properties can exhibit drastically different thermal characteristics.

The relationship between form factor and energy demand varies across different climates. For instance, in a hot climate of Egypt, buildings with an SV ratio below 0.38 are found to reduce cooling energy demand by over 30%, highlighting the efficiency of compact designs (Ragab, 2022). Moreover, a positive correlation exists between SV ratio and energy demand for cooling, such that a 0.01 increase in compactness ratio results in a 2.6% increase in energy consumption (Vasilenko, 2019). This aligns with findings from similar studies such as Puri (2021) and Ragab (2022), which emphasise that optimising the SV ratio yields substantial energy savings. Studies further identify optimal shape factors for selected climate zones: 0.29 for severe cold climates, 0.30 for cold regions, 0.23 for hot summer & cold winter climates, 0.31 for hot summers with warm winters and 0.33 for

mild regions (Zhao et al., 2023). In Chile's cold oceanic climate, an optimal shape factor of ≤ 0.767 was identified as effective in reducing energy demand (Carpio & Carrasco, 2021).

Despite the widespread use of these metrics, most studies offer no control for building volume and floor areas when comparing forms' energy performance. As a consequence, compactness is often conflated with size, limiting the reliability of compactness-based comparisons across different building typologies. These form factor variabilities indicate that form optimisation must be tailored to specific contexts rather than universal application.

2.3. Building Form and Energy Performance

The energy performance of a building is influenced by its shape, size and orientation, all of which are critical factors in energy studies (Akbari & Nezhad, 2020). While square, rectangular, L-shaped and U-shaped buildings are the most commonly adopted forms, considering alternative geometries during the early design phase can immensely influence energy efficiency and mitigate the built environment's carbon emissions (Khalil, 2023; Li et al., 2024). However, studies show that the effectiveness of building form often depends on its function and climate conditions. Alshboul and Alatrash (2024) and Vasilenko (2019) argue that a compact building has the highest energy efficiency owing to its reduced exposure to external temperature interference. This aligns with findings from Marincu et al. (2024) and Mutani et al. (2020), who opine that compact buildings are generally less energy intensive due to a lower surface-to-volume ratio, consequently reducing heat loss and heat gain. In fact, Remon (2019) reports that compact buildings can reduce energy consumption by up to 81%; but the extent of savings depends on geographical and climate dissimilarities. These studies widely evaluate compactness without considering façade orientation, solar exposure or window distribution in tandem. They widely assume that reduced envelope area automatically translates to lower cooling demand, overlooking cases where compact forms may increase solar gains due to façade arrangement.

D'Amico and Pomponi (2019) further assert that the minimisation of exposed surface area is critical in energy-efficient design, highlighting that semi-cube forms, due to their geometric efficiency, enhance thermal performance. Similarly, Hadjhafsi et al. (2024) identify the square-shaped building as the most effective for residential energy conservation in the Saharan climate of Algeria. The benefits of compact shapes extend beyond residential dwellings. Mba et al. (2024), for context, note that square plans are particularly beneficial for educational buildings as they not only improve energy efficiency but also enhance natural ventilation. However, the notion that a singular building shape is universally optimal is misleading since the effectiveness of a given form is climate-dependent. Notably, in Iran's hot-dry climate, a rectangular form with an east-west orientation achieves the best performance compared to squares, hexagons, octagons and circular forms of identical floor area and height (Akbari & Nezhad, 2020). Conversely, El-Agami et al. (2021) report that in Egypt, circular buildings exhibited superior energy efficiency compared to square, rectangular and elliptical forms in distinctive locations. Mohsenzadeh et al. (2021) further validate this by concluding that circular buildings, compared to square, rectangular and triangular structures, are more efficient. Other building forms are found to be widely energy-inefficient; for instance, triangular buildings are widely associated with poor energy efficiency due to poor compactness. According to Hatem and Karram (2020), triangular buildings consume up to 20% more than circular forms and generally underperform when compared to other geometric configurations. On the contrary, research by Makhloufi and Louafi (2023) in Algeria challenges this notion, showing the superior performance of a triangular-based building over others in terms of energy efficiency. These findings imply that the thermal performance of buildings is varied and complex and does not rely on compactness or geometric properties alone.

For office buildings in the hot climate of Cairo, circular and oval forms showed superior energy performance over several other forms (Khalil et al., 2023). Similarly, Boronbaev (2023, 2024) highlight that spherical buildings offer high energy-saving potential due to their intrinsic nominal thermal bridges. Despite the theoretical advantages of circular buildings, their feasibility in practice

is uncommon due to ergonomic and orientation challenges (Zankar et al., 2022). As Vasilenko (2019) admonishes, prioritising compactness alone over other factors may compromise building usability, since circular and spherical forms often present spatial inefficiencies in practical applications. Therefore, achieving a balance between geometric compactness, practical functionality and energy savings is crucial for building sustainability.

2.4. Building Height and Energy Use

Beyond geometric forms, building height and the number of storeys affect energy performance with mixed findings regarding their influences. Studies suggest that low-rise buildings exhibit the highest energy-saving potential, making them more ideal for energy-positive solutions (Ahmadian et al., 2021; Yadav & Kumar, 2022). Conversely, increasing a building's height, while maintaining the same floor area and envelope parameters, sometimes raises its compactness ratio and carbon emissions (Liang et al., 2023; Vasilenko, 2019). These inconsistencies arise because many studies do not maintain a constant floor area or volume during early-stage design interventions, when comparing buildings of different heights. Consequently, height-related findings are often confounded by changes in usable space or envelope area.

According to a study by Barssoum et al. (2020), adding storeys increased energy consumption by 60%, suggesting a strong correlation between building height and energy demand. This contradicts findings by Rahmani and Al-Sallal (2019), who observed a 46% reduction in energy demand when a school building in Abu Dhabi was transformed from single to two storeys, owing to self-shading and reduced solar exposure. Benkhelifa et al. (2019) support this finding by arguing that adding building storeys enhances energy efficiency by minimising heat loss per unit volume, reinforcing the notion that compactness under ideal conditions can be beneficial. Gamero-Salinas et al. (2020) assert that a high-rise building with a porous design achieves lower energy consumption compared to a compact, less porous one, further complicating the height-compactness-efficiency relationship.

From a geometric standpoint, larger buildings tend to have a lower surface-to-volume ratio, resulting in reduced heat loss per unit of volume (Vidmar, 2019). Several studies that evaluate building form and energy efficiency acknowledge that size, shape and compactness ratio interact in complex ways across different climatic conditions (Deng et al., 2020; Hatem & Karram, 2020; Pathirana et al., 2019), but a critical limitation in these studies is the failure to maintain a constant floor area and building volume when comparing buildings. A truly rigorous analysis of building forms must be evaluated with identical usable space to ensure that observed variations in energy performance differences stem only from its form, rather than differences in functional capacity or occupancy.

2.5. Thermal Bridges and Building Energy Performance

According to Parry and Strang (2021), thermal bridges are critical spots in a building envelope where heat flow deviates significantly from adjacent regions. These inefficiencies are particularly challenging in hot climates, where unwanted heat gains can elevate cooling energy demands. Alhawari and Mukhopadhyaya (2018) highlight that the presence of thermal bridges is an indicator of poorly performing buildings, exacerbating energy inefficiencies through unrestrained heat transfer. Similarly, Burrell (n.d.) describes the thermal envelope as the main interface through which heat is lost or gained, accentuating the significance of minimising thermal bridges to achieve energy efficiency.

Thermal bridges can be categorised into two main types: geometric and construction-based. Geometric thermal bridges occur at areas where there is an abrupt change in a building's shape, such as at eaves, junctions or external corners, making them integral in complex architectural forms. In contrast, construction thermal bridges occur when materials or components penetrate the building's insulation layer, as observed in cantilevers, exposed slabs and external porches.

Among these, exposed balcony slabs are challenging to curb, with reports indicating that they can account for up to 40% of thermal-bridging-related heat loss (Alhawari & Mukhopadhyaya, 2018; Pérez-Carramiñana et al., 2024). However, the impact of thermal bridges extends beyond energy consumption, influencing indoor comfort and material durability due to risks consideration. As mentioned by Guo et al. (2023), reducing the prevalence of thermal bridges not only improves energy efficiency in buildings, but also prevents interstitial condensation, which can degrade structural integrity over time. For early-stage design, where form factor optimisation plays a significant role in energy efficiency, the presence of thermal bridges on the building envelope can alter the expected energy performance of buildings. As a result, understanding and addressing thermal bridges is vital to ensure that form factor optimisation translates to real-world energy savings. Consequently, adopting simplified, thermally efficient design approaches can effectively minimise inefficiencies attributed to thermal bridges.

To ensure that the literature review directly informs the modelling strategy, and form transformation adopted in this research, Table 1 provides a structured synthesis of the key studies examined. By organising the literature according to research purpose, methodology, findings, limitations and relevance, the matrix clarifies the specific gaps—particularly in geometric isolation, compactness evaluation and early-stage predictive modelling—that shaped the methodological decisions presented in the next section.

Table 1 Critical Synthesis of Key Empirical and Theoretical Studies on Building Geometry and Energy Performance

Author(s) & Year	Research Purpose	Methodology	Key Findings	Limitations/Critical Gaps	Relevance to this Study
Adenaike and Opoko (2024)	To document local vernacular morphology in Nigeria.	Qualitative historical analysis.	Vernacular forms are compact and climate-responsive.	Descriptive; no simulation; no quantitative testing.	Provides cultural context but lacks computational validation — this study digitises Nigerian typologies.
Ahmadian et al. (2021)	To examine urban built form and density effects.	Urban-scale modelling of density and form.	Compact urban form reduces energy use.	Urban scale; not building-level geometry; no façade distribution analysis.	Shows compactness matters but lacks building-level geometric testing that the study addresses.
Akbari and Nezhad (2020)	To identify optimal aspect ratios and orientations in hot-dry climates.	Parametric modelling of rectangular forms with varying aspect ratios.	Moderate elongation improves solar performance.	Geometry and scale change simultaneously; confounding variables; no constant-volume control.	Demonstrates shape importance but lacks geometric isolation — the methodology of this study isolates proportionality.
Araji (2019)	To examine how SV ratio affects solar heat gain.	Simulation of various building geometries under solar exposure.	Higher SV increases solar heat gain.	Assumes a monotonic relationship; no constant-volume testing; no tropical climate validation.	Shows SV matters but does not evaluate compactness behaviour under tropical cooling conditions — this study fills this gap.
Benkhelifa et al. (2019)	To evaluate height effects on heating/cooling.	Simulation of Saharan buildings with varying heights.	Height reduces footprint and improves compactness.	Multi-storey forms treated as unglazed blocks; fenestration ignored.	Shows verticality matters but lacks WWR constraints that this study includes (fixed WWR).
D'Amico and Pomponi (2019)	To define a compactness measure separating size and shape effects.	Analytical decomposition of SV ratio and shape factor; no energy simulation.	Decouples scale-dependent size factors from scale-independent shape factors, establishing a geometric basis for compactness.	No thermal simulation; no tropical context; does not test how shape factor affects cooling loads.	Provides geometric foundation but lacks climatic and thermal validation — this study includes the missing performance evidence.
El-Agami et al. (2021)	To compare circular, square and rectangular massing forms.	Simulation of high-rise forms under Egyptian climate.	Circular forms outperform others.	Form changes alter envelope area, height and floor area; results are confounded.	Highlights geometric sensitivity but lacks controlled transformations that this study evaluates.
Hygh et al. (2012)	To use multivariate regression for early-stage energy prediction.	Regression modelling using geometric and mechanical variables.	Geometry can predict energy performance.	High parameter endogeneity: Requires extensive operational and mechanical boundary inputs rarely available during schematic massing.	Supports statistical modelling but limits transparency — the data analysis workflow in this study seeks to improve interpretability.
Mahmoud (2022)	To evaluate proportions and orientation in hot-arid climates.	Simulation of multiple building proportions.	Orientation strongly affects cooling demand.	Geometry, WWR and orientation vary together; no isolation of form factor.	Supports orientation relevance but lacks geometric isolation — this study decouples orientation from form.

Taştemir et al. (2024)	To develop a geometry-based decomposition method for early-stage energy prediction.	Parametric modelling of residential building geometries using decomposition-based predictive algorithms.	Demonstrates that geometric variables can be decomposed to predict energy behaviour in early design stages.	Uses parametric forms; no constant-volume control; no tropical context; does not test compactness paradox.	Strengthens the methodological foundation workflow by validating geometry-driven early-stage prediction.
Yip et al. (2021)	To develop an early-stage net-zero design methodology.	Sensitivity analysis of form and envelope parameters.	Form influences energy demand.	Non-linear interactions not fully explained; no tropical context.	Shows form matters but lacks tropical compactness testing — this study fills this gap.

3. Methodology

This study uses an integrated empirical and simulation-based approach to evaluate the impact of building form variability on energy efficiency at the early design stage. The methodology is structured into four key phases as shown in Figure 1 below.

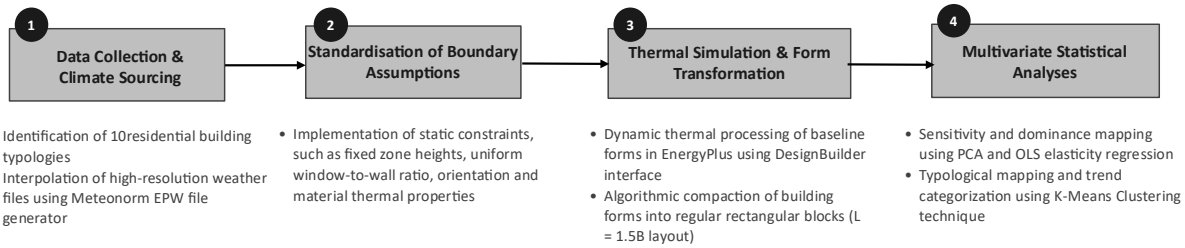


Figure 1 Methodological flowchart

3.1. Data Collection

Ten residential building drawings were collected from the archives of three architectural firms in Edo State, Nigeria, representing projects designed between 2015 and 2025. The study collected a mix of residential buildings with single to three storeys. No on-site measurements were conducted; instead, digitised architectural drawings were analysed to extract building parameters such as volume, envelope and floor areas. Additionally, contemporary climate data for the study location were generated using Meteonorm, widely used for its capability to interpolate high-resolution historical and future climate datasets (Viganò et al., 2024). This dataset serves as a key input in DesignBuilder simulations, ensuring that the models reflect actual climatic conditions. To ensure internal consistency, all extracted geometric parameters were cross-checked against the original CAD drawings and validated using SketchUp entity data before simulation. By doing so, envelope areas and volumetric values used in subsequent analyses were accurate and comparable across all building forms.

3.2. Standardisation of Assumptions

To isolate the effect of form factor on energy efficiency, the following assumptions were applied across all models:

I. **Fixed Building Height:** Each of the models within a group is assigned a constant height. For instance, single-storey and two-storey buildings are allotted a height of 3 meters and 6 meters, respectively. This is to ensure that changes in energy performance arise from changes in form rather than height differences.

II. **Absence of Internal Partitions:** No internal partitions from the building drawing were assigned, aligning with recommendations that early-stage design studies should focus on overall building form (Orçun & Onur, 2022).

III. **Window-to-Wall Ratio (WWR):** A uniform 30% WWR was applied to the building facades in DesignBuilder to align with design recommendations by El-Agami et al. (2021) and Pathirana et al. (2019).

IV. **Consistent Location and Orientation:** The buildings were simulated at the same geographical coordinates and reoriented west-east to minimise discrepancies due to site-specific variations.

V. **Uniform Material Properties:** Insulation, glazing and construction material properties were kept uniform across the models to ensure variations in performance are solely from geometric differences. These properties are key determinants of energy demands, particularly in tropical climates (Gupta & Gregg, 2018; Zhao et al., 2023).

VI. **Roof Height Exclusion:** The roof profile was excluded from form factor calculations to maintain a standardised volumetric form and reduce geometric thermal bridges during assessment.

VII. **Minimum Width Constraint:** A minimum width constraint (≥ 6 meters) was maintained in the transformed buildings to ensure architectural planning feasibility while adopting an elongated plan form (L = 1.5B) and to minimise east-west solar gains, a strategy proven to reduce cooling loads and enhance energy efficiency in hot climates (Fereidani et al., 2021).

VIII. **Geometric Simplification and Thermal Bridge Considerations:** Complex architectural forms, such as those with recesses, projections, articulated corners or irregular massing, introduce geometric thermal bridges that create discontinuities in heat flow. These changes distort energy anomalies unrelated to geometric proportionality. Because the objective of this study is to isolate the influence of form-factor, façade distribution, and solar exposure under constant conditions, geometric transformations were restricted to simple rectangular massing. This approach ensures that observed differences in cooling demand arise from geometric changes rather than construction-based thermal anomalies.

Other simulation constraints, including their parameters and operational specifications, are presented in Table 2 below.

Table 2 Fixed Simulation Control Parameters in DesignBuilder

Category	Parameter	Operational Value / Specification	Reference Standard Basis
Microclimate	Weather Profile Source File	Edo State, Nigeria (Meteonorm Data)	Tropical Savanna (Aw)—(Beck et al., 2023)
Opaque Envelope	External Wall U-Value	1.109 W/m²K	225 mm sandcrete blocks with 35 mm external and internal plaster layers—Local construction specifications
	Roof System	1.893 W/m²K	Flat roof, box form for preliminary analysis; Aluminium roofing sheets with wooden frames
Glazing Assembly	Fenestration Glass Specification	Single clear 3 mm sheet glass—1.960 W/m²K	Regional baseline
	Total Solar Heat Gain Coefficient (SHGC)	0.691	EnergyPlus regional glazing standard
Internal Loads	Occupancy Density	0.02 (people/m²)	Fixed residential operational profiles
	Lighting Power Density	5.0 W/m²	DesignBuilder default value
HVAC Scheduling	Cooling system CoP	2.5 with grid electricity supply	Local supply
	Infiltration Rate	3.0 ac/h	Mixed-mode DesignBuilder ventilation setup

3.3. Simulation and Form Transformation

Using DesignBuilder, digital models of the forms were developed, incorporating the standardised assumptions and Meteonorm-generated climate data. The simulation process involved two key stages:

I. **Baseline Energy Performance Assessment:** Each of the models was simulated to extract performance metrics such as energy consumption and cooling loads.

II. **Form Transformation:** The original building configurations were modified to assess how form transformation impacts performance metrics. The transformed buildings followed a more elongated form that minimised solar exposure, reducing direct solar gains, while maintaining the same volume, height and floor areas as the original buildings in an L = 1.5B

configuration. The transformation is particularly justified in tropical climates where solar exposure contributes immensely to cooling loads (Gupta & Deb, 2023).

The decision to adopt an L = 1.5B proportional constraint in the geometric transformation is grounded in established architectural design principles, climate-sensitive building design, and habitable space functional requirements. Studies show that moderate elongation reduces solar gains compared to highly stretched forms and that rectangular forms with controlled elongation outperform excessively stretched building shapes in hot climates. Moreover, early-stage architectural interventions consider ergonomics during space planning. Other constraints may collapse the width of the buildings below feasible planning limits, where WWR distribution would become unrealistic. Hence, the adopted transformation constraint ensures that the minimum breadth of the transformed buildings can meet basic architectural design requirements for occupied spaces.

3.4. Data Analysis Procedures

A multi-tiered analytical approach was applied to derive insights from the collected data. The analysis was conducted using descriptive statistics, Principal Component Analysis (PCA), and Ordinary Least Squares (OLS) regression and K-Means clustering in Python's Jupyter Notebook, utilising libraries such as Pandas, NumPy, Seaborn and Matplotlib. Although the dataset consists of ten building cases, PCA and clustering were applied not to infer population generalisations but to identify dominant geometric trends and classify form-based performance patterns. This aligns with early-stage architectural workflows where datasets are inherently limited.

3.4.1. Descriptive and Statistical Analysis

Descriptive statistics were used to characterise form factor variability between the original and transformed buildings. Metrics such as mean, standard deviation and ranges were derived to assess energy demand variance and compactness. Multivariate linear regression modelling operates as an effective screening tool during preliminary stages, demonstrating that high explanatory power can be achieved when inputs such as orientation and building shape parameters are evaluated (Hygh et al., 2012). This study builds directly upon this statistical screening philosophy, integrating ordinary least squares (OLS) sensitivity and principal component analysis (PCA) dimensionality mapping to extract geometric rules tailored for the study climate.

3.4.2. Principal Component Analysis (PCA) and Regression Analysis

Principal Component Analysis (PCA) was employed to identify the most influential variables affecting form factor and energy demand by reducing dimensionality and retaining key patterns in the dataset. Regression analysis, on the other hand, was conducted to quantify the statistical relationship between building volume, envelope area and surface-to-volume ratio. SV ratio was included as a dependent variable despite being derived from envelope area and volume because the regression was used to evaluate the strength of multicollinearity and to quantify the relative influence of each geometric parameter. This ensured that observed trends are statistically significant rather than occurring by random chance.

3.4.3. Comparative and Cluster Analyses

To substantiate results, boxplots were used to elucidate variations in heat loss form factor and surface-to-volume ratio across the building configurations. Additionally, a comparative analysis of the original and transformed building forms was performed to quantify energy savings, indoor comfort improvements and embodied carbon differences. Lastly, cluster analysis was used to group buildings based on their form factor characteristics, verifying that similar building typologies exhibited comparable performance metrics. By integrating multiple analytical approaches, findings from the study ensure robustness, reliability and statistical confidence, reinforcing the significance of form factor consideration in building performance.

3.5. Embodied Carbon Estimation and Operative Temperature Derivation

Preliminary carbon accounting was compiled using the carbon calculation screening matrix embedded within DesignBuilder (DesignBuilder, V7.0). Material carbon intensities are drawn from the University of Bath Inventory of Carbon and Energy (ICE) database (Circular Ecology, 2025), a globally recognised and validated lifecycle inventory reference for embodied carbon of materials. The lifecycle system boundary adopted the EN 15978 modules (British Standards Institution, 2012) and covers only the material (A1-A3) and operational emission (B6) lifecycle stages. The carbon tallies accumulate footprints arising exclusively from the raw materials extraction and processing, while operational emissions were derived from annual consumption.

Thermal indoor environment parameters for the buildings were captured continuously using deterministic physics-based calculation nodes executed within EnergyPlus. EnergyPlus establishes the hourly zone Operative Temperature (T_o) by evaluating internal radiative and convective fields under standardised airflow conditions using the formula:

$$T_o = 0.5 \times T_{air} + 0.5 \times MRT \qquad \ldots Equation\ III$$

Where :

T_{air} = calculated indoor mean air temperature (^{0}C) at the central thermal zone node

MRT= calculated mean radiant temperature (^{0}C) integrating the surface temperature vectors of all enclosing envelopes

4. Results

Table 3 summarises the geometric parameters and performance of ten distinct building forms. The first six cases represent single-storey buildings that exhibit more expansive ground floor cover but with smaller volumes, while Cases 7 – 10 represent multi-storey buildings with larger envelope areas and volumes. Table 4, on the other hand, represents the corresponding features and performance of the transformed buildings. Noticeably, a clear trend exists where the surface-to-volume (SV) ratio and the heat loss form factor (HLFF) consistently decrease as building volume and the number of floors increase. Specifically, the transformation process reduced the heat loss form factor by up to 7.6%, aligning with studies such as Hajtmanek et al. (2023) and Camporeale and Mercader-Moyano (2019) that infer that optimised buildings are characterised by better heat loss form factors, leading to improved energy efficiency.

However, despite these geometric modifications, the energy demand of the transformed buildings increased by up to 30.27% (Case 8), supporting studies that suggest that compactness alone, without energy-efficient measures, does not lead to energy efficiency (Galal Ahmed & Hossein Alipour, 2019; Marincu et al., 2024). These findings challenge the conventional notion that improving building compactness leads to reduced energy demand, particularly in tropical climates where orientation and façade exposure massively influence cooling demand.

Table 3 Case Buildings Parameters

Case Buildings															
Case Number	Building Form	Number of Floors	Total Wall Area (m^2)	Roof Area (m^2)	Total Envelope Area (m^2)	Total Floor Areas (m^2)	Heated Floor Area (m^2)	Building Volume (m^3)	Building Height (m)	Surface-to-Volume Ratio	Heat Loss Form Factor	Energy Consumption (kWh/m^2)	Cooling Energy (kWh/m^2)	Operative Temperature (°c)	Embodied Carbon ($kgCO_2$)
Case 1		1	218.710	239.050	457.760	239.050	179.288	717.150	3	0.638	2.553	315.49	109.9	27.4	79542.6
Case 2		1	139.200	114.590	253.790	114.590	85.943	343.770	3	0.738	2.953	323.73	118.14	27.61	40004.6
Case 3		1	190.800	197.960	388.760	197.960	148.470	593.880	3	0.655	2.618	318.38	112.8	27.49	66367
Case 4		1	200.490	207.900	408.390	207.900	155.925	623.700	3	0.655	2.619	315.79	110.21	27.41	69800.7
Case 5		1	273.600	326.590	600.190	326.590	244.943	979.770	3	0.613	2.450	311.56	105.98	27.28	107414.7
Case 6		1	192.590	189.640	382.230	189.640	142.230	568.920	3	0.672	2.687	318.1	112.51	27.45	64098.8
Case 7		2	472.500	265.090	737.590	530.180	397.635	1,590.54	6	0.464	1.855	332.78	127.19	28.86	105092.6
Case 8		2	374.400	167.730	542.130	335.460	251.595	1,006.38	6	0.539	2.155	340.65	135.06	28.96	70794.7
Case 9		2	432.000	212.240	644.240	424.480	318.360	1,273.44	6	0.506	2.024	335.46	129.88	28.85	87699.4
Case 10		3	572.400	170.350	742.750	511.050	383.288	1,533.15	9	0.484	1.938	360.55	154.97	29.71	84816.9

Table 4 Transformed Buildings Parameters

Transformed Buildings															
Case Number	Building Form	Number of Floors	Total Wall Area (m^2)	Roof Area (m^2)	Total Envelope Area (m^2)	Total Floor Areas (m^2)	Heated Floor Area (m^2)	Building Volume (m^3)	Building Height (m)	Surface-to-Volume Ratio	Heat Loss Form Factor	Energy Consumption (kWh/m^2)	Cooling Energy (kWh/m^2)	Operative Temperature (°c)	Embodied Carbon ($kgCO_2$)
Case 1		1	189.36	239.05	428.41	239.05	179.29	717.15	3	0.597	2.390	407.85	128.85	27.85	77858.1
Case 2		1	131.10	114.59	245.69	114.59	85.94	343.77	3	0.715	2.859	420.54	141.81	28.12	39527.6
Case 3		1	172.32	197.96	370.28	197.96	148.47	593.88	3	0.623	2.494	409.7	130.97	27.9	65370
Case 4		1	176.60	207.90	384.50	207.90	155.93	623.70	3	0.616	2.466	408.95	130.21	27.88	68416.4
Case 5		1	221.34	326.59	547.93	326.59	244.94	979.77	3	0.559	2.237	402.48	123.74	27.73	104471.3
Case 6		1	168.66	189.64	358.30	189.64	142.23	568.92	3	0.630	2.519	410.45	131.72	27.92	62815.1
Case 7		2	398.82	265.09	663.91	530.18	397.64	1,590.54	6	0.417	1.670	431.63	152.9	29.51	100910.6
Case 8		2	317.22	167.73	484.95	335.46	251.60	1,006.38	6	0.482	1.928	443.76	165.03	29.68	67333.8
Case 9		2	356.86	212.24	569.10	424.48	318.36	1,273.44	6	0.447	1.788	436.59	157.85	29.58	82807.2
Case 10		3	479.54	170.35	649.89	511.05	383.29	1,533.15	9	0.424	1.696	468.49	189.76	30.56	79632.9

5. Discussion

5.1. Building Form Transformation and Compactness

Descriptive statistics of the datasets in Tables 3 and 4 were first examined to provide a basic understanding of key parameters influencing building form variability. The analyses focused on building envelope characteristics, energy performance, operative temperature variance, building initial cost and preliminary embodied carbon assessment. The analyses reveal substantial changes in the building attributes following the transformation of the original forms. Single-storey buildings (Cases 1-6), with a building height of 3 meters, generally have higher surface-to-volume ratios and heat loss form factors. This is due to the heat loss tendencies of the exposed surface areas compared to the buildings' volumes. A larger external surface area compared to enclosed volume exposes more pathways for heat to escape or enter (Li et al., 2024).

Conversely, multi-storey buildings (Cases 7-10), with height above 3 meters, show lower SV ratios because increasing the building height and enclosed volume typically leads to a smaller ratio of envelope area per unit of heated floor area. In this study, the Global Form Factor was considered for the multi-storey simulation, where internal separating floors are not factored, but considered as a single thermal envelope. One of the improvements is the reduction in the mean SV ratio of the buildings, which decreased from 0.596 to 0.551. This reduction suggests that all the transformed buildings become more compact, simply by assuming a rectangular shape. A similar trend is observed where a comparison of Heat Loss Form Factor (HLFF) and SV ratios highlights the overall shift towards lower values in the transformed buildings (Figure 2). The reduction in the mean HLFF, which declined by 7.6%, aligns with expectations, as compact buildings tend to exhibit lower heat loss due to reduced envelope area and geometric thermal bridges. Building shape or footprint matters, as among single-storey or multi-storey cases, a more spread-out or irregular shape tends to have a higher form factor than a regular or consolidated footprint.

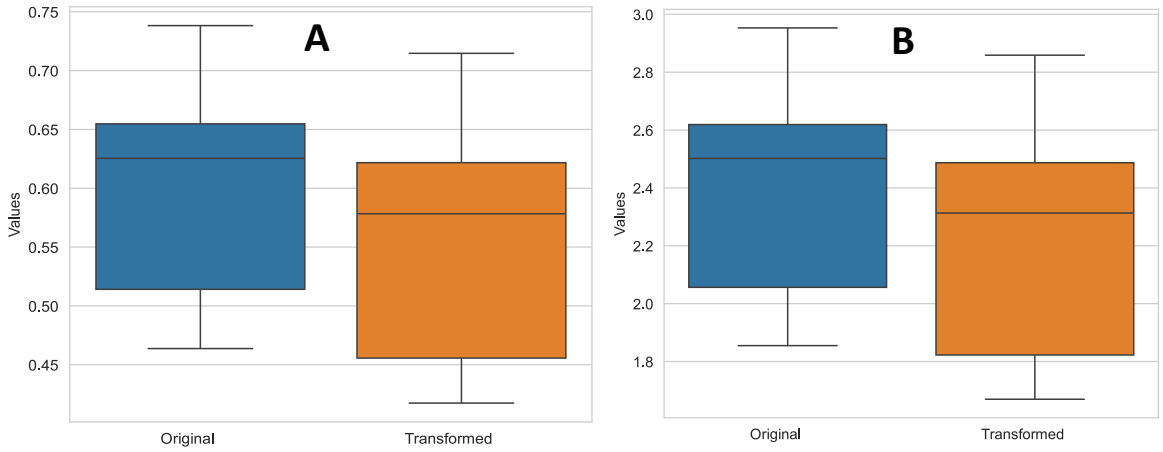


Figure 2 Boxplot comparing HLFF (A) and SV ratio (B) of buildings

The Total Envelope Area, one of the contributing factors to a building's compactness, also experienced approximately a 9% reduction, decreasing from an average of 515.78 m² in the original buildings to 470.30 m² in the transformed buildings (Figure 3). The transformed buildings maintained the same building floor area, floor numbers and building volume as the original counterpart. A large building, if designed with a compact geometry, can have a lower SV ratio and heat loss form factor. For example, Case 7, with the largest volume and envelope area, exhibits the smallest SV ratio in both configurations, suggesting a strong relationship between building compactness and exposed surface area and volume. Generally, transforming the buildings to a more compact form while maintaining the usable floor area and volume yielded lower SV ratios.

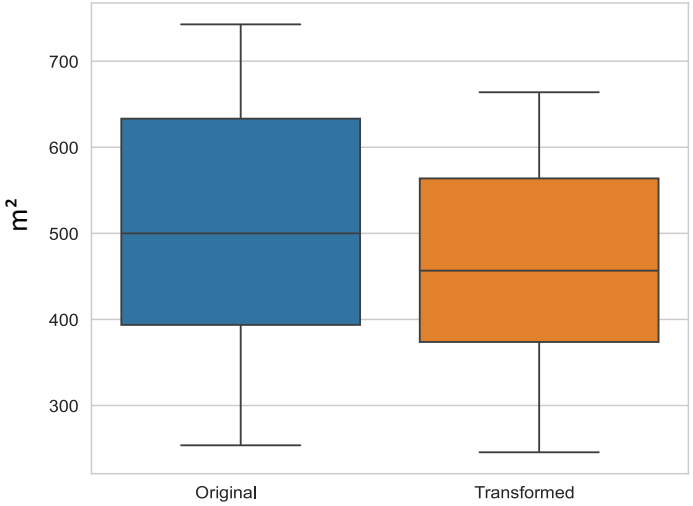


Figure 3 Total envelope area comparison

5.2. Energy Performance Implication of Compact Building Forms

Emerging studies show that increasing the compactness of buildings improves their thermal performance but, in this regard, the mean cooling energy demand of the transformed buildings with lower SV ratios exhibited an unexpected increase of approximately 19.4% (Figure 4). One possible explanation is that changes in façade exposure, which did not account for energy-efficient measures, might have offset the expected energy savings.

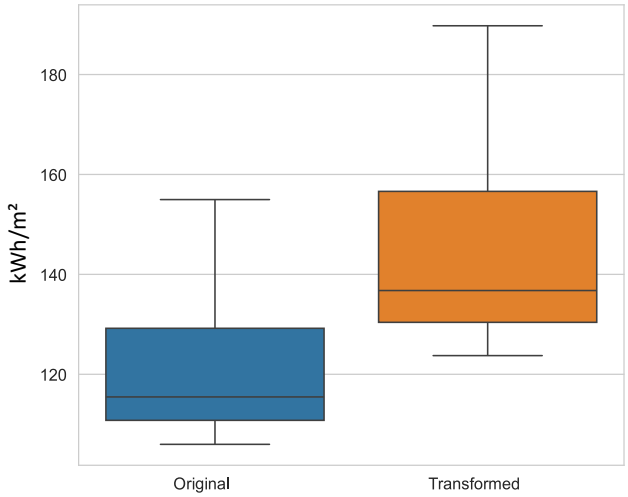


Figure 4 Cooling energy comparison-original vs. transformed buildings

It was observed that the transformed building's reduced energy efficiency is due to increased solar exposure, mainly via the south-facing façades. Since the modelling set-up assigned a fixed 30% window-to-wall ratio, the transformed buildings, with their longer façades, resulted in significantly more exposed areas to direct solar radiation. This prolonged exposure of the buildings could have led to high indoor heat gain, consequently increasing cooling load. In contrast, the case buildings with irregular forms and geometric thermal bridges, varied orientations and complex geometries may have inadvertently provided self-shading on large surfaces. This finding provides insights into form optimisation for early-stage design, noting that without shading or strategic adjustments to window placements, excessive heat buildup could occur, leading to increased energy demand (Kabanshi et al., 2023; Ran et al., 2022).

The relationship between form factor and energy demand in the early design phase is further depicted in Figure 5 using Seaborn's scatter plots. The plots reveal a moderate to strong correlation between SV ratio and energy demand, with 6 out of the 10 data points placed within the regression threshold and clustered next to the regression line. The downward-sloping regression lines indicate that for the building collection, those with high SV ratios tend to have reduced energy demand. However, Case 10 (three floors) and Case 2 (one floor) are outside the confidence interval (above the regression line), suggesting the model may have underestimated energy demand for these buildings. While the latter has the highest SV ratio with a moderate energy demand, the former has a small SV ratio but with an elevated energy demand, possibly owing to the energy loadings of the multiple floors of the building. Conversely, Case 5 (one floor) falls below the regression threshold due to its complex geometry and large floor area but emerged as the most energy-efficient building, implying that specific forms, due to their geometric configurations, may exhibit better thermal performance. Although a comparatively lower SV ratio is typically associated with improved energy performance (Rahmani & Al-Sallal, 2019), the transformed buildings' increased energy demand suggests that for operational buildings, energy-efficiency strategies need to be featured.

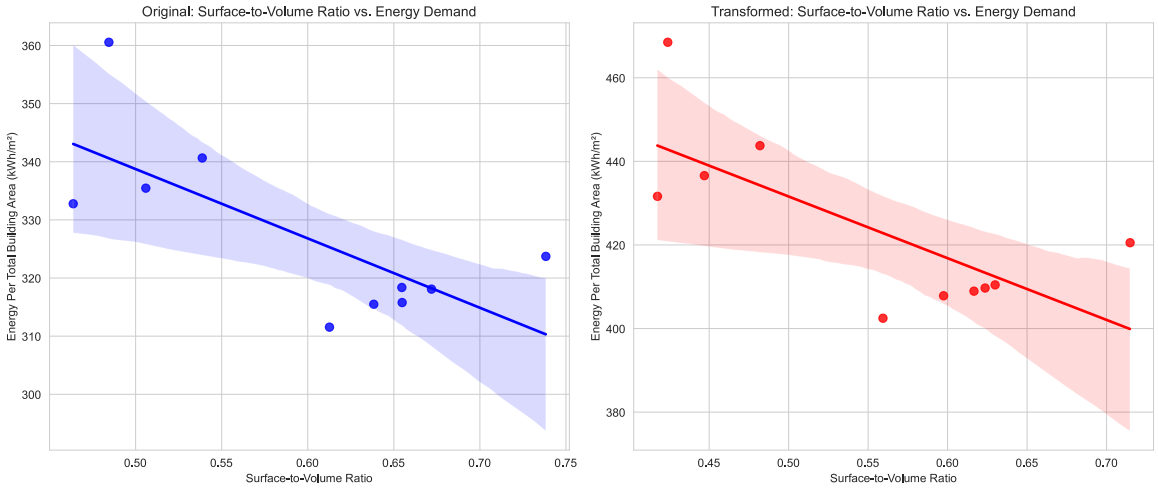


Figure 5 Scatter plot showing the relationship between buildings' SV ratios and energy demand

5.3. Impact of Form Factor on Thermal Comfort and Embodied Carbon

As reflected in the mean annual operative temperatures' columns (Tables 3 and 4), thermal comfort exhibited a slight increase of 2%. This increase is mainly attributed to excessive heat gains due to exposed window openings and walls. However, the narrow standard deviation of ±1.04 °C across the dataset suggests that these temperature variations are relatively small, which can be improved using passive design strategies. Notwithstanding, even minor temperature increases can translate into higher cooling loads, further explaining the observed energy demand increase highlighted in Section 5.2. Conversely, the overall mean embodied carbon emissions of the buildings reduced by 3.4% from 77,563 $kgCO_2e$ to 74,914 $kgCO_2e$, which can be attributed to the changes in envelope area between the original and building forms. This variance in embodied carbon across building forms is depicted in Figure 6 below.

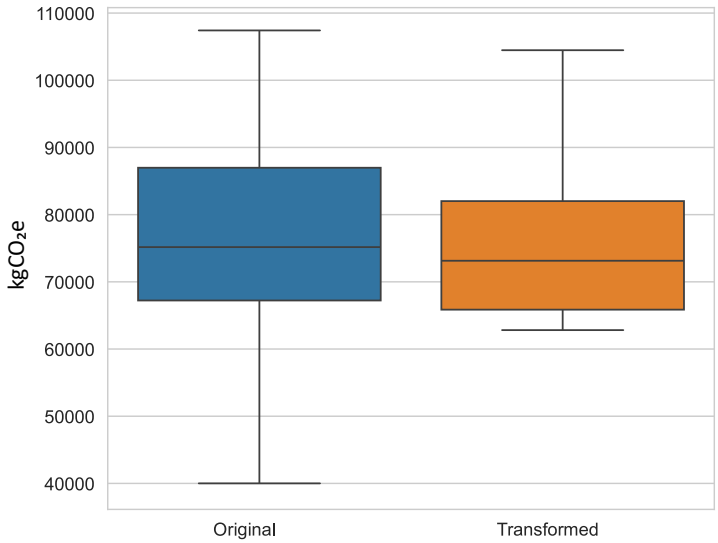


Figure 6 Embodied carbon comparison of building forms

While compactness may reduce envelope material use, other factors such as size and building use influence embodied carbon levels (He et al., 2024; Kern et al., 2021). As depicted in Figure 7, improving building compactness does not reduce embodied carbon, since the least compact buildings account for the smallest embodied carbon, while more compact buildings tend to have high embodied carbon. Specifically, Case 5 (one floor) and Case 7 (two floors), far above the best-fit regression line and with the largest floor areas, account for the most embodied carbon, yet with varied SV ratios. Also, Case 2 (one floor) and Case 8 (two floors), with the smallest floor areas and below the confidence interval, also have diverse SV ratios and embodied carbon. Most of the

buildings with high SV ratios have low to moderate embodied carbon, while the majority with low SV ratios have high embodied carbon. Predicting embodied carbon using early design form optimisation is a complex task requiring other building elements for accurate estimates and reliability.

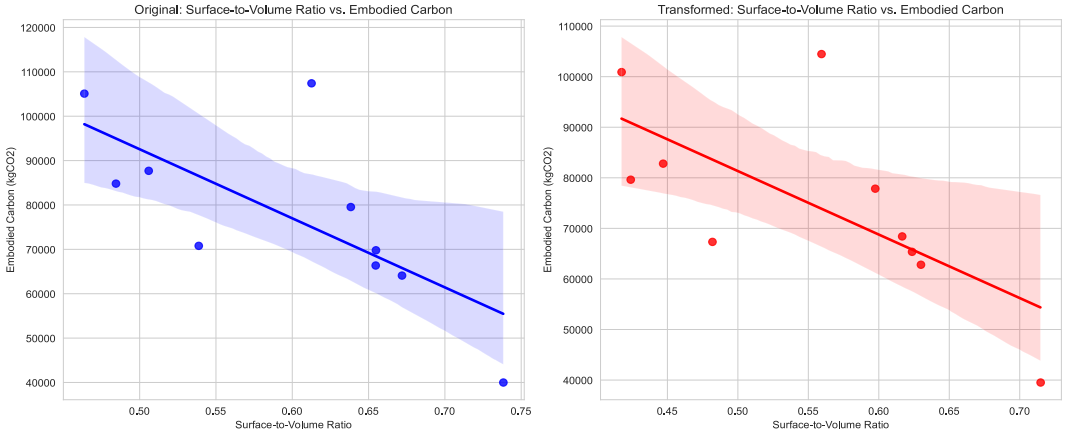


Figure 7 Scatter plot showing the relationship between buildings' SV ratio and embodied carbon

5.4. Factors Influencing Form Factor Variability

5.4.1. Principal Component Analysis (PCA) of Energy Performance Metrics

A Principal Component Analysis (PCA) biplot (Figure 8) is a visual representation of the interconnection between Volume, Total Envelope Area, Surface-to-Volume (SV) Ratio and Energy per Total Building Area. The PCA analysis was conducted using data from the original building forms as presented in Table 3. It shows how these variables interact along the first two principal components (PC1 and PC2), which together explains much of the variability in the dataset. Understanding these patterns is essential for optimising building forms for energy efficiency and sustainability.

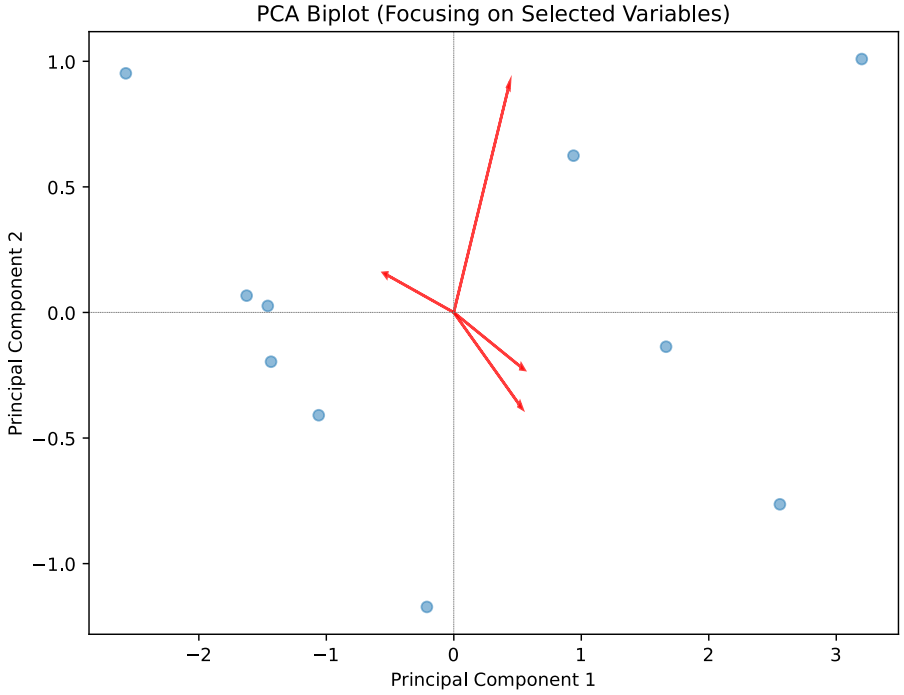


Figure 8 Biplot of principal component loadings

The principal component (PC) loadings clarify this interconnectedness by measuring the contributions of these variables to PC1 and PC2. In PC1, Volume (0.53) and Total Envelope Area (0.51) have strong positive loadings (see vectors in Figure 8), implying that this component is primarily driven by building size. The SV ratio, on the other hand, has a negative loading of -0.52, reinforcing its inverse relationship with Volume and Envelope Area. As corroborated by D'Amico and Pomponi (2019), the negative influence of SV ratio suggests that buildings with lower SV ratios are typically associated with larger volumes. Energy per Total Area also contributes to PC1 with a moderate loading of 0.43, implying that while size-related factors do influence energy use, they are not the sole determinants.

In contrast, PC2 is overwhelmingly influenced by Energy per Total Area, with the highest loading of 0.89. This confirms that energy performance varies independently of size-related parameters and is largely responsible for the differentiation captured along this axis. The vector position of Energy loading, perpendicular to other variables, implies little or no direct influence by other variables. Furthermore, the negative loading of Total Envelope Area (-0.37) on PC2 suggests that buildings with large envelope areas are weakly associated with low energy use. A clear example is a comparison between Case 8 and 9. Despite Case 8 having a lower total surface area (542.130 m²) and a lower SV ratio (0.539), its energy use is higher at 340.65 kwh/m². In contrast, Case 9, with a larger total surface area (644.240 m²) and a slightly lower SV ratio (0.506), records a lower energy consumption of 335.46 kwh/m². The strength of energy use on PC2 indicates that other factors likely dominate energy performance, making it crucial to look beyond building form when evaluating energy efficiency.

5.4.2. Regression Analysis of Form Factor Variance

A regression analysis was further conducted on the dataset to determine the degree to which building volume and envelope area influence the surface-to-volume (SV) ratio of buildings. The objective is to ascertain the primary determinant driving variations in the SV ratio, which is crucial for understanding compactness. The regression models for the building configurations exhibit high explanatory power, with R-squared values above 94%, indicating that building volume and total envelope area together explain nearly all variations in the SV ratio. However, despite the inclusion of both independent variables, the results show that building volume plays a far more significant role in determining the SV ratios than the envelope area. For the original form, the model has an R-squared value of 0.955, meaning that 95.5% of the variability in the form factor is explained by the predictors, while the transformed buildings model has an R-squared value of 0.947. The high adjusted R-squared values (0.942 for the original and 0.932 for the transformed buildings) reinforce the reliability of these models. The statistical significance of the models is further supported by F-statistics of 73.71 (p = 1.98e-05) for the case buildings and 62.45 (p = 3.44e-05) for the transformed buildings, confirming that at least one of the independent variables plays a crucial role.

5.4.2.1. Impact of Building Volume on Surface-to-Volume Ratio

Across both building configurations, the regression analysis shows that building volume is the dominant factor driving SV ratio variations. For instance, in the original forms, the regression coefficient for building volume is -0.0003, with a p-value of 0.038, making it statistically significant. Likewise, in the transformed buildings, the coefficient remains negative (-0.0002) but with a p-value of 0.051 (slightly above the significance threshold). There is a strong tendency for voluminous buildings to have small SV ratios, leading to more compact forms. In Figure 9 below, Cases 7, 8, 9 (two floors) and 10 (three floors) have the largest volumes and lower SV ratios, while Case 2 (one floor), with the least volume, possesses the highest SV ratio. The reason for this is straightforward: SV ratio is expressed as the ratio of the total envelope area by building volume (Equation I). For buildings with larger volumes than their envelope area, the SV ratio would be small, while buildings with more surface area than their volumes will have large SV ratios. Since volume remains fixed for each of the buildings, the only way to achieve a lower SV ratio is by reducing the total envelope

area. This is the reason all the transformed buildings achieved lower SV ratios compared to their original forms.

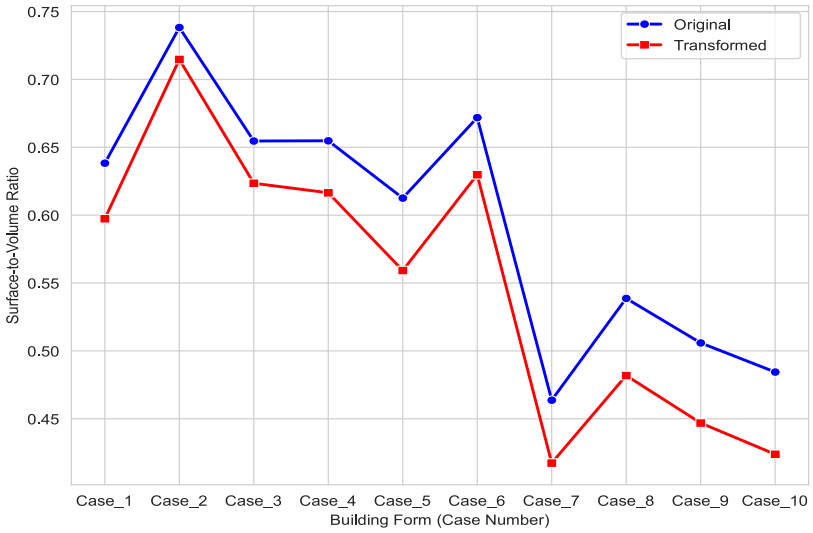


Figure 9 Comparison of surface-to-volume ratios for different building forms

5.4.2.2. Impact of Envelope Area on Surface-to-Volume Ratio

Despite its presence in the regression model, the building's total envelope area does not significantly influence the SV ratio. In the original form, the coefficient for total envelope area is 0.0001, but its p-value of 0.662 shows that its effect is not statistically significant. Likewise, in the transformed buildings, the coefficient is even smaller (4.047e-05), and the p-value is extremely high (0.905), confirming no meaningful impact. This result suggests that merely adjusting a building's envelope area does not independently dictate its SV ratio unless it is accompanied by changes in its volume. The reduction in envelope area during transformation directly lowered the SV ratio, but the analysis from the previous section reveals that this relationship is primarily driven by volume rather than the envelope area.

A Pearson correlation heatmap (Figure 10) shows the connection between SV ratio and key building parameters and performance metrics. Broadly, a correlation coefficient value ranges from -1 to 1, with values of 1 or close to 1 suggesting a perfect or strong positive relationship, while values of -1 or close to -1 indicate a perfect or strong negative correlation. A positive correlation suggests that as one variable increases, the other also increases linearly, while a negative correlation indicates that as one variable increases, the other decreases proportionately. A correlation value of 0 indicates that there is no linear relationship between the variables. In this regard, a strong negative correlation exists between envelope area and surface-to-volume ratio in both building forms, -0.96 for the original form and -0.95 for the transformed building. This implies that as the building envelope area increases, the SV ratio tends to decrease proportionately. However, as discussed earlier, this relationship is mainly influenced by building volume, the principal determinant of SV, with a correlation coefficient of -0.98 and -0.97 in the original and transformed buildings, respectively.

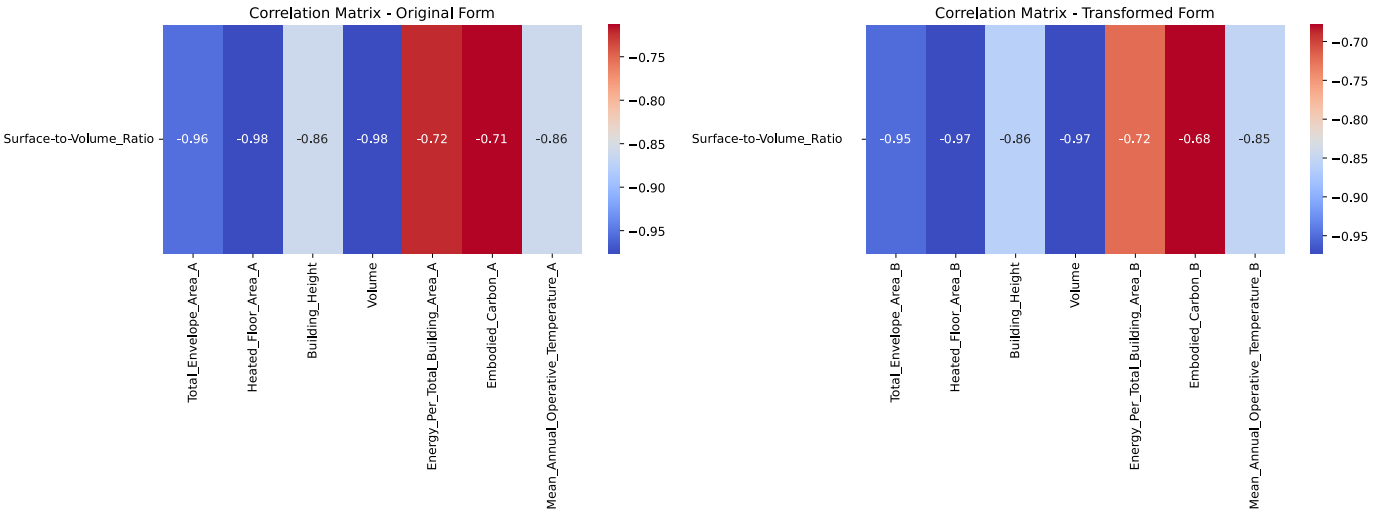
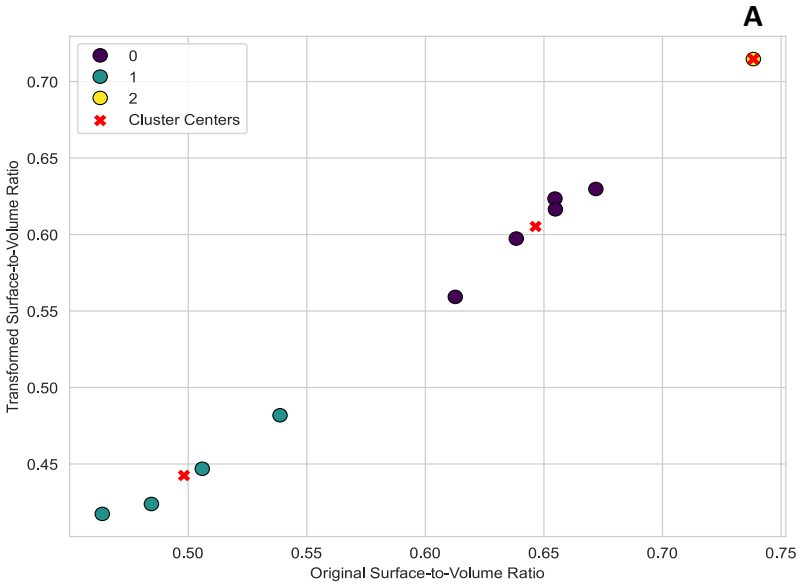


Figure 10 Pearson correlation matrix of building forms

5.5. Building Form Clusters and Overall Implications

K-Means clustering algorithm was used to cluster the buildings based on surface-to-volume ratio and their energy efficiency (Figure 11), uncovering patterns that would have otherwise remained obscured. The analyses highlight three distinct clusters, each representing different relationships between form and energy efficiency. From Figure 11A, the first cluster (0) encompasses building Cases 1, 3, 4, 5 and 6 (one floor). These buildings, with moderate SV ratios, all share a single-storey configuration in both configurations, indicating their volumetric efficiency remained relatively stable despite morphological adjustments. On the other hand, the second cluster (1) comprises building Cases 7-10, all two-storey buildings except for Case 10 (three storeys). This cluster contains buildings with the largest volumes, yet the lowest SV ratios, corroborating the significance of large-volume buildings in reducing SV ratio, as highlighted in section 5.4.2.1. Since buildings in cluster 0 are single-storey, and cluster 1 are multi-storeys, building levels positively correlate with compactness, indicating the likelihood for taller buildings to be more compact (Vasilenko, 2019). Nonetheless, a single-storey building (Case 2) appears as an outlier in cluster 2, mainly due to its comparatively lower volume (343.77 m^3) and significantly high SV ratios: 0.74 and 0.72 for the original and transformed buildings, respectively. The isolated position of this case suggests that not all single-storey buildings behave similarly when transformed, as some may still experience significant SV ratio reductions depending on their initial complexity.



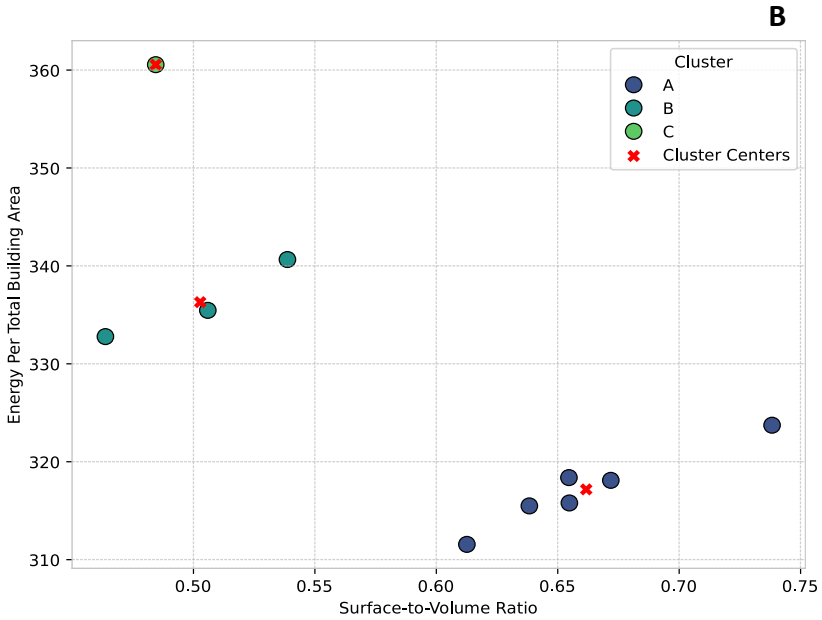


Figure 11 Buildings cluster based on SV ratios (A), and buildings energy efficiency (B)

The cluster result, as illustrated in Figure 11B, reveals intriguing insights into the relationship between surface-to-volume (SV) ratio and building energy performance. The building forms are classified into Clusters A, B and C, highlighting unexpected patterns that challenge conventional assumptions about form factor and energy efficiency. Cluster A consists of building Cases 1 to 6 (single storey), with high SV ratios. Ideally, a high SV ratio is expected to lead to greater heat loss and higher energy demand, but these buildings in the cluster exhibit the best energy performance, with values ranging between 310 kWh/m² and 325 kWh/m². This counterintuitive finding suggests that factors beyond compactness, such as internal heat gain tendencies, may be compensating for their inherently inefficient form. Some of these buildings have complex geometries (see Table 3) that offer self-shading of the envelope, possibly reducing heat gains.

Furthermore, Cluster B includes Cases 7, 8 and 9 (two storeys) with moderate SV ratio, with Case 7 having the lowest ratio (0.464). This cluster is more compact compared to Cluster A; however, their small SV ratio did not automatically translate to better energy efficiency, as they exhibit higher energy demand. The implication of this finding is that while compactness reduces heat loss, other factors such as increased thermal loads and heated floor areas may contribute to their poor energy efficiency. Cluster C, on the other hand, is a three-storey building with an incredibly low SV ratio (0.484), but its energy demand is the highest, owing to its treated floor areas and volumetric properties, which demand increased cooling requirements, overriding the benefits of its compact form. Findings from these analyses insinuate that compactness alone does not guarantee energy efficiency in buildings, as those with exceptionally low SV ratios can still have high energy demands compared to other forms with higher SV ratios. This study emphasises the importance of early design decisions which must transcend simple form optimisation. Building energy performance is influenced by a complex interplay of form, internal loads and passive design strategies that may not be accounted for in the early phases of building design; hence, making energy demand trajectory vis-à-vis form factor optimisation unpredictable (Li et al., 2014; Yao et al., 2021; Zhuravchak et al., 2022).

6. Conclusion and Recommendations

6.1. Conclusion

This study examined the impact of form factor variance on early-stage design performance in Nigeria using computational and empirical analyses. Findings from the study challenge conventional assumptions that compact buildings are energy efficient. Out of ten buildings evaluated in their original and transformed cases, single-storey buildings with higher surface-to-volume (SV) ratios exhibited better energy efficiency compared to the most compact building (three storeys). Principal component analysis (PCA) further revealed that building volume and envelope area explained more than 97% of observed form factor differences, while regression analysis confirmed building volume as the key player in form factor variability ($p = 0.038$). With a p-value of 0.662, it was concluded that building envelope area had no statistical significance on form factor changes. By implication, building form optimisation should prioritise volume over envelope area reduction.

Cluster analysis, however, highlighted that building energy efficiency is informed by the interplay between SV ratio, volume and building façade exposure to solar radiation. Case 2, a single-storey building, emerged as an outlier among the buildings with a disproportionately high heat loss form factor (2.95) and SV ratio (0.74), owing to its lesser floor area and volume. Despite SV ratio reductions of 3.19% to 12.50% following form transformation ($L = 1.5B$), energy demand unexpectedly increased by 28.68% to 30.27%, suggesting that compactness alone does not ensure energy efficiency. These findings emphasise the importance of shading and passive cooling considerations in form optimisation for representative estimates of operational energy and embodied carbon during early design development.

6.2. Recommendations

Based on the study findings, the following recommendations have been outlined to inform building designers, policymakers and researchers on building form optimisation for energy efficiency in tropical climates.

1. Optimisation of Compactness and Façade Exposure

Compact buildings should be designed with solar exposure mitigation in mind, especially for multi-storey buildings. Passive strategies such as dynamic shading, glazing optimisation and low-albedo material use should be incorporated for enhanced energy efficiency.

2. Prioritisation of Volumetric Efficiency

Since building volume is the primary driver of form factor, energy-efficient designs should focus on optimising volume without compromising functional architectural requirements and passive cooling strategies.

3. Development of Hybrid Form Factor Indices

Future research should consider integrated metrics that combine form factor, façade exposure, material performance and cooling strategies to provide more reliable energy efficiency predictions for early-stage design.

4. Empirical Validation Through Longitudinal Studies

While this study provides valuable insights, longitudinal studies incorporating real-world occupancy patterns are needed to validate the effectiveness of form optimisation in the long-term in tropical climates.

5. Exploration of Morphological Adaptations in High-Rise Buildings

Given the high energy demand of the three-storey building, despite its low SV ratio, future studies should explore alternative high-rise morphologies such as stepped massing, double-skin façades and natural ventilation corridors to mitigate heat stress in compact multi-storey tropical buildings.

CRediT Authorship Contribution Statement

Mark Alegbe: Conceptualisation, Writing – original draft, review & editing, Writing – Methodology, Investigation, Simulation, Results interpretation. Hammed Nasiru: Writing – formatting, editing & literature review. John Lekwauwa Kalu: Data curation, Investigation, Visualisation. Laurence Chukwuemeka: Data curation, Visualisation. Nnamdi Diribe: Writing – review & editing.

Declaration of Competing 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 paper.

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Data Availability

Data will be made available on request.

Ethics Committee Approval

Approval from an ethics committee was not required for this research.

References

Adenaike, F. A., & Opoko, A. P. (2024). Thresholds of architectural morphology of Yoruba buildings in Southwest Nigeria till the millenia. *European Journal of Theoretical and Applied Sciences*, *2*(2), 180–193. https://doi.org/10.59324/ejtas.2024.2(2).17

Agbete, M. A., & Frank, O. L. (2020). Modern vernacular architecture: An ecological approach towards energy efficiency; toreduce climate change impact in Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, *14*(3), 20–34.

Ahmadian, E., Sodagar, B., Bingham, C., Elnokaly, A., & Mills, G. (2021). Effect of urban built form and density on building energy performance in temperate climates. *Energy and Buildings*, *236*, 110762. https://doi.org/10.1016/J.ENBUILD.2021.110762

Ahmed, N., Abdel-Hamid, M., Abd El-Razik, M. M., & El-Dash, K. M. (2021). Impact of sustainable design in the construction sector on climate change. *Ain Shams Engineering Journal*, *12*(2), 1375–1383. https://doi.org/10.1016/j.asej.2020.11.002

Akbari, H., & Nezhad, F. S. H. (2020). Optimum form, aspect ratio and orientation of building based on solar energy receiving in hot-dry climate: Case studies of Isfahan, Semnan, Kashan and Kerman cities, Iran. *Journal of Solar Energy Research (JSER)*, *5*(1), 341_350. https://doi.org/10.22059/JSER.2020.299320.1145

Algburi, O., & Ferah, B. (2021). *Simulation comparative study to highlight the relation between building form and energy consumption*. International Conference on Advanced Engineering, Technology and Applications.

Alhawari, A., & Mukhopadhyaya, P. (2018). Thermal bridges in building envelopes – An overview of impacts and solutions. *International Review of Applied Sciences and Engineering IRASE*, *9*(1), 31–40. https://doi.org/10.1556/1848.2018.9.1.5

Alshboul, A., & Alatrash, D. (2024). Natural design procedures for enhancing energy efficiency in buildings [Article]. *International Journal of Design and Nature and Ecodynamics*, *19*(5), 1527–1539. https://doi.org/10.18280/ijdne.190507

Araji, M. T. (2019). *Surface-to-volume ratio: How building geometry impacts solar energy production and heat gain through envelopes* IOP Conference Series: Earth and Environmental Science, Graz. *323*(1), pp. 012034. https://doi.org/10.1088/1755-1315/323/1/012034

Arbabzadeh, M., Etessam, I., & Shemirani, M. (2020). Passive thermoregulation in vernacular and biomimetic architecture in hot and arid climate. *International Journal of Architecture, Engineering and Urban Planning*, *30*(2), 198–211. https://doi.org/10.22068/ijaup.30.2.198

Archi-Monarch. (n.d.). *Form in architecture*. Archi-Monarch. Retrieved March 6, 2025 from https://archi-monarch.com/form-in-architecture/

Aydın, M. A., & Koçlar Oral, G. (2024). Evaluation of building energy performance based on settlement scale design parameters using BIM tools. *Gazi University Journal of Science*, *37*(2), 501–518. https://doi.org/10.35378/gujs.1277880

Barssoum, M., Knudsen, H., Macdonald, I., & Vuong, E. (2020). *A parametric study on the impact of geometric building shapes on energy consumption*. Proceedings of the eSIM:11th Conference of IBPSA, Canada.

Beck, H. E., McVicar, T. R., Vergopolan, N., Berg, A., Lutsko, N. J., Dufour, A., Zeng, Z., Jiang, X., van Dijk, A. I. J. M., & Miralles, D. G. (2023). High-resolution (1 km) Köppen-Geiger maps for 1901–2099 based on constrained CMIP6 projections. *Scientific Data*, *10*(1), 724. https://doi.org/10.1038/s41597-023-02549-6

Belussi, L., Barozzi, B., Bellazzi, A., Danza, L., Devitofrancesco, A., Fanciulli, C., Ghellere, M., Guazzi, G., Meroni, I., Salamone, F., Scamoni, F., & Scrosati, C. (2019). A review of performance of zero energy buildings and energy efficiency solutions. *Journal of Building Engineering*, *25*, 100772. https://doi.org/https://doi.org/10.1016/j.jobe.2019.100772

Benkhelifa, A., Bekkouche, S., Allaoui, T., Cherier, M., Hamdani, M., Mihoub, R., & Djeffal, R. (2019). Application of the building height concept to energy-efficient heating and cooling for Saharan buildings. *Modelling, Measurement and Control 80*(2-4), 71–78. https://doi.org/10.18280/mmc_c.802-405

Boronbaev, E. (2023). *Energy saving architecture concept: Buildings with low energy consumption and emissions in Kyrgyzstan*. E3S Web of Conferences, *405*, pp. 04039. https://doi.org/10.1051/e3sconf/202340504039

Boronbaev, E. (2024). *Energy saving architecture: Multidisciplinary improvement of buildings shape, energy-efficiency, microclimate, seismic-resistance and prevention influences of thermal bridges and mold growth*. Proceedings of the International Conference on Geosynthetics and Environmental Engineering, Singapore. *374*, pp. 251–259. https://doi.org/10.1007/978-981-99-4229-9_22

British Standards Institution. (2012). *BS EN 15978:2011: Sustainability of construction works. Assessment of environmental performance of buildings*. Calculation method. In: British Standards Institute.

Burrell, E. (n.d.). *Heat loss form factor*. Greenspec. Retrieved 8th March 2025 from https://www.greenspec.co.uk/building-design/heat-loss-form-factor/

Camporeale, P., & Mercader-Moyano, P. (2019). Towards nearly zero energy buildings: Shape optimization of typical housing typologies in Ibero-American temperate climate cities from a holistic perspective. *Solar Energy*, *193*, 738–765. https://doi.org/10.1016/j.solener.2019.09.091

Carpio, M., & Carrasco, D. (2021). Impact of shape factor on energy demand, CO2 emissions and energy cost of residential buildings in cold oceanic climates: Case study of South Chile. *SUSTAINABILITY*, *13*(17), 9491. https://doi.org/10.3390/su13179491

Circular Ecology. (2025). *Inventory of carbon & energy (ICE) database v4.1*. circularecology.com/news/ice-database-v4-1-released

D'Amico, B., & Pomponi, F. (2019). A compactness measure of sustainable building forms. *Royal Society Open Science*, *6*(6), 181265. https://doi.org/10.1098/rsos.181265

D'Amico, B., Pomponi, F., & Hart, J. (2021). Global potential for material substitution in building construction: The case of cross laminated timber. *Journal of Cleaner Production*, *279*, 123487. https://doi.org/10.1016/j.jclepro.2020.123487

Dada, A. D., & Alibaba, H. Z. (2023). *Comparison analysis between the components of vernacular and modern architectures for sustainable housing in Niger State* IOP Conference Series: Earth and Environmental Science, *1210*(1), pp. 012011. https://doi.org/10.1088/1755-1315/1210/1/012011

Deng, X., Wang, M., Sun, D., & Fan, Z. (2020). *Effect of building form on energy consumption of academic library buildings in different climate zones in China*. IOP Conference Series: Earth and Environmental Science, *531*, pp. 012060. https://doi.org/10.1088/1755-1315/531/1/012060

DesignBuilder. (V7.0). *LCA And Embodied carbon*. Retrieved 11 August 2026 from https://designbuilder.co.uk/helpv7.0/Content/Carbon.htm

Djeddou, B., Daich, S., & Femmam, A. (2024). The impact of urban form on the energy efficiency of residential buildings in a hot climate. Case study: Ouargla city. *Journal of Building Physics*, *48*(5), 1–29. https://doi.org/10.1177/17442591241289579

Driga, A. M., & Drigas, A. S. (2019). Climate change 101: How everyday activities contribute to the ever-growing issue. *International Journal of Recent Contributions from Engineering, Science & IT (iJES)*, *7*(1), 22–31. https://doi.org/10.3991/ijes.v7i1.10031

El-Agami, M., Hanafy, G., & Osman, M. (2021). Investigating the effect of high-rise buildings' mass geometry on energy efficiency within the climatic variation of Egypt. *SUSTAINABILITY*, *13*(19), 10529. https://doi.org/10.3390/su131910529

Fereidani, N. A., Rodrigues, E., & Gaspar, A. R. (2021). A review of the energy implications of passive building design and active measures under climate change in the Middle East. *Journal of Cleaner Production*, *305*, 127152.

Folorunso, C., Akingbohungbe, D., & Ogunruku, M. (2017). Choice prediction factors in building exterior finishes' selection in Lagos, Nigeria: Clients' perspective. *International Journal of Research in Engineering and Social Sciences*, *7*(1), 14–20.

Freewan, A. (2022). Energy-efficient solutions depending on building forms design with tilted South and North Facades. *Buildings*, *12*, 753. https://doi.org/10.3390/buildings12060753

Galal Ahmed, K., & Hossein Alipour, S. M. (2019). *Investigating the effect of urban compactness on energy efficiency in recent urban communities in UAE*. IOP Conference Series: Materials Science and Engineering, *603*(2), pp. 022092. https://doi.org/10.1088/1757-899X/603/2/022092

Gamero-Salinas, J., Kishnani, N., Monge-Barrio, A., Gandhi, B., Bilgi, M., & Sánchez-Ostiz, A. (2020). *The influence of building form on energy use, thermal comfort and social interaction A post-occupancy comparison of two high-rise residential buildings in Singapore* 35th PLEA Conference. Planning Post Carbon Cities., *1*, pp. 61. https://doi.org/10.17979/spudc.9788497497947

Guo, M., Wu, Y., & Miao, X. (2023). Thermal bridges monitoring and energy optimization of rural residences in China's cold regions. *SUSTAINABILITY*, *15*(14), 11015. https://doi.org/10.3390/su151411015

Gupta, R., & Gregg, M. (2018). Assessing energy use and overheating risk in net zero energy dwellings in UK. *Energy and Buildings*, *158*, 897–905. https://doi.org/10.1016/j.enbuild.2017.10.061

Gupta, V., & Deb, C. (2023). Envelope design for low-energy buildings in the tropics: A review. *Renewable and Sustainable Energy Reviews*, *186*, 113650. https://doi.org/10.1016/j.rser.2023.113650

Hadjhafsi, L., Benaissa, F. T., Redjem, A., & Derradji, K. (2024). Residential building forms and energy efficiency in the Saharan climate: the case of Adrar, Algeria. *Geomatics, Landmanagement and Landscape*, *2*, 85–98. https://doi.org/10.15576/GLL/2024.2.06

Hajtmanek, R., Morgenstein, P., Hubinský, T., Legény, J., & Špaček, R. (2023). Determination of solar-surface-area-to-volume ratio: Early design stage solar performance assessment of buildings. *Buildings*, *13*(20), 296. https://doi.org/10.3390/buildings13020296

Hatem, H. M., & Karram, M. A. (2020). *Integrating layout geometry with architectural requirements to achieve energy-efficient office buildings in Egypt*. ASHRAE Topical Conference Proceedings, pp. 610–617.

He, H., Zhao, Z., Yan, H., Zhang, G., Jing, R., Zhou, M., Wu, X., Lin, T., & Ye, H. (2024). Urban functional area building carbon emission reduction driven by three-dimensional compact urban forms' optimization. *Ecological Indicators*, *167*, 112614. https://doi.org/10.1016/j.ecolind.2024.112614

Hong, T., Malik, J., Krelling, A., O'Brien, W., Sun, K., Lamberts, R., & Wei, M. (2023). Ten questions concerning thermal resilience of buildings and occupants for climate adaptation. *Building and Environment*, *244*, 110806. https://doi.org/10.1016/j.buildenv.2023.110806

Hygh, J. S., DeCarolis, J. F., Hill, D. B., & Ranji Ranjithan, S. (2012). Multivariate regression as an energy assessment tool in early building design. *Building and Environment*, *57*, 165–175. https://doi.org/10.1016/j.buildenv.2012.04.021

Kabanshi, A., Choonya, G., Ameen, A., Liu, W., & Mulenga, E. (2023). Windows of opportunities: Orientation, sizing and PV-shading of the glazed area to reduce cooling energy demand in Sub-Sahara Africa. *Energies*, *16*(9), 3834. https://doi.org/10.3390/en16093834

Kahraman, Ö., & Köymen, E. (2023). The influence of building form compactness on energy efficiency in accommodation structures: The case of Türkiye. *Sakarya University Journal of Science*, *27*(5), 1055–1078. https://doi.org/10.16984/saufenbilder.1253136

Kern, A. P., Postay, R., Schneck, E. R., Mancio, M., González, M. A. S., & Guerra, G. (2021). Cost and environmental impacts reduction through building compactness. *Engineering, Construction and Architectural Management*, *28*(4), 1176–1195. https://doi.org/10.1108/ECAM-03-2020-0147

Keskisalo, M., & Matveinen, M. (2021). *Form factor for efficient low carbon construction* InnoRenew CoE International Conference (Book of Abstracts), Online. pp. 12.

Khalil, A. (2023). *Design optimization of building form and fenestration for daylighting and thermal energy in three variations of the hot climate of Egypt*. Building Simulation Conference Proceedings, Shanghai, China. pp. 2274–2282. https://doi.org/10.26868/25222708.2023.1649

Khalil, A., Lila, A., & Ashraf, N. (2023). Optimization and prediction of different building forms for thermal energy performance in the hot climate of cairo using genetic algorithm and machine learning. *Computation*, *11*(100), 192. https://doi.org/10.3390/computation11100192

Kheiri, F. (2018). A review on optimization methods applied in energy-efficient building geometry and envelope design. *Renewable and Sustainable Energy Reviews*, *92*, 897_920. https://doi.org/10.1016/j.rser.2018.04.080

Kistelegdi, I., Horváth, K. R., Storcz, T., & Ercsey, Z. (2022). Building geometry as a variable in energy, comfort, and environmental design optimization—A review from the perspective of architects. *Buildings*, *12*(100), 69. https://doi.org/10.3390/buildings12010069

Koźniewski, E., Sadowska, B., & Banaszak, K. (2022). Geometric aspects of assessing the anticipated energy demand of a designed single-family house. *Energies*, *15*(9), 3308. https://doi.org/10.3390/en15093308

Li, C., Hong, T., & Yan, D. (2014). An insight into actual energy use and its drivers in high-performance buildings. *Applied Energy*, *131*, 394–410. https://doi.org/10.1016/j.apenergy.2014.06.032

Li, J., Liang, C., & Zhou, W. (2024). A review of building physical shapes on heating and cooling energy consumption. *Energies*, *17*(22), 5766. https://doi.org/10.3390/en17225766

Li, J., Yue, T., & Zhang, Y. (2023). Experimental and simulation study on the modified shape coefficient of building integrated thermal considerations for heating buildings in solar-enriched areas. *Solar Energy*, *264*, 112060. https://doi.org/10.1016/j.solener.2023.112060

Lian, H., Zhang, J., Li, G., & Ren, R. (2023). The relationship between residential block forms and building carbon emissions to achieve carbon neutrality goals: A case study of Wuhan, China. *Sustainability (Switzerland)*, *15*(22), 15751. https://doi.org/10.3390/su152215751

Liang, Y., Yuan, X., Pan, Y., & Kosonen, R. (2023). *Passive design and shape optimization for carbon emissions reduction for residential-and-commercial buildings in cold climate zone* Healthy Buildings Europe 2023: Beyond Disciplinary Boundaries, Germany. *2*, pp. 947–953.

Lodson, J., Ogbeba, J. E., & Elinwa, U. K. (2018). A lesson from vernacular architecture in Nigeria. *Journal of Contemporary Urban Affairs*, *2*(1), 84–95. https://doi.org/10.25034/ijcua.2018.3664

Lucchi, E. (2023). Energy and climatic performances of modern architecture: A complete overview of building physics implications. *Engineering Proceedings*, *53*(1), 19. https://doi.org/10.3390/IOCBD2023-15203

Mahmoud, A. R. (2022). The influence of buildings proportions and orientations on energy demand for cooling in hot arid climate. *SVU-International Journal of Engineering Sciences and Applications*, *3*(1), 8–20. https://doi.org/10.21608/svusrc.2022.119125.1028

Makhloufi, W. A., & Louafi, S. (2023). Parametric study for optimising building form and height: An approach toward net zero energy & carbon in buildings. *Tehnički Glasnik*, *17*(4), 501–507. https://doi.org/10.31803/tg-20221119182144

Marincu, C., Dan, D., & Moga, L. (2024). Investigating the influence of building shape and insulation thickness on energy efficiency of buildings. *Energy for Sustainable Development*, *79*, 101384. https://doi.org/10.1016/j.esd.2024.101384

Mba, E. J., Okeke, F. O., Oforji, P. I., Ozigbo, I. W., Emmanuel, E. C., & Ozigbo, C. A. (2024). *Impact of building plan shape on natural ventilation efficiency*. Proceedings of the 8th International Conference on Civil Engineering: ICOCE 2024, Singapore. *539*, pp. 355. https://doi.org/10.1007/978-981-97-5910-1_28

Mohsenzadeh, M., Marzbali, M. H., Tilaki, M. J. M., & Abdullah, A. (2021). Building form and energy efficiency in tropical climates: A case study of Penang, Malaysia. *City. Brazilian Journal of Urban Management*, *13*. https://doi.org/10.1590/2175-3369.013.e20200280

Mutani, G., Todeschi, V., Marta, C., & Andrea, R. (2020). *Urban-scale energy models:* Relationship *between urban form and energy performance*. 2020 IEEE 3rd International Conference and Workshop in Óbuda on Electrical and Power Engineering (CANDO-EPE), pp. 185–190. https://doi.org/10.1109/CANDO-EPE51100.2020.9337760

Noah, E. A., & Çağnan, Ç. (2021). A study of vernacular architecture in relation to sustainability: The Case of Northern Nigeria. *Near East University Faculty of Architecture Journal*, *3*(1), 21–35.

Notodipuro, P., & Mandala, A. (2022). The effect of building shape and orientation on energy use at sloped sites in tropical climates using sefaira. *ARTEKS : Jurnal Teknik Arsitektur*, *7*(7), 131–142. https://doi.org/10.30822/arteks.v7i1.1397

Nwalusi, D. M., Obi, N. I., Chendo, I. G., & Okeke, F. O. (2022). *Climate responsive design strategies for contemporary low-rise residential buildings in tropical environment of Enugu, Nigeria* IOP Conference Series: Earth and Environmental Science, *1054*(1). https://doi.org/10.1088/1755-1315/1054/1/012052

Ochedi, E. T., & Taki, A. (2022). A framework approach to the design of energy efficient residential buildings in Nigeria. *Energy and Built Environment*, *3*(3), 384–397.

Offor, J., & Emenike, A. (2019). Passive strategies for enhancing indoor comfort and air quality of high-density zones of South eastern Nigeria. *African Research Journal of the Environment*, *2*(1), 1–7. https://doi.org/10.36265/arejoen.2019.020101

Oh, M., & Kim, Y. (2019). Identifying urban geometric types as energy performance patterns. *Energy for Sustainable Development*, *48*, 115–129. https://doi.org/10.1016/j.esd.2018.12.002

Orçun, K. İ., & Onur, D. (2022). The impacts of early architectural design decisions on building performance. *International Journal of Digital Innovation in the Built Environment*, *11*(2), 1_21. https://doi.org/10.4018/IJDIBE.301245

Parry, C., & Strang, M. (2021). Airtightness and thermal bridging in buildings. *Environment*(3), 1–18. https://www.jstor.org/stable/27091017

Pathirana, S., Rodrigo, A., & Halwatura, R. (2019). Effect of building shape, orientation, window to wall ratios and zones on energy efficiency and thermal comfort of naturally ventilated houses in tropical climate. *International Journal of Energy and Environmental Engineering*, *10*(1), 107_120. https://doi.org/10.1007/s40095-018-0295-3

Pérez-Carramiñana, C., de la Morena-Marqués, A., González-Avilés, Á. B., Castilla, N., & Galiano-Garrigós, A. (2024). Influence of balcony thermal bridges on energy efficiency of dwellings in a warm semi-arid dry mediterranean climate. *Buildings*, *14*(3), 703. https://doi.org/10.3390/buildings14030703

Premrov, M., Žigart, M., & Žegarac Leskovar, V. (2018). Influence of the building shape on the energy performance of timber-glass buildings located in warm climatic regions. *Energy*, *149*, 496–504. https://doi.org/10.1016/j.energy.2018.02.074

Puri, U. (2021). Influence of building shape on area to volume ratio and thermal loads in warm climate - Case of Itahari, Nepal. *International Journal of Engineering Research and*, *10*(1), 231–235. https://doi.org/10.17577/IJERTV10IS010084

Ragab, A. (2022). The influence of buildings proportions and orientations on energy demand for cooling in hot arid climate. *SVU-International Journal of Engineering Sciences and Applications*, *3*(1), 8–20. https://doi.org/10.21608/svusrc.2022.119125.1028

Rahmani, M., & Al-Sallal, K. (2019). *Impact of building form on energy performance in new school models*. 16th IBPSA International Conference, Rome, Italy. pp. 5123_5129. https://doi.org/10.26868/25222708.2019.210309

Ran, J., Xiong, K., Dou, M., Zhong, H., Feng, Y., Tang, M., & Yang, Z. (2022). Effect of window openable area and shading on indoor thermal comfort and energy efficiency in residential buildings with various operating modes. *Atmosphere*, *13*(12), 2020. https://doi.org/10.3390/atmos13122020

Remon, L. (2019). The effect of building geometric shape and orientation on its energy performance in various climate regions. *GEOMATE Journal*, *16*(53), 11_119. https://geomatejournal.com/geomate/article/view/2660

Sokar, L., Brakez, A., & Sobhy, I. (2023). A scientific process for a sustainable architectural design: A case study of a rural pavilion in a hot semi-arid climate. *Journal of Building Engineering*, *79*, 107816. https://doi.org/10.1016/j.jobe.2023.107816

Song, J., & Sun, S. (2021). *Research on architectural form optimization method based on environmental performance-driven design*. Proceedings of the 2020 DigitalFUTURES: The 2nd International Conference on Computational Design and Robotic Fabrication, Shanghai, China. pp. 217–228. https://doi.org/10.1007/978-981-33-4400-6_21

Song, S., Leng, H., Xu, H., Guo, R., & Zhao, Y. (2020). Impact of urban morphology and climate on heating energy consumption of buildings in severe cold regions [Article]. *International Journal of Environmental Research and Public Health*, *17*(22), 1–25, Article 8354. https://doi.org/10.3390/ijerph17228354

Taştemir, İ. A., Koymen, E., & Yasa, E. (2024). A geometry-based decomposition method for energy prediction in early design stages of residential buildings. *Open House International*, *50*(3), 452–469. https://doi.org/10.1108/OHI-05-2024-0178

The Archspace. (n.d.). *Form in architecture – An important element of design*. The Archspace. Retrieved March 6, 2025 from https://thearchspace.com/an-important-element-of-design-form-in-architecture/

Umar, G. K., Yusuf, D. A., & Mustapha, A. (2019). Theory and design for the contemporary residential building: A case study of Kano Metropolis, North-Western part of Nigeria. *International Journal of Innovative Environmental Studies Research*, *7*(1), 1–8.

Umaru, N., Adamu, S., Bello, M., & Jolaoso, A. B. (2022). Review of selected features of hausa vernacular architecture, case study of Dakali and Zaure in Jos, Plateau State, Nigeria. *ARTEKS: Jurnal Teknik Arsitektur*, *7*(3), 421–432.

Vasilenko, N. A. (2019). *Parametric optimization of an architectural object's form as a method to improve its energy efficiency*. IOP Conference Series: Materials Science and Engineering, *552*(1), pp. 012027. https://doi.org/10.1088/1757-899X/552/1/012027

Vidmar, J. (2019). *How can using form factor reduce energy consumption of buildings?* AgiliCity. Retrieved 8th March 2025 from https://modelur.com/use-form-factor-to-reduce-energy-consumption-of-buildings/

Viganò, G. S. M., Rugani, R., Marengo, M., & Picco, M. (2024). Assessing the impact of climate change on building energy performance: A future-oriented analysis on the UK [Article]. *Architecture*, *4*(4), 1201–1224. https://doi.org/10.3390/architecture4040062

Whole Building Design Guide. (n.d.). *Form*. National Institute of Building Sciences. Retrieved March 6, 2025 from https://www.wbdg.org/resources/form

Yadav, N., & Kumar, P. (2022). Energy-positive rectangular office building - a study of high rise, mid rise and low rise buildings. *Tuijin Jishu/Journal of Propulsion Technology*, *43*(4). https://doi.org/10.52783/tjjpt.v43.i4.1760

Yao, J., Huang, Y., & Cheng, K. (2021). Coupling effect of building design variables on building energy performance. *Case Studies in Thermal Engineering*, *27*, 101323. https://doi.org/10.1016/j.csite.2021.101323

Yip, S., Athienitis, A., & Lee, B. (2021). Early stage design for an institutional net zero energy archetype building. Part 1: Methodology, form and sensitivity analysis. *Solar Energy*, *224*, 516–530. https://doi.org/10.1016/j.solener.2021.05.091

Zankar, R., El-Kaaki, L., & Fares, J. (2022). Design challenges of solving circular geometry in residential buildings. *Architecture and Planning Journal (APJ)*, *28*(1), 1–23. https://doi.org/10.54729/BZXI2461

Zhao, S., Si, J., Chen, G., Shi, H., Lei, Y., Xu, Z., & Yang, L. (2023). Research on passive design strategies for low-carbon substations in different climate zones. *Processes*, *11*(6), 1814. https://doi.org/10.3390/pr11061814

Zhu, S., Ma, C., Wu, Z., Huang, Y., & Liu, X. (2024). Exploring the impact of urban morphology on building energy consumption and outdoor comfort: A comparative study in hot-humid climates. *Buildings*, *14*(5), 1381. https://doi.org/10.3390/buildings14051381

Zhuravchak, R., Nord, N., & Brattebø, H. (2022). The effect of building attributes on the energy performance at a scale: an inferential analysis. *Building Research & Information*, *50*(6), 662–680. https://doi.org/10.1080/09613218.2022.2038537

Resume

Mark Alegbe is a registered Architectural Technologist with the Nigerian Institute of Architects (NIA) and an emerging specialist in low-carbon construction. He holds a Distinction MSc in Climate Resilience and Environmental Sustainability in Architecture (CRESTA) from the University of Liverpool, a First-Class BSc in Architecture from Ambrose Alli University, and earlier Distinctions in Architectural Technology from Nuhu Bamalli Polytechnic. His research interests span embodied carbon assessment, building optimisation, life-cycle impact analysis, and sustainable construction, supported by several peer-reviewed publications and conference contributions. Mark is skilled in energy performance modelling and life-cycle analysis, using tools such as DesignBuilder, EnergyPlus, and leading LCA platforms. He is currently expanding his expertise through advanced study in Construction Management at Liverpool John Moores University, deepening his understanding of how sustainable construction principles integrate across the full building lifecycle.

Hammed Nasiru is a PMP-certified Project Manager and Architect with expertise in architectural design and construction project management. He began his academic journey with a Higher National Diploma in Architectural Technology from Auchi Polytechnic, Edo State and went on to earn a BSc in Architecture from Bells University of Technology, Ota, Nigeria. In 2023, he received a grant from the "Architecture Is Free" Foundation to support the construction of a community school in Makoko, Lagos and is currently leading efforts to equip the school's library through additional grant opportunities. His dedication to sustainable development was further recognised in 2025 when he was selected for the United Nations SDGs Advocate Programme (Cohort 6), focusing on SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action) and SDG 15 (Life on Land). Passionate about climate education and community engagement, his professional interests include sustainable construction, climate-resilient architecture and socially responsive design.

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User satisfaction in home office environments: A comparative analysis of environmental factors by gender and age

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Abstract

This study examines how physical environmental characteristics shape user satisfaction in home office settings and whether these evaluations differ according to gender and age variables. The research was conducted within a quantitative research design framework, based on data obtained from 231 participants with active remote working experience. Satisfaction levels were evaluated using descriptive statistics and comparative analyses (One-Way Analysis of Variance-ANOVA). The findings indicate that home office satisfaction does not exhibit a homogeneous structure; rather, it demonstrates significant differences particularly in the dimensions of ergonomic adequacy, spatial organization, technical equipment sufficiency, and perceived work flexibility. Gender-based differences were primarily observed in perceptions of ergonomic and technical adequacy, whereas the age variable exerted a broader and more comprehensive effect, emerging as a determining factor especially in the dimensions of concentration, work management, and equipment adequacy. These results suggest that age may be a more distinctive factor than gender in shaping home office satisfaction. Overall, the study emphasizes that home office design should be evaluated not only in terms of physical comfort and functionality but also within the context of users' demographic characteristics. The findings provide important implications for interior design strategies, ergonomic support policies, and sustainable remote working practices.

Keywords: age, ergonomics, gender, home office, physical environment, user satisfaction

1. Introduction

The acceleration of digitalization, the widespread diffusion of communication technologies, and structural transformations in the labor market have led to profound changes in working patterns. This transformation became particularly evident on a global scale with the COVID-19 pandemic, during which remote working evolved into a permanent component of hybrid and flexible work arrangements across many sectors. Reports by the OECD (2021) and the International Labour Office (ILO, 2020) indicate that the pandemic transformed remote working from a temporary crisis response into a sustainable work practice. Ahrendt et al. (2022) report that working-from-home rates in European Union countries reached historically unprecedented levels, while Allen et al. (2015) note that although the concept of telework has long existed in the literature, contemporary digital infrastructures have significantly expanded its scope and effectiveness. Evaluated within the context of postmodern work culture by Baş and Kayan (2023), this transformation has redefined the functional boundaries of residential spaces by increasing the demand for spatial and temporal flexibility.

Within this context, spatial organization within the home has undergone substantial change, and the concept of the "home office" has evolved beyond being a temporary workspace into a multidimensional environmental system influencing user performance, psychological well-being, and work productivity. Home office environments require the holistic evaluation of numerous

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physical components, including ergonomic furniture, spatial layout, lighting quality, acoustic control, thermal comfort, storage solutions, and digital technical infrastructure. The environmental psychology literature demonstrates that physical environmental characteristics exert significant effects on user perception, behavioral performance, and stress levels (Vischer, 2007). Kim et al. (2016) reveal that workspace ownership and desk organization directly influence user satisfaction and perceived productivity, while Candido et al. (2019) emphasize the relationship between workplace design, user satisfaction, and levels of physical activity. These findings indicate that home office environments should be evaluated not merely as functional settings but as environmental systems that shape cognitive and behavioral performance.

Numerous studies in the interior design literature similarly demonstrate that spatial quality and ergonomic arrangements affect users' perceptual and behavioral performance. Yıldırım et al. (2005) identified the effects of residential interior elements on user satisfaction, while Yıldırım and Uzun (2010) examined the relationship between perceived spatial quality and functional performance. Yıldırım et al. (2007), Yıldırım et al. (2008), and Yıldırım et al. (2014) analyzed the perceptual and behavioral outcomes of interior design across different space types. Yıldırım and Akalın (2009) addressed the effects of spatial dimensioning problems on user evaluations, whereas Yıldırım et al. (2019; 2020) demonstrated the contributions of workspace partition heights and vegetative elements to user perception. Özkan and Yıldırım (2016) evaluated the effects of design methods on quality and performance. Studies conducted in educational environments (Müezzinoğlu et al., 2020; 2021) further revealed the effects of wall color and correlated color temperature on user perception, highlighting the relationship between environmental factors and cognitive performance. Taken together, this comprehensive body of literature demonstrates that physical environmental characteristics are strong determinants of user satisfaction. Collectively, these studies indicate that physical environmental decisions systematically influence user satisfaction, perceptual evaluations, and performance outcomes.

The advantages of remote working for individuals have also been widely discussed in the literature. Tuna and Türkmendağ (2020) and Akça and Küçükoğlu (2020) emphasize the positive effects of working from home on time management and motivation, while Wheatley (2012) examines the relationship between home-based telework, time use, and life satisfaction. However, Naktiyok and İşcan (2003) indicate that individual characteristics and job-related drivers influence attitudes toward working from home. Krautzel (2016) suggests that remote working may provide productivity and cost advantages for organizations, whereas Tutar (2007) cautions that virtualized work structures may increase employee loneliness. Graham et al. (2021), Oakman et al. (2020), and Xiao et al. (2021) investigate the physical and mental health impacts of working from home, demonstrating that ergonomic inadequacies may lead to health problems. Ipsen et al. (2021) systematically evaluate the advantages and disadvantages of working from home within the European context. Accordingly, the remote working experience should be considered not only as an organizational and psychosocial phenomenon but also as one directly associated with spatial and ergonomic conditions.

Research conducted within the framework of demographic variables reveals that the remote working experience does not represent a homogeneous structure. In terms of gender, studies indicate that women's working experiences during the pandemic may have differed due to increased domestic responsibilities (Del Boca et al., 2020; Shockley et al., 2021; Craig & Churchill, 2021). Chung and Van der Horst (2018) examine the effects of flexible working and telework on female employment. Conversely, some studies argue that spatial satisfaction is more strongly associated with physical environmental characteristics (Vischer, 2007; Kim et al., 2016). Age emerges as a determining factor in terms of technological competence, ergonomic requirements, and spatial adaptation capacity (Oakman et al., 2020; Ipsen et al., 2021; Ivasciuc et al., 2022). Candido et al. (2019) draw attention to generational differences in spatial expectations. These

findings demonstrate that home office satisfaction cannot be evaluated independently of demographic variables.

Within this literature framework, although numerous studies have examined remote working satisfaction, comprehensive quantitative and comparative research addressing the physical environmental characteristics of home offices in conjunction with demographic variables remains limited. A significant portion of existing studies focuses primarily on the psychosocial dimensions of remote work, whereas research jointly evaluating ergonomic furnishings, spatial organization, and technical infrastructure adequacy within the context of age and gender variables remains relatively scarce. Quantitative studies analyzing physical environmental characteristics alongside demographic variables through statistical comparisons are limited in the literature. This study aims to address this gap by examining user satisfaction with home office environments in relation to physical environmental factors and by identifying the effects of demographic differences on satisfaction levels. In this respect, the study seeks to contribute interdisciplinarity to the remote working literature by integrating the physical environment dimension with demographic differences. Accordingly, the following hypotheses were tested in this study:

H1: There are significant differences between female and male users' satisfaction evaluations regarding home office environments.

H2: There are significant differences among users from different age groups in their satisfaction evaluations regarding home office environments.

2. Method

In this study, a quantitative research design was adopted to determine the level of user satisfaction regarding the physical environmental characteristics of home office spaces and to examine whether this satisfaction differs according to gender and age variables. The research process consisted of three main stages: participant characteristics, data collection instrument, and statistical analysis.

2.1. Participant Characteristics

The study sample comprised a total of 231 home office users with active remote working experience. A purposive sampling method was employed, with prior experience of working from home established as the primary inclusion criterion. This approach ensured that the study was grounded directly in the evaluations of individuals with actual home office experience. Participation was voluntary, and respondents took part in the study of their own accord.

Of the participants, 54.5% were male (n = 126) and 45.5% were female (n = 105). In terms of age distribution, 34.2% of the participants were between 18-35 years old (n = 79), 40.7% were between 36-45 years old (n = 94), and 25.1% were between 46-55 years old (n = 58). The basic demographic characteristics of the participants are presented in Table 1. This distribution provided a balanced sample structure that allowed for comparative analyses across different age groups.

Table 1 Gender and Age Distribution of Home Office Users Participating in the Study

General Characteristics of Employees		n	%
Gender	Male	126	54,5
	Female	105	45,5
Age	18-35	79	34,2
	36-45	94	40,7
	46-55	58	25,1

2.2. Survey Design and Data Collection Process

A structured questionnaire consisting of two sections was used as the data collection instrument. The first section included questions related to participants' demographic characteristics, while the second section comprised 20 statements measuring user satisfaction with home office environments. The satisfaction items were developed based on the relevant literature

to encompass the dimensions of interior space evaluation, environmental comfort, ergonomic suitability, spatial organization, and technical infrastructure adequacy (Yıldırım, 1999; Yıldırım et al., 2005; 2007; 2008; 2014; 2019; 2020; Yıldırım & Akalın, 2009; Yıldırım & Uzun, 2010; Akalın et al., 2010; Özkan & Yıldırım, 2016; Müezzinoğlu et al., 2020; 2021). The scale aimed to evaluate physical environmental factors in a multidimensional manner.

Participants evaluated each statement using a five-point Likert-type scale (1 = Strongly agree, 5 = Strongly disagree). Lower scores indicated more positive evaluations, whereas higher scores reflected more negative evaluations. Negatively worded items were reviewed and appropriately coded prior to analysis.

The survey was administered online via Google Forms in February 2024. Participants were informed about the purpose of the study, and voluntary participation was ensured. Incomplete or inconsistent responses were excluded from the analysis. Valid data were transferred to the SPSS statistical software package for further analysis.

2.3. Statistical Analysis

The research data were analyzed using both descriptive and inferential statistical techniques. To determine participants' demographic characteristics and general trends regarding satisfaction items, frequency, percentage, arithmetic mean, and standard deviation values were calculated.

The internal consistency of the scale was assessed using Cronbach's alpha coefficient, with values of 0.70 and above interpreted as indicating acceptable reliability. Item–total correlations were also examined to verify scale consistency.

To determine whether satisfaction items differed according to gender (female/male) and age groups (18-35, 36-45, 46-55), one-way analysis of variance (ANOVA) was conducted. Prior to analysis, the assumption of homogeneity of variances was tested using Levene's test. The level of statistical significance was set at $p < 0.05$, while findings at the $p < 0.10$ level were interpreted as indicating marginal significance. The results of these analyses formed the basis for testing the research hypotheses.

3. Findings

This section presents the findings obtained from the satisfaction evaluations of home office users. First, the reliability results of the measurement scale are reported, followed by the comparative analyses conducted according to gender and age variables.

3.1. Reliability Analysis Results

In order to determine the internal consistency of the 20-item scale used to measure home office satisfaction, Cronbach's alpha reliability analysis was conducted. The overall reliability coefficient of the scale was calculated as $\alpha = 0.78$. This value exceeds the commonly accepted threshold of 0.70 in the literature (Cronbach, 1951), indicating that the scale demonstrates acceptable internal consistency.

Item-level analysis revealed that the corrected item–total correlations were at satisfactory levels and that removing any individual item would not result in a meaningful increase in the overall reliability coefficient. Therefore, all items were retained for the subsequent analyses. The reliability values of the items and the overall scale are presented in detail in Table 2.

Table 2 Cronbach's Alpha Reliability Levels of Satisfaction Evaluation Items

Dependent Variables		Item Reliability	Scale Reliability
H1	I consider my home office to be an adequate overall working environment.	0,764	0,78
H2	During work, household tasks and/or other concentration difficulties negatively affect me.	0,792	

H3	I experience difficulties in communicating with my colleagues and supervisors.	0,793
H4	I have difficulty coping with work-related technical problems.	0,788
H5	I experience difficulties in teamwork and collaboration related to my job.	0,756
H6	Working from home has a positive effect on my physical and mental health.	0,758
H7	I am able to allocate more time to family members.	0,760
H8	My work productivity and performance are at a higher level.	0,759
H9	I am able to take regular breaks at certain intervals.	0,787
H10	I experience difficulty in maintaining work–life balance.	0,761
H11	I can comfortably participate in video conferences and similar meetings.	0,798
H12	The interior layout of my home office makes it difficult for me to concentrate on work.	0,769
H13	My employer does not provide sufficient support during the work-from-home process.	0,795
H14	I can manage work projects and tasks more effectively from my home office.	0,794
H15	I prefer working from home rather than working at the workplace.	0,758
H16	The flexibility of my working hours in my home office boosts my morale.	0,753
H17	I find the equipment/furniture I use in my home office ergonomically adequate.	0,755
H18	I find the equipment/furniture I use in my home office adequate in terms of storage.	0,755
H19	I find the number of equipment/furniture I use in my home office sufficient.	0,752
H20	I find the number of devices such as computer, printer, scanner, photocopier, etc., in my home office sufficient.	0,763

In this study, participants' satisfaction levels regarding their home office environments were measured through a questionnaire. The findings obtained from the survey are examined separately below according to the gender and age characteristics of home office users.

3.2. Gender-Based Findings

The survey data obtained regarding home office satisfaction evaluations according to participants' gender were analyzed using statistical methods. The mean and standard deviation values, along with the ANOVA test results, are presented in Table 3.

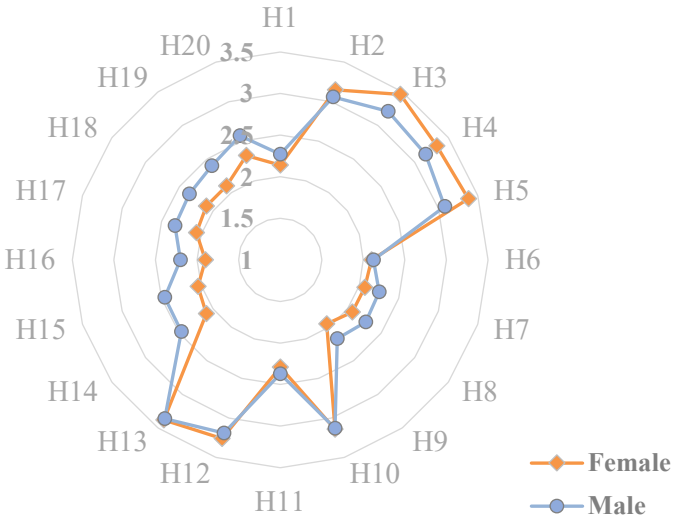
Table 3 Satisfaction Evaluation Results According to Gender of Home Office Users

Dependent Variables	Gender						ANOVA Results		
	Female		Male		Total				
	M[a]	SD	M	SD	M	SD	F	df	Sig.
H1	2,14	1,01	2,27	1,02	2,21	1,01	0,897	1	0,344 is
H2	3,15	1,12	3,06	1,10	3,10	1,10	0,439	1	0,508 is
H3	3,46	1,19	3,21	1,25	3,32	1,22	2,267	1	0,134 is
H4	3,33	1,13	3,16	1,27	3,24	1,21	1,189	1	0,277 is
H5	3,38	1,19	3,08	1,24	3,22	1,23	3,509	1	**0,062****
H6	2,10	1,04	2,12	1,04	2,11	1,04	0,011	1	0,917 is
H7	2,07	1,03	2,25	1,07	2,17	1,05	1,823	1	0,178 is
H8	2,07	0,92	2,27	1,08	2,18	1,01	2,320	1	0,129 is
H9	1,95	0,86	2,17	1,11	2,07	1,01	2,615	1	**0,105****
H10	3,14	1,16	3,13	1,15	3,14	1,15	0,003	1	0,959 is
H11	2,29	0,94	2,37	1,18	2,33	1,08	0,375	1	0,541 is
H12	3,26	1,15	3,19	1,15	3,22	1,15	0,192	1	0,662 is
H13	3,38	1,25	3,36	1,21	3,37	1,23	0,022	1	0,884 is
H14	2,10	0,90	2,47	1,06	2,30	1,00	7,763	1	**0,006***
H15	2,04	0,91	2,46	1,18	2,27	1,08	9,022	1	**0,003***
H16	1,90	0,81	2,20	1,15	2,06	1,02	5,199	1	**0,024***
H17	2,06	0,91	2,33	1,09	2,21	1,02	4,282	1	**0,040***
H18	2,10	0,98	2,35	1,06	2,24	1,03	3,259	1	**0,072****
H19	2,10	1,01	2,40	1,10	2,27	1,07	4,607	1	**0,033***
H20	2,32	1,08	2,57	1,14	2,46	1,12	2,833	1	**0,094****

*Note: **p < 0,10 ve *p< 0,05 indicate statistical significance. ns: not significant at the p < 0.05 level.*
M: Mean value; SD: Standard deviation; F: F value; df: Degrees of freedom.
a: Variable means range from 1 to 5 (1 = Strongly agree, 5 = Strongly disagree).

The findings presented in Table 3 indicate that the satisfaction evaluations of female and male users regarding home office environments differ statistically significantly not across all items, but

across certain satisfaction dimensions. According to the results of the ANOVA test, statistically significant differences were identified between female and male users for nine items at the $p < 0.05$ and $p < 0.10$ levels. The graphical representation of these findings is provided in Figure 1.



The variable means range from 1 to 5 (1 = Strongly agree, 5 = Strongly disagree).

Figure 1 The effect of gender on home office users' satisfaction evaluations

In the graph presented in Figure 1, it is observed that female and male users generally selected the response "disagree" for the following items in their satisfaction evaluations of home office environments: H2 (Household tasks and/or other concentration difficulties negatively affect me during work), H3 (I experience difficulty communicating with my colleagues and supervisors), H4 (I have difficulty coping with work-related technical problems), H5 (I experience difficulty in teamwork and collaboration), H10 (I experience difficulty maintaining work–life balance), H12 (The interior layout of my home office makes it difficult for me to concentrate on work), and H13 (My employer does not provide sufficient support during the work-from-home process). Therefore, it can be stated that users demonstrate a more positive attitude toward these seven aspects of working from home. When these findings are examined by gender, it is observed that female users exhibit a more positive attitude than male users for items H3, H4, and H5; however, a statistically significant difference is identified only for H5 (see Table 3). For the remaining significant items, male users, compared to female users, demonstrate a more positive attitude toward H14 (I can manage work projects and tasks more effectively from my home office), H15 (I prefer working from home rather than at the workplace), H16 (The flexibility of my working hours in my home office boosts my morale), H17 (I find the furniture/equipment I use in my home office ergonomically adequate), H18 (I find the furniture/equipment I use in my home office adequate in terms of storage), H19 (I find the number of furniture/equipment items in my home office sufficient), and H20 (I find the number of devices such as computer, printer, scanner, photocopier, etc., in my home office sufficient), and statistically significant differences are observed for these seven items (see Table 3). In addition, the evaluations of both genders appear to be very close to each other for items H2, H6, H10, H11, H12, and H13. These findings indicate that the hypothesis proposed in H1 - "There are differences between female and male users' satisfaction evaluations regarding home office environments." - is supported not at the level of all items, but rather in specific satisfaction dimensions.

3.3. Age-Based Findings

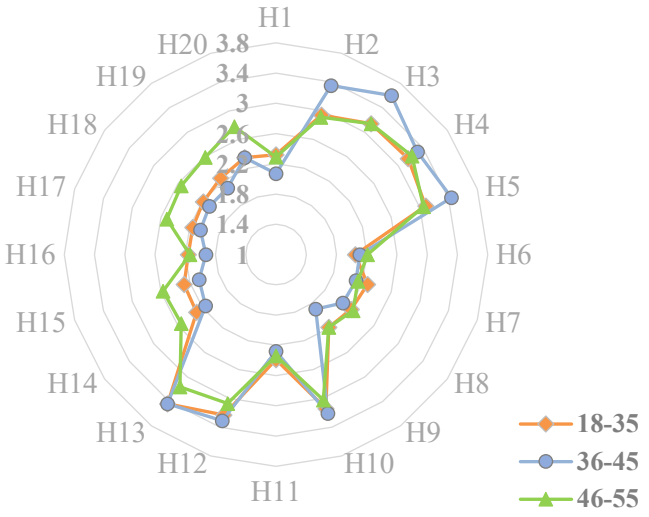
The survey data obtained regarding home office satisfaction evaluations according to participants' age were analyzed using statistical methods, and the mean and standard deviation values together with the ANOVA test results are presented in Table 4.

Table 4 Satisfaction Evaluation Results According to Age of Home Office Users

Dependent Variables	Age								ANOVA Results		
	18-35		36-45		46-55		Total				
	M[a]	SD	M	SD	M	SD			F	df	Sig.
H1	2,32	1,07	2,07	0,91	2,29	1,09	2,21	1,01	1,475	2	0,231 [is]
H2	2,94	1,14	3,35	0,99	2,91	1,17	3,10	1,10	4,230	2	**0,016***
H3	3,14	1,26	3,60	1,02	3,14	1,41	3,32	1,22	3,987	2	**0,020***
H4	3,16	1,20	3,31	1,08	3,22	1,43	3,24	1,21	0,306	2	0,737 [is]
H5	3,08	1,24	3,44	1,06	3,05	1,41	3,22	1,23	2,591	2	**0,077****
H6	2,05	0,92	2,11	0,97	2,21	1,28	2,11	1,04	0,381	2	0,684 [is]
H7	2,27	1,09	2,11	0,86	2,14	1,26	2,17	1,05	0,524	2	0,593 [is]
H8	2,23	1,02	2,09	0,89	2,26	1,18	2,18	1,01	0,673	2	0,511 [is]
H9	2,19	1,12	1,89	0,73	2,19	1,19	2,07	1,01	2,445	2	**0,089****
H10	3,14	1,24	3,21	1,01	3,02	1,25	3,14	1,15	0,514	2	0,599 [is]
H11	2,39	1,19	2,28	0,82	2,34	1,28	2,33	1,08	0,250	2	0,779 [is]
H12	3,23	1,18	3,31	1,03	3,07	1,30	3,22	1,15	0,780	2	0,460 [is]
H13	3,44	1,25	3,44	1,09	3,16	1,39	3,37	1,23	1,169	2	0,313 [is]
H14	2,30	1,10	2,15	0,83	2,55	1,08	2,30	1,00	2,949	2	**0,054***
H15	2,28	1,13	2,07	0,92	2,57	1,20	2,27	1,08	3,843	2	**0,023***
H16	2,16	1,14	1,93	0,79	2,14	1,15	2,06	1,02	1,419	2	0,244 [is]
H17	2,16	1,02	2,05	0,86	2,52	1,19	2,21	1,02	3,938	2	**0,021***
H18	2,19	1,01	2,09	0,89	2,55	1,20	2,24	1,03	3,910	2	**0,021***
H19	2,25	1,10	2,09	0,90	2,59	1,20	2,27	1,07	4,082	2	**0,018***
H20	2,35	1,06	2,35	1,05	2,78	1,24	2,46	1,12	3,173	2	**0,044***

*Note: **p < 0,10 ve *p< 0,05 indicate statistical significance. ns: not significant at the p < 0.05 level.*
M: Mean value; SD: Standard deviation; F: F value; df: Degrees of freedom.
a: Variable means range from 1 to 5 (1 = Strongly agree, 5 = Strongly disagree).

The findings presented in Table 4 indicate that the satisfaction evaluations of users in the 18–35, 36–45, and 46–55 age groups differ statistically significantly not across all items, but across certain dimensions. According to the ANOVA results, statistically significant differences were identified for ten items at the $p < 0.05$ and $p < 0.10$ levels among users aged 18–35, 36–45, and 46–55 regarding their satisfaction evaluations of home office environments. The graphical representation of these findings is provided in Figure 2.



The variable means range from 1 to 5 (1 = Strongly agree, 5 = Strongly disagree).

Figure 2 The effect of age on home office users' satisfaction evaluations

In the graph presented in Figure 2, it is observed that users in the 18-35, 36-45, and 46-55 age groups generally selected the response "disagree" for the following items in their satisfaction

evaluations of home office environments: H2 (Household tasks and/or other concentration difficulties negatively affect me during work), H3 (I experience difficulty communicating with my colleagues and supervisors), H4 (I have difficulty coping with work-related technical problems), H5 (I experience difficulty in teamwork and collaboration), H10 (I experience difficulty maintaining work-life balance), H12 (The interior layout of my home office makes it difficult for me to concentrate on work), and H13 (My employer does not provide sufficient support during the work-from-home process). Therefore, it can be stated that users demonstrate a more positive attitude toward these seven aspects of working from home. When these findings are examined by age, it is observed that users in the 36-45 age group exhibit a more positive attitude than those in the 18-35 and 46-55 age groups for items H2, H3, H4, and H5; however, no statistically significant difference is found for H4 (see Table 4). For the remaining seven items, users in the 46-55 age group demonstrate a more positive attitude than those in the 36-45 age group for H9 (I am able to take regular breaks at certain intervals), H14 (I can manage work projects and tasks more effectively from my home office), H15 (I prefer working from home rather than at the workplace), H17 (I find the furniture/equipment I use in my home office ergonomically adequate), H18 (I find the furniture/equipment I use in my home office adequate in terms of storage), H19 (I find the number of furniture/equipment items in my home office sufficient), and H20 (I find the number of devices such as computer, printer, scanner, photocopier, etc., in my home office sufficient), and statistically significant differences are identified for these seven items (see Table 4). These findings indicate that the hypothesis proposed in H2 - “There are differences among users from different age groups in their satisfaction evaluations regarding home office environments.” - is supported not at the level of all items, but rather in specific satisfaction dimensions.

4. Conclusion and Recommendations

In this study, the effects of the physical environmental characteristics of home office spaces on user satisfaction were examined, and the ways in which gender and age variables create differences in these satisfaction levels were revealed through quantitative data. The findings indicate that the remote working arrangement is evaluated as a functional and acceptable working model by a significant proportion of participants. Indeed, 70.1% of the participants stated that they consider their home office suitable as a general working environment. This result suggests that remote working has evolved beyond being merely a compulsory pandemic practice and has become, to a certain extent, an adopted working model. This finding supports the studies of Wheatley (2012), Tuna and Türkmendağ (2020), and Akça and Küçükoğlu (2020), which emphasize that working from home can generate positive outcomes in terms of time management, flexibility, and job satisfaction.

However, it is also evident that the home office experience does not present a seamless structure across all dimensions. Of the participants, 26.4% reported experiencing concentration difficulties, 22.6% indicated challenges in communicating with colleagues and supervisors, and 24.2% reported encountering technical problems. These findings are consistent with the evaluations of Tutar (2007), ILO (2020), Graham et al. (2021), Oakman et al. (2020), and Xiao et al. (2021), which highlight that remote working may generate disadvantages such as social isolation, communication breakdowns, and technical infrastructure inadequacies.

Analyses concerning the gender variable demonstrate that satisfaction evaluations differ not across all items, but within specific dimensions. Significant differences were identified in H5 (I experience difficulty in teamwork and collaboration), H9 (I am able to take regular breaks at certain intervals), H14 (I can manage work projects and tasks more effectively from my home office), H15 (I prefer working from home rather than at the workplace), H16 (The flexibility of my working hours boosts my morale), H17 (I find the furniture/equipment in my home office ergonomically adequate), H18 (I find the furniture/equipment in my home office adequate in terms of storage), H19 (I find the number of furniture/equipment items sufficient), and H20 (I find the number of

technical devices sufficient). These findings indicate that gender may lead to differences particularly in work preference, perceptions of flexibility, ergonomic adequacy, and technical equipment sufficiency. Nevertheless, no significant gender differences were found in certain fundamental dimensions such as concentration, communication, technical problems, and work–life balance. This finding aligns with the approaches of Vischer (2007) and Kim et al. (2016), which emphasize the primary determining role of physical environmental characteristics on satisfaction. Additionally, the findings of Del Boca et al. (2020), Shockley et al. (2021), and Craig and Churchill (2021), who draw attention to increased domestic responsibilities of women during the pandemic, suggest that satisfaction perceptions cannot be evaluated entirely independently of social roles.

The age variable, on the other hand, revealed more pronounced differences in home office satisfaction. Significant differences were observed in H2 (Household tasks and/or other concentration difficulties negatively affect me during work), H3 (I experience difficulty communicating with colleagues and supervisors), H5 (I experience difficulty in teamwork and collaboration), H9 (I am able to take regular breaks at certain intervals), H14 (I can manage work projects and tasks more effectively from my home office), H15 (I prefer working from home rather than at the workplace), H17 (I find the furniture/equipment ergonomically adequate), H18 (I find the furniture/equipment adequate in terms of storage), H19 (I find the number of furniture/equipment items sufficient), and H20 (I find the number of technical devices sufficient). This result demonstrates that spatial expectations, ergonomic requirements, and perceptions of technical infrastructure may differ across generations. These findings are consistent with the evaluations of Oakman et al. (2020), Ipsen et al. (2021), and Ivasciuc et al. (2022), and support the findings of Candido et al. (2019) regarding intergenerational differences in spatial expectations.

Overall, home office satisfaction does not exhibit a homogeneous structure; rather, it is shaped by the interaction between physical environmental quality, ergonomic equipment adequacy, technical infrastructure capacity, and users' demographic characteristics. The findings particularly reveal that the adequacy of ergonomic furnishings, the quantity of equipment, and the capacity of technical devices play a determining role in satisfaction levels. This result supports the studies of Yıldırım et al. (2005), Yıldırım and Uzun (2010), and Müezzinoğlu et al. (2020; 2021), which demonstrate the influence of interior design on user perception and performance.

In light of the findings, it is recommended that home office spaces be designed in a manner that is responsive to users' ergonomic, technical, and spatial needs; that age-related differences be taken into consideration; that employees be provided with ergonomic furniture and technical equipment support; and that communication and organizational support mechanisms in remote working processes be strengthened. Such an approach will enhance the sustainability of the remote working model and contribute to establishing a more balanced structure of user satisfaction.

CRediT Authorship Contribution Statement

Kemal Yıldırım: Writing – review & editing, Writing – original draft, Methodology, Investigation, Analysis, Data curation, Conceptualization, Data visualization. Kübra Müezzinoğlu Başpınar: Writing – review & editing, Writing – original draft, Investigation. Pınar Arı: Writing – review & editing, Writing – original draft, Investigation.

Declaration of Competing 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 paper.

Data Availability

Data will be made available on request.

Ethics Committee Approval

Ethical approval for this study was obtained from the Social and Human Sciences Research Ethics Committee of Fırat University at its meeting held on 04 March 2026, with decision number 2026/5.

References

Ahrendt, D., Mascherini, M., Sándor, E., Ganko, I., Jansova, E., Kärkkäinen, O., & di Vozzo, D. (2022). *Living, working and COVID-19 in the European Union and 10 EU neighbouring countries*. Eurofound.

Akalın, A., Yıldırım, K., Wilson, C., & Saylan, A. (2010). Users' evaluations of house façades: Preference, complexity and impressiveness. *Open House International*, *35*(1), 57-65.

Akça, M., & Küçükoğlu, M. T. (2020). Covid-19 ve iş yaşamına etkileri: Evden çalışma. *Journal of International Management Educational and Economics Perspectives*, *8*(1), 71-81.

Allen, T. D., Golden, T. D., & Shockley, K. M. (2015). How effective is telecommuting? Assessing the status of our scientific findings. *Psychological Science in the Public Interest*, *16*(2), 40_68. https://doi.org/10.1177/1529100615593273

Baş, K., & Kayan, H. Z. (2023). Yenilikçi ofis yaklaşımı: Aktivite temelli ofis (ATO). *bab Journal of FSMVU Faculty of Architecture and Design*, *4*(2), 208-223.

Candido, C., Thomas, L., Haddad, S., Zhang, F., Mackey, M., & Ye, W. (2019). Designing activity-based workspaces: Satisfaction, productivity and physical activity. *Building Research & Information*, *47*(3), 275-289. https://doi.org/10.1080/09613218.2018.1476372

Chung, H., & Van der Horst, M. (2018). Women's employment patterns after childbirth and the perceived access to and use of flexitime and teleworking. *Human Relations*, *71*(1), 47_72. https://doi.org/10.1177/0018726717713828

Craig, L., & Churchill, B. (2021). Dual-earner parent couples' work and care during COVID-19. *Gender, Work & Organization*, *28*(S1), 66-79. https://doi.org/10.1111/gwao.12497

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, *16*(3), 297-334. https://doi.org/10.1007/BF02310555

Del Boca, D., Oggero, N., Profeta, P., & Rossi, M. (2020). Women's and men's work, housework and childcare before and during COVID_19. *Review of Economics of the Household*, *18*(4), 1001_1017. https://doi.org/10.1007/s11150-020-09502-1

Graham, M., Weale, V., Lambert, K. A., Kinsman, N., Stuckey, R., & Oakman, J. (2021). Working at home: The impacts of COVID-19 on health, family-work-life conflict, gender, and parental responsibilities. *Journal of Occupational and Environmental Medicine*, *63*(11), 938_943. https://doi.org/10.1097/JOM.0000000000002337

International Labour Office. (2020). *Teleworking during the COVID-19 pandemic and beyond: A practical guide*. International Labour Organization.

Ipsen, C., Van Veldhoven, M., Kirchner, K., & Hansen, J. P. (2021). Six key advantages and disadvantages of working from home in Europe during COVID-19. *International Journal of Environmental Research and Public Health*, *18*(4), 1826. https://doi.org/10.3390/ijerph18041826

Ivasciuc, I. S., Epuran, G., Vuță, D. R., & Tescașiu, B. (2022). Telework implications on work-life balance, productivity, and health of different generations of Romanian employees. *Sustainability*, *14*(23), 16108. https://doi.org/10.3390/su142316108

Kim, J., Candido, C., Thomas, L., & de Dear, R. (2016). Desk ownership in the workplace: The effect of non-territorial working on employee workplace satisfaction, perceived productivity and health. *Building and Environment*, *103*, 203-214. https://doi.org/10.1016/j.buildenv.2016.04.015

Krautzel, J. (2016). *The ups and downs of telecommuting for businesses and workers*. Nexxt. https://www.nexxt.com/articles

Müezzinoğlu, M. K., Hidayetoğlu, M. L., & Yıldırım, K. (2020). The effects of the wall colors used in educational spaces on the perceptual evaluations of students. *Megaron*, *15*(1), 1-11.

Müezzinoğlu, M. K., Hidayetoğlu, M. L., & Yıldırım, K. (2021). The effects of light color temperatures on students' perceptual evaluations in design studios. *Color Research & Application*, *46*(5), 1006-1018. https://doi.org/10.1002/col.22630

Naktiyok, A., & İşcan, Ö. F. (2003). İşgörenlerin evden çalışmaya ilişkin tutumları: Bireysel özellikler ve iş sürükleyicileri açısından bir uygulama. *Akdeniz İİBF Dergisi*, *6*, 53-72.

Oakman, J., Kinsman, N., Stuckey, R., Graham, M., & Weale, V. (2020). A rapid review of mental and physical health effects of working at home: How do we optimise health? *BMC Public Health*, *20*, 1825. https://doi.org/10.1186/s12889-020-09875-z

OECD. (2021). Teleworking in the COVID-19 pandemic: Trends and prospects. *OECD Publishing*. https://doi.org/10.1787/72a416b6-en

Özkan, A., & Yıldırım, K. (2016). Comparison of conventional and computer-aided drafting methods from the view of time and drafting quality. *Eurasian Journal of Educational Research*, *62*, 239-254.

Shockley, K. M., Clark, M. A., Dodd, H., & King, E. B. (2021). Work-family strategies during COVID-19: Examining gender dynamics among dual-earner couples with young children. *Journal of Applied Psychology*, *106*(1), 15-28. https://doi.org/10.1037/apl0000857

Tuna, A. A., & Türkmendağ, Z. (2020). Covid-19 pandemi döneminde uzaktan çalışma uygulamaları ve çalışma motivasyonunu etkileyen faktörler. *İşletme Araştırmaları Dergisi*, *12*(3), 3246-3260.

Tutar, H. (2007). Katı olan her "iş" sanallaşıyor veya işgörenin artan yalnızlığı üzerine: Kuramsal bir yaklaşım. *İş Güç Endüstri İlişkileri ve İnsan Kaynakları Dergisi*, *9*(2), 116-141.

Vischer, J. C. (2007). The effects of the physical environment on job performance: Towards a theoretical model of workspace stress. *Stress and Health*, *23*(3), 175-184. https://doi.org/10.1002/smi.1134

Wheatley, D. (2012). Good to be home? Time-use and satisfaction levels among home-based teleworkers. *New Technology, Work and Employment*, *27*(3), 225_238. https://doi.org/10.1111/j.1468_005X.2012.00289.x

Xiao, Y., Becerik-Gerber, B., Lucas, G., & Roll, S. C. (2021). Impacts of working from home during COVID-19 pandemic on physical and mental well-being of office workstation users. *Journal of Occupational and Environmental Medicine*, *63*(3), 181-190. https://doi.org/10.1097/JOM.0000000000002097

Yıldırım, K. (1999). Günümüz konut mutfağında donatı elemanları üzerine bir araştırma. *Politeknik Dergisi*, *2*(4), 7-14.

Yıldırım, K., & Akalın, A. (2009). Problems related to the dimensions of curved areas in the main living rooms of apartment housing. *Journal of Architectural and Planning Research*, *26*(1), 70-87.

Yıldırım, K., & Uzun, O. (2010). The effects of space quality of dormitory rooms on functional and perceptual performance of users. *Gazi University Journal of Science*, *23*(4), 519-530.

Yıldırım, K., Akalın, A., & Çağatay, K. (2008). Otel yatak odalarının iç mekân tasarımının kullanıcıların algı-davranışsal performansı üzerine etkisi. *Politeknik Dergisi*, *11*(2), 175-185.

Yıldırım, K., Akalın, A., Yıldırım Kaya, N. N., & Olmuş, F. (2020). The effects of indoor plants on customers' shopping decisions in a restaurant environment. *International Journal of Retail & Distribution Management*, *48*(12), 1301-1314. https://doi.org/10.1108/IJRDM-07-2019-0235

Yıldırım, K., Ayalp, N., Aktaş, G. G., & Hidayetoğlu, M. L. (2014). Consumer perceptions and functional evaluations of cash desk types in the clothing retail context. *International Journal of Retail & Distribution Management*, *42*(6), 542-552. https://doi.org/10.1108/IJRDM-01-2013-0015

Yıldırım, K., Başkaya, A., & Hidayetoğlu, M. L. (2005). Farklı sosyo-ekonomik düzeye sahip blok-konut kullanıcılarının sabit iç donatım elemanlarından memnuniyeti. *Politeknik Dergisi*, *8*(2), 189-196.

Yıldırım, K., Güneş, E., & Yılmaz, G. P. (2019). The effects of workstation partition heights on employees' perceptions in open_plan offices. *Journal of Corporate Real Estate*, *21*(2), 148_166. https://doi.org/10.1108/JCRE-12-2017-0047

Yıldırım, K., Hidayetoğlu, M. L., & Şen, A. (2007). Farklı mimari biçimlerdeki kafe/pastane mekânlarının kullanıcıların algı-davranışsal performansı üzerine etkisi. *Politeknik Dergisi*, 10, 295-301.

Resume

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Sustainability theory and practice in industrial design education: A comparative case study

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Abstract

Sustainability has become a significant part of design education, either as an integrated subject or as a central focus in courses with diverse structures and pedagogical approaches. The necessary approaches, tools, and methods have been developed over the past thirty years and continue to evolve. This study examines how design for sustainability can be taught in undergraduate design education. First, background information is established on the scope of design, design for resilience and sustainability, and design education. While the literature focuses primarily on integrating sustainability into design curricula or studios, theoretical courses on design for sustainability in undergraduate design education have not been sufficiently explored. Therefore, this study examines two consecutive semesters of an elective course on design for sustainability, which has both a theoretical and practical structure, through a comparative case study. Course documents and outcomes from two semesters, before and after the course's time plan and evaluation criteria were updated, were analyzed and compared. The comparison focused on the course process and the themes of the final projects, as well as the sustainability goals they aimed to contribute to. The findings reveal that shifting the focus of the course process and outcome criteria from the design ideation phase to the design development phase altered the course outcomes. Furthermore, examining the results obtained by students participating in an international student design competition on sustainable design, using the projects they developed during the course, indicates that competitions improve the quality of project outcomes and student motivation, while also providing validation of design success and sustainability impact. The study can provide information to researchers, instructors, and practitioners working on design for sustainability and design education.

Keywords: design for resilience, design for sustainability, product design, product-service system design

1. Introduction

The concepts of sustainable development and the circular economy have been integrated into design theories and practices, and the integration is continually evolving (Faludi et al., 2023). Design approaches, tools, and methods for sustainability began to be developed in the 1990s, and their dissemination has been supported by leading organizations such as the United Nations Environment Programme (Brezet & van Hemel, 1997; Crul et al., 2009). This is also relevant for the circular economy, a newer approach to sustainability (UNEP, 2025; EMF, 2016).

While most studies in the literature focus on integrating sustainability into design curricula and design studios at both undergraduate and graduate levels (Bakırlıoğlu & McMahon, 2021; Boks & Diehl, 2006; Calikusu et al., 2023; Lawton & Judd, 2025; Lockrey & Bissett Johnson, 2013; Yavuz Özgür & Çalışkan, 2025; Yilmaz & Kapkin, 2021; Tümtürk et al., 2025; Küçüksayraç & Arıburun Kırca, 2020), some studies focus on how theoretical courses on sustainability support design studios in graduate education (Dhaouadi & Leclercq, 2022) and on developing content and resources for such courses (Faludi et al., 2023). There is a need to share current, in-depth experiences with courses of different structures in undergraduate design education on design for sustainability.

This study examines how design-for-sustainability approaches can be taught in undergraduate industrial design education through a course that includes both theoretical and practical settings.

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The research method is a comparative case study, involving two consecutive semesters of a recently updated course on design for sustainability offered over seven semesters in eight years. The study aims to share experiences with researchers and instructors working in the fields of design and sustainability.

This paper is structured as follows: Section 2 provides background information on the scope of industrial design, design for resilience, sustainability, and circularity, and their integration into undergraduate education. Section 3 presents the research method, comparative case study, and background information on the cases. Section 4 presents the findings, focusing on the course process and the projects developed in the course, their themes, and sustainability goals. Section 5 provides a discussion, and Section 6 presents the conclusions.

2. Background

2.1. Industrial Design Scope

The definition of industrial design is dynamic and evolving, broadening its scope from products to services, experiences, and systems. The World Design Organization (WDO, 2015) has updated the definition to "a strategic problem-solving process that drives innovation, enhances business success, and leads to a better quality of life through innovative products, systems, services, and experiences." They list the United Nations Sustainable Development Goals (UN SDGs, 2015), to which designers are primarily expected to contribute, as follows: SDG 3 (Good health and well-being), SDG 6 (Clean water and sanitation), SDG 7 (Affordable and clean energy), SDG 9 (Industry, innovation and infrastructure), SDG 11 (Sustainable cities and communities), SDG 12 (Responsible consumption and production) and SDG 17 (Partnerships for the goals) (WDO, 2015).

Industrial design has been examined across three eras: industrial, service, and digital, which are sequential yet continue to coexist (Calabretta & Kleinsmann, 2017). These eras differ in human-centeredness, collaborative and prototyping practices, value creation mechanisms, and design impact. Moreover, human-centeredness has been defined as the fundamental way designers create value (Norman, 1988). This focus has recently been further developed to shift from people to ecosystems and is referred to as humanity-centered design, with its principles also updated (Norman, 2024).

Over time, the main theories and models related to the design process have remained valid (e.g., Roozenburg & Eekels, 1995). The updated models emphasize the cyclical nature of the design process, highlighting values and needs along with functions at the starting point (Van Boeijen et al., 2013). Design thinking (Design Council, 2003) has also become widespread and even found its place outside the design discipline; it is taught in some engineering and management departments (Sanders, 2017). The steps of design thinking are modeled as the Double Diamond, encompassing the steps: discover, define, develop, and deliver (Design Council, 2003). The Hasso Plattner Institute of Design at Stanfor (2010) proposes a five-step design thinking model consisting of empathize, define, ideate, prototype, and test steps. Here, design ideation refers to the designer generating ideas by combining an understanding of the problem space and the user for whom they are designing.

2.2. Design for Resilience, Sustainability, and Circularity

Design for resilience is defined as “creating a material culture that not only is lasting and has enduring usefulness but also – through its continued presence – can acquire other kinds of meaning” (Walker, 2023). The ten principles defining the qualities of design for resilience are: Beautiful, enduring, restrained, equitable, situated, enabling, trustworthy, farsighted, holistic, and transformational. While the concepts of resilience and sustainability are closely related, they are not the same. For resilience, adaptability, robustness, and endurance are essential, while originality and innovation are approached thoughtfully. In design for sustainability, sustainability is seen as a source of innovation (Thackara, 2005), and promising social and technological innovations should be sustained (Manzini, 2009).

Design for sustainability aims to balance environmental, social, and economic aspects in design processes and encompasses various approaches with different focuses (Crul et al., 2009). Ceschin and Gaziulusoy (2019) map design-for-sustainability approaches across different levels of innovation, describing each level and approach and how they have evolved over time and in relation to one another. They propose five levels of innovation: (1) The material / component, (2) Product, (3) Product-service system, (4) Spatio-social, and (5) socio-technical system. The authors also state that all approaches are important and useful, and that several design-for-sustainability approaches should be applied in an integrated manner to address sustainability.

According to Ceschin and Gaziulusoy's (2019) classification, the product innovation level includes approaches such as eco-design (e.g., Brezet & van Hemel, 1997), design for sustainable behavior (e.g., Lilley, 2009), cradle-to-cradle design (e.g., McDonough & Braungart, 2002), and design for the base of the pyramid (e.g., Kandachar & Halme, 2008). Circular product design (e.g., Den Hollander et al., 2017; EMF, 2016) is not included directly in the classification, but its relationship with design for sustainability is discussed separately. Compared with other approaches, circular design strategies place greater emphasis on user engagement and business models. Furthermore, they help create new contexts grounded in emerging social and technological paradigms, revitalizing sustainability and industrial ecology research for the next generation of researchers and designers (Bakker et al., 2021).

Methods for assessing product sustainability have been developed, starting with the eco-design approach. Based on life cycle assessment and management, eco-design offers the eco-design strategy wheel as a tool (Brezet & Van Hemel, 1997; Van Boeijen et al., 2013). It aims to evaluate products according to eight criteria: new concept development, selection of low-impact materials, reduction of material usage, optimization of production techniques, optimization of the distribution system, reduction of impact during use, optimization of initial lifetime, and optimization of the end-of-life system. The tool relies on data interpretation and is often used to compare the sustainability of old and new product versions in a radar chart when products are redesigned (Van Boeijen et al., 2013). While more advanced life cycle analysis tools and software are primarily used by environmental engineers, they are also taught in some design engineering programs specializing in design for sustainability, and their graduates apply them in the industry (Küçüksayraç et al., 2015).

Manufactured products and product concepts are primarily evaluated by third-party certification organizations and design competitions. Cradle to Cradle Products Innovation Institute, one of the organizations providing product certification, evaluates manufactured products according to five criteria: material health, product circularity requirements, clean air & climate protection requirements, water & soil stewardship requirements, and social fairness requirements (C2C, 2026). Sustainability is also a criterion in design competitions today, both for manufactured products and design concepts (e.g., iF Design, 2026). Green Product Award is one such example, focusing particularly on sustainability. Its criteria include seven titles that place the highest weight on sustainability (GP-Award, 2026).

The sustainable product-service system approach (and innovation level) is defined as “the result of an innovative strategy that shifts the center of business from the design and sale of (physical) products alone, to the offer of product and service systems that are together able to satisfy a particular demand” (Manzini & Vezzoli, 2002). When designing sustainable product-service systems, it is important to identify and illustrate the relationships between the various stakeholders that constitute the actors or support systems using flows. With the Stakeholder System Map tool, Vezzoli et al. (2014) define four types of flows: information, material, labor, and financial.

Product-service systems are categorized along a spectrum of product and service orientation: product-oriented, use-oriented, and results-oriented. Product-oriented services include product-related services, advice, and consultancy. Use-oriented services include product leasing, renting, sharing, and pooling. Result-oriented services include activity management, pay-per-service unit,

and functional result (Tukker, 2004). Software was later added to this categorization, spanning all types of product-service systems (VentureWell, 2022).

2.3. Design Education and Sustainability

The backbone of design education is the design studio course and the critique (Uluoğlu, 2020), which require distinctive pedagogical approaches (Süner-Pla-Cerdà et al., 2025) and are supported by other theoretical and elective courses (Demirbaş & Demirkan, 2003). Experiential learning (Kolb, 2015) and project-based learning (Larmer et al., 2015) are common learning theories applied in design studio courses. Furthermore, collaboration, teamwork, and group work are effective pedagogies in design studios (Anteet & Binabid, 2025).

To categorize the outcomes of design studios, the Structure of Observed Learning Outcomes (SOLO) taxonomy can be used (Biggs & Collis, 1982; Biggs & Tang, 2011). According to this taxonomy, intended learning outcomes are categorized under five headings in an increasing hierarchy, and a pool of verbs is created for each category. It starts with the prestructural (1) category for failed outcomes. The next categories (and three example verbs) are: (2) Unistructural (memorize, draw, write), (3) Multistructural (describe, discuss, illustrate), (4) Relational (integrate, differentiate, solve a problem), (5) Extended abstract (reflect, generate, create). Teaching and learning activities, intended learning outcomes, and assessment tasks should be constructively aligned. Undergraduate courses are usually graded using norm-based assessment, in which grades are determined by comparisons among students, as opposed to criterion-based assessment, in which criteria or standards are established before the assessment. Biggs and Tang (2011) also identify four types of motivation to enhance the value of the task for students: (1) extrinsic (what the outcome produces), (2) social (what other people value), (3) achievement (the opportunity for ego enhancement), and (4) intrinsic (the process of doing it).

In architecture, design, and planning, it is common to apply to competitions with projects developed during courses. While some competitions have special, free-to-apply categories for students (e.g., iF Design, 2026; GP-Award, 2025), some are specifically designed for graduation projects (e.g., Archiprix, 2021). Awards primarily contribute to reputation and are listed among the categories used to measure design value (Lockwood, 2007). The ten categories used to measure design value are: (1) Purchase influence / emotion, (2) Enable strategy / enter new markets, (3) Build brand image and corporate reputation, (4) Improve time to market and development processes, (5) Design return on investment / cost savings, (6) Enable product and service innovation, (7) Increase customer satisfaction / develop communities of customers, (8) Design patents and trademarks / create intellectual property, (9) Improve usability, (10) Improve sustainability.

A study on the changing design education in the 21st century (Meyer & Norman, 2020) lists eleven challenges, grouped under four main themes: Performance, systemic, contextual, and global. Sustainability is the only challenge listed under global challenges, and three of the contextual challenges relate to the complex systems of projects, products, and services that designers must address. These complex systems often transcend the boundaries of organizations, stakeholders, producers, and user groups, and must meet demands and expectations at every level of production, distribution, reception, and control.

A comprehensive study (Faludi et al., 2023) offers recommendations for integrating sustainability into the design education curriculum at three levels of student specialization: all design students, students expecting to practice design for sustainability, and students pursuing elective or advanced studies. The study lists sustainability topics under six headings: (1) Fundamentals of sustainability, (2) circular economy, (3) whole systems thinking, (4) sustainable innovation strategies, (5) impact assessment, and laws and standards, and (6) communication, collaboration, and leadership. According to the classification, product and product-service-systems-focused strategies are primarily grouped under the headings of circular economy and sustainable innovation strategies. While all students should be taught that sustainable innovation tools and

methods exist, specific strategies should be taught to the second type of students who will be practicing in sustainable design. Furthermore, the product-service system approach should be taught to all students, external stakeholder management to the second type of students, and systems mapping to the third type of students pursuing elective or advanced studies.

3. Research Method

The research method of this study is a comparative case study (Yin, 2018). The case is "Sustainable Product Design", an elective course on design for sustainability offered at the Department of Industrial Design at Istanbul Technical University, which awards a B.Sc. degree after four years of undergraduate education. The comparative case study examines two semesters of the course: Fall 2024/2025 and Fall 2025/2026 (hereafter abbreviated as 2024 and 2025, respectively). The primary reason for selecting these two semesters is that the course plan was updated in the latter semester; the content remained the same, but the time plan, number of assignments, and evaluation criteria were updated.

Furthermore, in 2025, four projects developed individually and as a team by students were selected as finalists in the international competition, the Green Product Concept Award (GP-Award, 2025), among 183 projects from around the world across 13 categories. The jury of the competition consists of 24 experts in sustainability and design, from leading companies, universities, research organizations, public institutions, and publishers.

The data analyzed in this study consisted of archival materials, course documents, and course outputs. In 2024, 54 projects were submitted by 27 students; in 2025, 34 projects were submitted individually or in teams by 26 students, resulting in a total of 87 projects analyzed. During the analysis, the focus was on the design process, how each project was developed, and the themes and UN SDGs the projects aim to contribute to.

3.1. Background Information on the Case Course

The course content was developed by the author, and the course was first offered in the 2017 / 2018 Spring Semester. The developed course curriculum was tested through a workshop with students (Küçüksayraç & Arıburun Kırca, 2020). The course aims to provide in-depth knowledge of design for sustainability and its approaches at the product and product-service-system innovation levels. The course is a fourth-year elective course with four ECTS credits. When the course was first offered, it consisted of two theoretical and two practical hours, and three local credits. In the 2021 / 2022 Fall Semester, a new second-year compulsory course on sustainability was added to the undergraduate program, which focuses on society and sustainability. The same year, all elective courses in the program were set at two local credits and three weekly hours. Therefore, the weekly hours of the case course were also reduced to three hours, consisting of one theoretical and two practical hours. Following these updates to the undergraduate program and the course, its content was also updated.

In recent years, the student quota has been set at 30, consistent with most program electives. This course is offered to industrial design students; however, Erasmus+ Programme students enrolled in other programs may also take it. The course has been offered to 186 students over seven semesters. Furthermore, the course instructor teaches a course on environmental sustainability in the master's program in the same department and has also been one of the instructors in a first-year interdisciplinary elective course on sustainability offered by the Department of Urban and Regional Planning to all five programs in the Faculty of Architecture at Istanbul Technical University.

The course description in the course catalog includes the following topics and approaches to design for sustainability: Sustainability concept, design for sustainability and its approaches, eco-design strategies, eco-friendly materials and production techniques, sustainable energy technologies, life cycle assessment (LCA), design for sustainable behavior and lifestyles, design for the base of the pyramid, cradle to cradle, and sustainable product-service system. Circular product

design was not included in the initial course description but was later added to the course content because it is a more recently developed approach (see Bakker et al., 2021; Charter, 2018).

The course outcomes consist of two projects: one at the product level and the other at the product-service system innovation level. Additionally, students must submit a sketchbook containing assignments completed during the practical hours of the course. Assignments are determined according to the course content and the topics covered in the theoretical hours and are structured as design-idea-generation exercises. They serve as assessment tasks and usually include the verbs design, analyze, illustrate, apply, as well as list, make a plan, research, answer, select, compare, redesign, review, and rewrite.

Since it started, the course content has been improved each year, while the core of the process described above has remained the same. Observations made during the course and improvements made to the course content over the years are summarized in Table 1. In addition to observations, students complete an anonymous satisfaction survey developed by the Rectorate each semester, which is then shared with the course instructors. This feedback has also been considered and contributed to improvements.

Table 1 Observations and Improvements for Improving the Course Content

Observation	Improvement
Students' questions	Elaboration of theoretical content and sharing best practice examples
Themes frequently chosen by students for their projects	Adding best practice examples related to these themes to the course content, aiming to improve final projects beyond existing solutions
Quality of students' assignments	Balancing course content and outcomes by increasing or decreasing the complexity and requirements
The use of AI tools by students	Aiming to develop AI-resistant assignments, if possible; otherwise, explaining how to use AI responsibly and efficiently

4. Findings

The course plan followed a similar theoretical and practical flow until 2025; preliminary and final juries were held on sustainable product design and sustainable product-service system projects. In 2025, the course schedule was revised to include a condensed theoretical section in the first five classes. Following the theoretical hours, assignments were briefly introduced to the students, and time was given for them to begin their work and ask questions. Following these first five weeks, a preliminary jury was held on sustainable product design. Then, three practical classes focusing on project development were conducted. Separating theoretical and practical hours of a course into different classes, rather than implementing them within the same class, was used in hybrid (online and in-person) education during the COVID-19 pandemic. The reason for the update was to limit the number of assignments, encourage students to develop their projects in depth, and allow for more detailed design critique. Assignments were revised to offer students options of design-for-sustainability approaches to choose from, or to combine closely related approaches, such as eco-design and LCA, or cradle-to-cradle and circular product design. This way, the number of assignments students had to complete was reduced, while the scope of the content remained the same.

In 2025, the course's final submission requirements were revised to require students to enter the sustainable product design project they developed during the course in a design competition. Students were required to submit proof of participation in a design competition in addition to the project. This was not compulsory, but it affected the grading. In previous years of the course, the Green Product Concept Award had been introduced to students in the theoretical part on certifications, laws, and standards, but their participation was not tracked.

There were no changes in the final requirements for the sustainable product-service system design. The sketchbook content was revised to include fewer assignments. The weekly course plan and content for 2024 and 2025 are shown in Figure 1. It should also be noted that in both semesters,

one class was suspended due to public holidays, resulting in 13 classes in the standard 14-week semester. Final projects were submitted on the exam date officially announced by the Registrar's Office (usually one or two weeks after the last class).

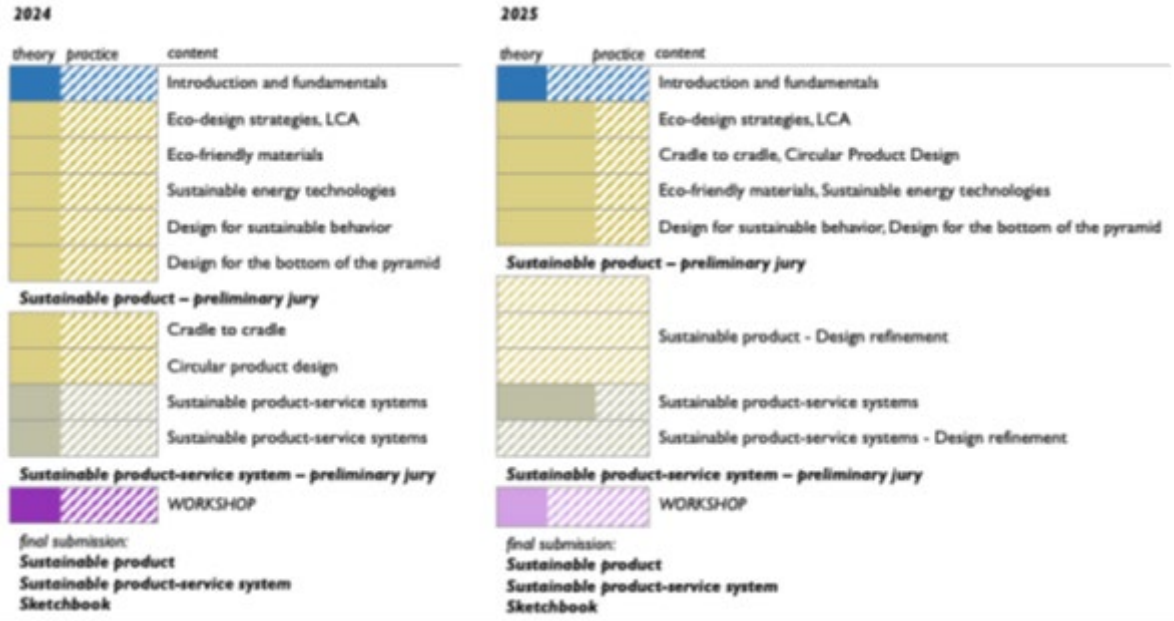

Figure 1 The course plan and contents in 2024 and 2025

In both 2024 and 2025, the last class was dedicated to two separate workshops on eco-friendly materials, conducted by graduate students and supervised by the instructor. Both workshops received ethical approval from the Istanbul Technical University Social and Human Sciences Scientific Research and Publication Ethics Board. Student participation was voluntary and confirmed by written consent from the participating students. The specific theme of the 2024 workshop was the use of generative artificial intelligence in material research and selection in design, while the theme of the 2025 workshop was material tinkering with living organisms in design (Karaca & Küçüksayraç, 2026). The workshops helped students expand their knowledge of materials, provided them with hands-on experience, and gave them insight into the content of graduate studies in industrial design.

In 2024, 28 students took the course, and 27 of them completed their submissions and passed. In 2025, 26 students took the course, and all of them completed their submissions and passed. Two Erasmus+ Program students from Germany took the course in 2024, while four students from Italy, the Netherlands, and Germany took the course in 2025. In 2024, all students were required to present individual projects. However, in 2025, teamwork was encouraged in project submissions. Sketchbooks were still required to be completed and submitted individually by the students. As a result, eight teams were formed, seven of which consisted of two students each. The only team of three students consisted of three Erasmus+ Programme students from Italy and the Netherlands. In total, 26 students submitted 17 sustainable product design projects, 17 sustainable product-service system projects, and 26 sketchbooks.

The task assessment type of the course is criterion-referenced, in which individual submissions are graded based on predetermined criteria. While norm-referenced assessment and bell curves are commonly used in undergraduate education and are mandatory for courses with more than 30 students at Istanbul Technical University, a criterion-referenced assessment was chosen to ensure that students who meet the criteria could receive a good grade. In 2024, one student failed the course for not completing assignments, while another student completed assignments at a satisfactory level. In 2025, all submissions were at least good, and the number of students demonstrating excellent performance increased from five to nine compared with the previous year.

Student feedback was not collected for research purposes; it was collected and reported solely through the survey conducted by the Rectorate. Since completing the online survey is not mandatory for students, no students completed it in 2024, and only one student completed it in 2025. For all Likert scale items, the student chose the most positive response category. In the only open-ended item regarding opinions and suggestions about the course, the student wrote: "…Our instructor effectively taught me different methods from a sustainable design perspective and, through hands-on activities, enabled me to reflect these principles in my own designs. Furthermore, the instructor truly encouraged me to participate in competitions, providing a significant contribution to my professional growth." The anonymous survey results are shared with faculty members through the online Student Information System.

4.1. The Projects Developed in the Course

When developing the sustainable product design project, students are expected to present two alternative design concepts, either selected from their assignment outcomes or by proposing a new concept based on the design-for-sustainability approaches at the product level. In both cases, they are expected to apply multiple design-for-sustainability approaches to increase the sustainability impact. During and after the preliminary jury, students select a sustainable product design concept to continue developing, taking into account the instructor's critiques and their peers' feedback. The second project on the sustainable product-service system was developed by students in response to the assignment given after the theoretical part. Students are also given the option to work on these two projects at separate levels in a compatible way; this means they can develop a product-service system starting from a product idea they developed during the course. Similarly, after the preliminary jury of the product-service system design project, students are given the option to develop a product that is necessary for or complements the product-service system they have presented and submit it as the final sustainable product design project. The aim is to equip students with the ability to build relations among various design-for-sustainability approaches across different levels of innovation, iterate by applying multiple approaches, and thus deeply examine user needs and sustainability goals to obtain a more impactful sustainable solution. The course process in 2024 and the flows of design ideas between the two projects are shown in Figure 2.

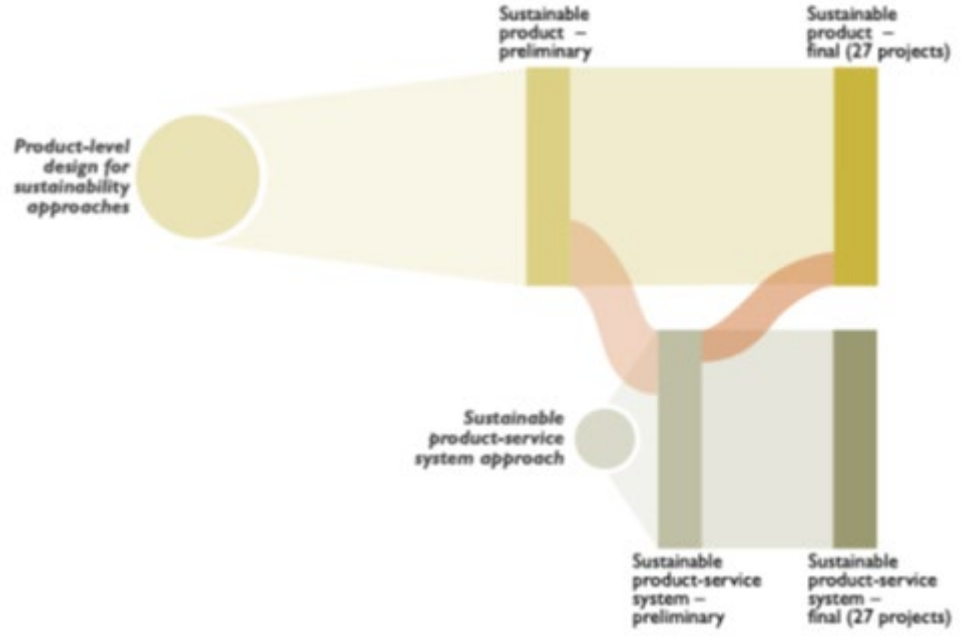

Figure 2 The course process in 2024 and the flow between the projects

In 2025, students went through a similar presentation and jury process to previous years; however, the timeline was changed, and the submission of a competition entry certificate was added to the grading, as previously mentioned. The course process in 2025 and the flow of design ideas between the two projects are shown in Figure 3.

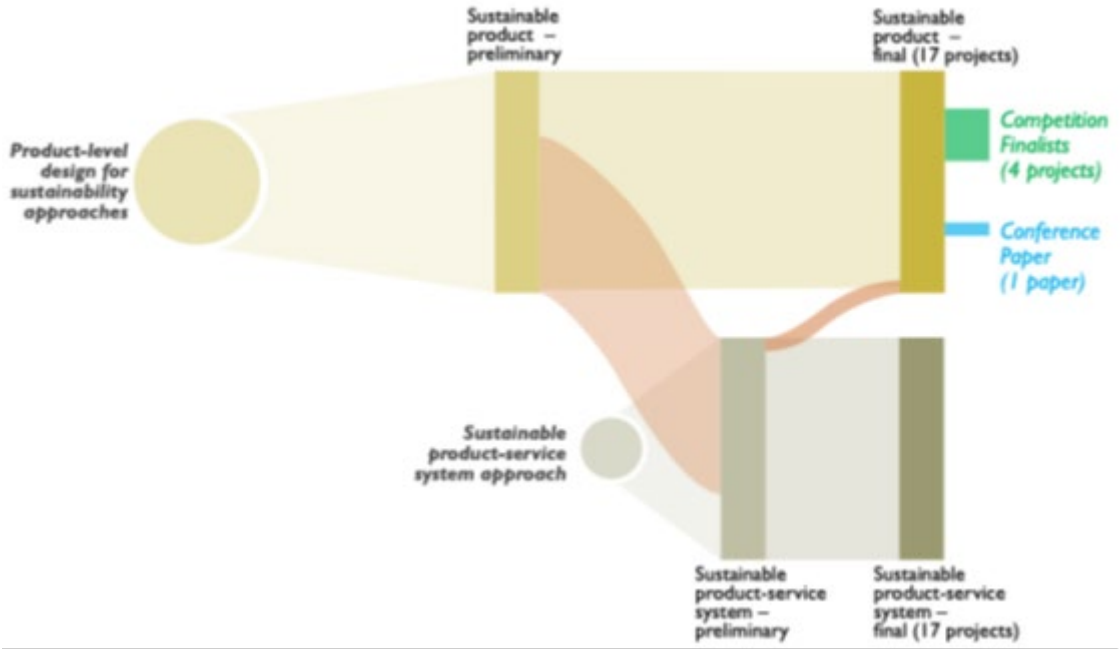

Figure 3 The course process in 2025 and the flow between the projects

As a result of the competitions in which students participated with projects they developed during the course, four projects were selected as finalists in the Green Product Concept Award. The product and product service system dimensions of the finalist products are shown in Table 2, and selected visuals of the finalist projects are shown in Figure 4. These projects belonged to two individual students and two teams, one of which consisted of three Erasmus+ Program students. However, the Green Product Concept Award was not the only competition students were encouraged to enter; the Istanbul Mining and Metals Exporters Association (IMMIB) (2025), Industrial Design Competition was also offered as an option. Unlike the Green Product Concept Award, this competition had four sub-categories under the specific theme of "Creative Solutions and Designs for Unforeseen Situations": (1) Disasters and emergencies, (2) Unforeseen, sudden crises in daily life, (3) Sudden situations arising from individual needs, and (4) Small, preventive and interventional solutions. The projects were evaluated in two main categories: Metal and plastic products. Also, the winners were announced at the end of the competition, but not the finalists.

Table 2 Product and system sustainability aspects of the finalist projects (based on GP-Award, 2025)

Project title (category) and short description	**Product aspect**	**Product-Service System aspect**	**The UN-SDG targets primarily contributed**
Coffee Pur (workspace) Coffee waste-to–carbon cartridge system	Design supports sustainable material cycles	Product-oriented: Cafés and hotels convert their own coffee waste into carbon cartridges to be used for water purification	SDG 12.4; environmentally sound management of chemicals and all wastes throughout their life cycle
Cook A Pack (packaging) The packaging that makes you want to play	Mono-material recycled solid cardboard and eco-friendly inks	Product-oriented: Packaging becomes a creative kit for children, extending the play experience beyond the product through a digital tutorial	SDG 12.5; substantially reduce waste generation through prevention, reduction, recycling and reuse
HUSK (consumer goods) Turkish coffee cup made by coffee ground	Bio-composite exterior manufactured from coffee waste and ceramic interior	Product-oriented: Local production through coffee-waste collection from users	SDG 12.4; environmentally sound management of chemicals and all wastes throughout their life cycle
Mico-Guard (kitchen) Circular fire Safety integrated with insurance	Steel body, magnetic mounting detail, and refillable cartridge	Result-oriented: Fire safety service integrated with home insurance, products owned by the service provider	SDG 7.1; universal access to affordable, reliable and modern energy services

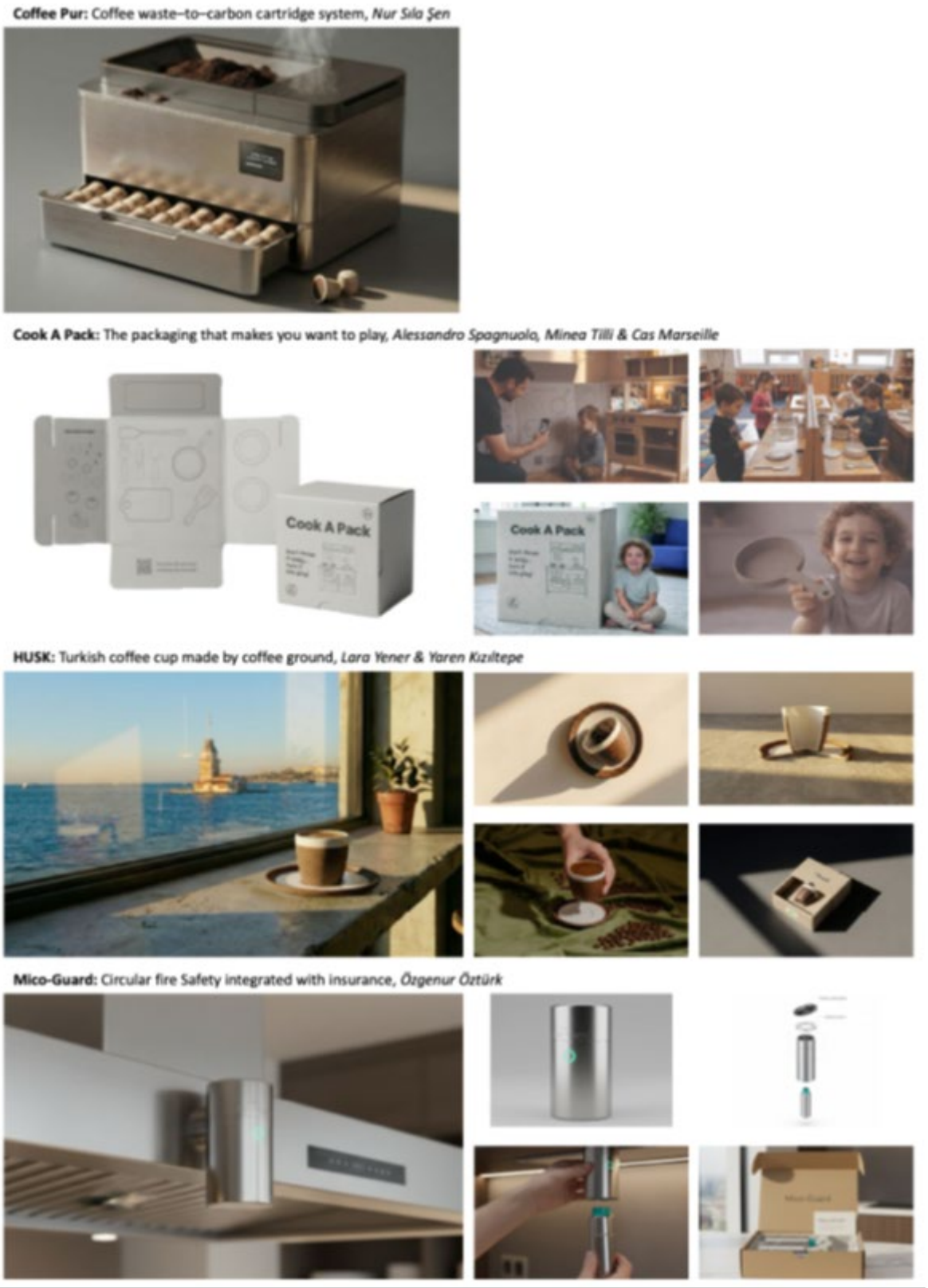

Figure 4 The projects that were developed in the course and were selected among finalist in the Green Product Concept Award (GP-Award, 2025)

According to the submitted competition entry documents, nine students participated in the Green Product Concept Award, six students and a team participated in IMMIB, and one team participated in a different competition. One student did not participate in any competition; this will be explained below. Given that the Green Product Concept Award is an international competition

and that nine projects were submitted, the number of finalists can be considered a success in terms of design, sustainability, and innovation.

Another difference from previous courses was that, in 2025, a student requested to focus on design research rather than product development for the first project and to submit a draft research paper. Since the student was already formally involved in a research project at another university, she aimed to enhance her research skills and experience. While presenting a paper at an academic conference is a requirement for completing graduate studies at Istanbul Technical University, writing a research paper is uncommon and not an evaluation criterion in the industrial design undergraduate program, especially in courses with a practical part. The instructor supported this request by informing all students in the course. Instead of a sustainable product design project, the student developed and presented a draft of a research paper. After the course was completed, she continued to develop the draft with the instructor's supervision. The paper was completed in the following semester, submitted to a national design research conference, and was accepted. The student also developed and presented a sustainable product-service system project with a product component, based on her research, like the other students. Therefore, the project was included among the sustainable product design projects shown in Figure 3 and was linked to the sustainable product-service system project.

The specific design-for-sustainability approach, which is the starting point for sustainable product design projects, is not included in Figure 2 and Figure 3 due to the submission process. Assignments were submitted as a compilation in a sketchbook, rather than as weekly submissions. Furthermore, students were able to work on the same product in multiple assignments. Therefore, it is not possible to fully define the design-for-sustainability approach that served as the starting point for each project.

4.2. The Project Themes and UN SDGs Targeted

The theme list for grouping student projects is based on the categories of the Green Product Concept Award (GP-Award, 2025). It is arranged alphabetically as follows: (1) Architecture, (2) Building design, (3) Consumer goods, (4) Fashion, (5) Startups, (6) Interior and lifestyle, (7) Children, (8) Kitchen, (9) Mobility, (10) New materials, (11) Packaging, (12) Personal care and (13) Workspace. As additional information, the sports category has been added to the competition in 2026. The ratios of themes covered in the projects in 2024 and 2025 are shown in Figure 5.

Figure 5 The project themes in 2024 and 2025, according to the Green Product Concept Award (GP-Award, 2025) categories

Although a single category was chosen for each project, some concepts could be evaluated under more than one category. For example, a wearable product that supports people's well-being was considered a consumer good, rather than a fashion product. If the business model of product-service systems predominantly encompassed businesses or public institutions, it was classified in the initiative category. Nevertheless, by comparing the number of themes in 2024 and 2025, it can be observed that the 2024 projects have greater category diversity. This can be explained by the

difference in the number of projects and the decrease in the number of assignments. In addition, in both 2024 and 2025, students did not work in the architecture and building design categories, which is expected, given that they are mostly industrial design students.

Figure 6 shows the UN SDG to which each project can contribute the most. Considering all projects, the SDGs to which the greatest contribution can be made are, in order: SDG 12, SDG 3, SDG 11, SDG 7, SDG 6, and SDG 15. While the number of sustainable product design and sustainable product-service system projects is the same for each goal for 2025, the goals are not the same for each student or team's projects, but the total numbers are the same. In terms of themes, a project can generally contribute to more than one SDG, but a single selection is made for each project. For example, projects aiming to change existing materials and production techniques with more sustainable ones are grouped under SDG 12, while products primarily aimed at improving health, well-being, and lifestyles are grouped under SDG 3. Projects that aim to contribute to sustainable cities and disaster resilience and to build communities through sustainable product-service systems and platforms are grouped under SDG 11. Furthermore, projects related to stray and wild animals are evaluated under SDG 15, while projects related to domestic animals are evaluated under SDG 3.

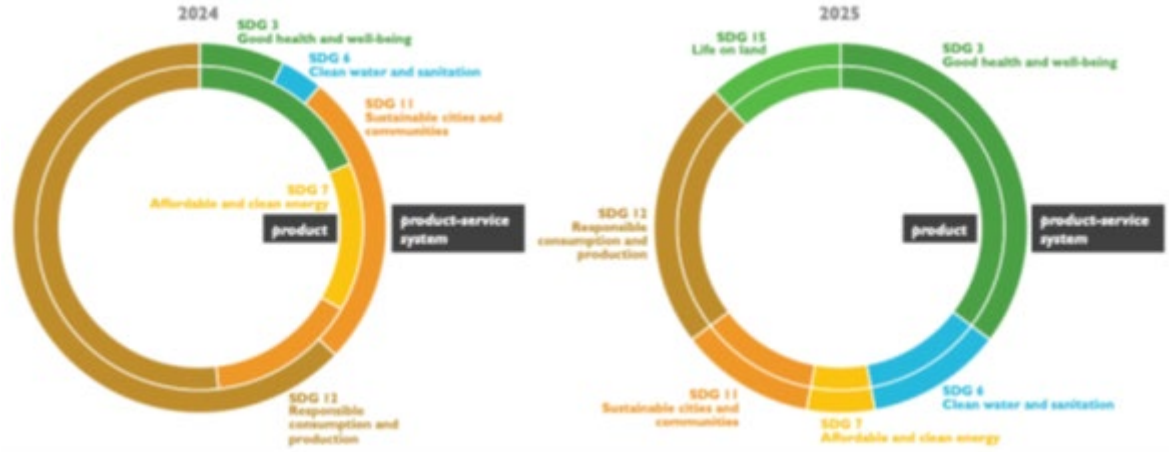

Figure 6 The UN SDG that each project aims to contribute to in 2024 and 2025

5. Discussion

The course examined in this study, an elective in undergraduate industrial design education with both theoretical and practical components, primarily aims to develop students' skills in applying design strategies for sustainability at the levels of product and product-service system innovation. While the course briefly addresses the fundamentals of sustainability, it primarily focuses on sustainable innovation strategies. In this respect, it is consistent with the topics suggested by Faludi et al. (2023) for elective or advanced studies. A workshop conducted to develop the course content showed that the biggest challenge students faced in applying design-for-sustainability strategies was deciding which strategy to focus on (Küçüksayraç & Arıburun Kırca, 2020). Furthermore, the literature emphasizes that, although their effects differ, all approaches are important for achieving sustainability and should be applied together (Crul et al., 2009; Ceschin & Gaziulusoy, 2019). Figure 2 and Figure 3 show that students were able to explore different design approaches for sustainability, even at different innovation levels, and apply more than one approach in a single project.

The assessment tasks and verbs used for the intended learning outcomes of the course are listed in Table 3 and classified according to the SOLO taxonomy levels (Biggs & Collins, 1982; Biggs & Tang, 2011) and the list of sustainability topics (Faludi et al., 2023). All sub-topics listed as necessary for sustainability-specific programs are covered in the course. The first class begins with an introduction to the course content and a summary of sustainability fundamentals, followed by an assignment on students' daily sustainability-related habits. This assignment and its revision in the

last week can be assessed within the relational category of the SOLO taxonomy. In subsequent weeks, design-for-sustainability approaches are taught, and students begin working on related assignments. Among these assignments, only the first assignment, which focuses on eco-design strategies, can be categorized as relational, as students are asked to redesign a product, analyze and compare it, illustrate the eco-design strategy wheel, and answer eco-design checklist questions. The following assignments and the two projects can be assessed in the extended abstract category.

Table 3 Assessment Tasks, Verbs of the Intended Learning Outcomes, and Their Analysis

Assessment Tasks	**Verbs of the Intended learning outcomes**	**SOLO taxonomy levels (Biggs & Tang, 2011)**	**Sustainability Topics (Faludi et al., 2023)**
Assignment 1: Daily habits and plans	List, make a plan	Relational	Fundamentals of sustainability
Assignment 2: Eco-design strategies, checklist, and wheel	Redesign; select, analyze, compare, illustrate, answer	Relational	Sustainable innovation strategies Impact assessment and laws and standards
Assignment 3: Cradle to cradle, circular product design	Design; apply, analyze, illustrate	Extended abstract	Sustainable innovation strategies Circular economy
Assignment 4: Eco-friendly materials, sustainable energy technologies	Design; select, research	Extended abstract	Sustainable innovation strategies
Assignment 5: Design for sustainable behavior, design for the bottom of the pyramid	Design; apply, illustrate	Extended abstract	Sustainable innovation strategies
Assignment 6: Sustainable product-service systems	Design; analyze, illustrate	Extended abstract	Sustainable innovation strategies Whole systems thinking
Assignment 7: Revision of Assignment 1	Review and rewrite	Relational	Communication, collaboration, and leadership
Project 1: Sustainable product design	Design, apply, analyze	Extended abstract	Sustainable innovation strategies Circular economy
Project 2: Sustainable product-service systems	Design, analyze, illustrate	Extended abstract	Whole systems thinking

The assignments students must complete after each theoretical section aim to support the development of design ideas based on the design-for-sustainability approaches taught. Reducing the number of assignments has helped students focus on developing sustainable product design ideas further in terms of user scenarios, materials and production techniques, product technical drawings, CAD models and renders, and presentations, as well as the design-for-sustainability approaches applied. If a course aims to have students generate design ideas rather than focus on product detailing and development, increasing the number of assignments may lead to broader coverage of themes. However, as in this study, if the course aims to enhance students' product detailing and development and the rigorous application of design-for-sustainability approaches, limiting the number of assignments may be preferable.

Examining Figure 2 and Figure 3, it can be observed that in 2025, the starting points for most sustainable product-service system design projects are sustainable product design projects. This may be due to the increased emphasis on sustainable product design projects, as students were encouraged to submit these projects to competitions. Furthermore, when comparing the number of flows for each project type in both 2024 and 2025, it can be observed that sustainable product design projects serve as the starting point for sustainable product-service system design projects more than the other way around. This situation may stem from differences in the complexity of the projects' innovation levels and in the timeline and flow of the course structure. In any case, it can be concluded that students can establish relationships among design-for-sustainability approaches at different levels of innovation.

As an additional observation, the concentration of theoretical content in fewer classes creates a disadvantage for students who miss these courses. This situation is intended to be addressed by having the instructor repeat important theoretical parts when necessary, or by students reviewing course materials and engaging in peer learning. It should also be noted that students take an eight-

hour design studio course each semester in addition to other compulsory and elective courses; therefore, the time they can dedicate to electives is limited. Nevertheless, students can complete their projects according to the specified criteria.

The number of projects developed within the scope of the course and selected as finalists in the 2025 Green Product Concept Award can be considered an indicator of success in design, sustainability, and innovation. Several factors were observed to be important in this process. First, instructors need to select and suggest the right competitions for student participation. The application requirements and schedule of the Green Product Concept Award competition were well-aligned with the course's project outcome criteria, timeline, and deadlines. Furthermore, its international nature motivated the students. Second, the Green Product Concept Award announced the finalist projects, while IMMIB announced only the winners, who are fewer in number, although only Turkish citizens can apply. Identifying and announcing finalists before the winners in a two-stage evaluation is a common strategy, also observed in other international design student awards. This can both motivate more students and provide transparency for all participants and those following the competition results. Although more data are needed, based on limited formal student feedback on the courses, participating in competitions may provide students with social and achievement motivation in addition to extrinsic and intrinsic motivation, as defined by Biggs and Tang (2011).

The UN SDGs targeted by the students in their projects largely overlap with the goals that the design field can contribute to, as defined by the WDO (2015), although there are also projects developed targeting SDG 15 (Life on Land) in the course. In contrast, SDG 9 (Industry, Innovation and Infrastructure) was not considered as most relevant for the projects in this paper, as the projects focused more on people, ecosystems, and communities. Thus, it can be stated that the projects embrace the definition of humanity-centered design proposed by Norman (2024). However, innovation is one of the criteria for both outcome projects in this course; therefore, SDG 9 is also relevant for all projects. Furthermore, the sustainability aspects of the finalist projects are presented in detail in Table 2, including the type of product-service system (Tukker, 2004; VentureWell, 2022), and the specific targets they can primarily contribute to in relation to the UN SDGs (2015). In the future, this can be added as a task for students to analyze and report on the intended contribution of the projects.

As a final point of discussion, the sustainable products and product-service systems developed in the scope of the course, their target themes and SDGs, and the finalist projects exemplify the complexity in terms of the number of sectors in which industrial design education operates, the stakeholders it must consider or interact with, and therefore the knowledge that needs to be integrated into the curriculum. These challenges have also been addressed in the literature (e.g., Faludi et al., 2023; Meyer & Norman, 2020). In design studios, complexity is often limited by problems, categories, or themes defined in design briefs. This study exemplifies a course with theoretical and practical content that is primarily concerned with design for sustainability, encompasses the complexity of both sustainability and design, and therefore presents unique challenges. In this course, complexity is intended to be navigated by integrating theoretical and practical parts across assignments and project outcome criteria.

6. Conclusions

This study aimed to exemplify a specific type of undergraduate course in design for sustainability and to share findings and experiences from the course. The case course is a fourth-year undergraduate elective with both theoretical and practical parts. The study aimed to inform researchers, lecturers, and practitioners working in the fields of design for sustainability and design education. Data from two semesters, before and after the course update, were compared in terms of course content, processes, outcomes, themes arising from these outcomes, and alignment with the UN SDGs. The findings showed that although the theoretical content remained unchanged, changes to the course schedule and assignments were reflected in the scope and quality of the

course outcomes. Furthermore, encouraging student participation in design competitions that aligned with the course content and schedule improved the quality of course outcomes. Such recognition of achievements beyond the course grade is important for students' professional development and can motivate them to succeed in real-world situations.

One limitation of the study is that the data are limited to archival materials, course documents, and course outcomes and do not focus on student feedback. Furthermore, it is a comparative case study covering two semesters of a single course. Future studies could focus on courses with different structures and pedagogies in industrial design, architecture, and planning that aim to contribute to the sustainability and continuous improvement of design education.

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CRediT Authorship Contribution Statement

Elif Küçüksayraç: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The author declares no conflict of interest or competing interests.

Data Availability

Data will be made available on request.

Ethics Committee Approval

Ethics committee approval was not required for this study as it relied on archival data and did not involve human participants. No active data collection methods, such as surveys, interviews, or focus groups, were utilized. The product and product-service system descriptions and visuals presented in Table 2 and Figure 4 are based on the cited GP-Awards (2025).

References

Anteet, Q., & Binabid, J. (2025). Investigating the discourse on pedagogical effectiveness in the architectural design studio. *Architectural Engineering and Design Management, 21*(1), 17_34. https://doi.org/10.1080/17452007.2024.2402055

Archiprix. (2021). *About Archiprix international*. Retrieved April 13, 2026, from https://www.archiprix.org/2021/

Bakırlıoğlu, Y., & McMahon, M. (2021). Co-learning for sustainable design: The case of a circular design collaborative project in Ireland. *Journal of Cleaner Production, 279*, 123474. https://doi.org/10.1016/j.jclepro.2020.123474

Bakker, C., Mugge, R., Boks, C., & Oguchi, M. (2021). Understanding and managing product lifetimes in support of a circular economy. *Journal of Cleaner Production, 279*, 123764. https://doi.org/10.1016/j.jclepro.2020.123764

Biggs, J. B., & Collis, K. F. (1982). *Evaluating the quality of learning: The SOLO taxonomy (Structure of the observed learning outcome)*. Academic Press.

Biggs, J. B., & Tang, C. S. (2011). *Teaching for quality learning at university: What the student does* (4th ed.). McGraw-Hill/Society for Research into Higher Education/Open University Press.

Boks, C., & Diehl, J. C. (2006). Integration of sustainability in regular courses: Experiences in industrial design engineering. *Journal of Cleaner Production, 14*(9_11), 932_939. https://doi.org/10.1016/j.jclepro.2005.11.038

Brezet, H., & van Hemel, C. (1997). ECODESIGN: *A promising approach to sustainable production and consumption*. UNEP.

Calabretta, G. & Kleinsmann, M. (2017). Technology-driven evolution of design practices: Envisioning the role of design in the digital era. *Journal of Marketing Management*, *33*(3_4), 292_304. https://doi.org/10.1080/0267257X.2017.1284436.

Calikusu, A. N., Cakmakli, A. B., & Gursel Dino, I. (2023). The impact of architectural design studio education on perceptions of sustainability. *Archnet-IJAR: International Journal of Architectural Research, 17*(2), 375-392. https://doi.org/10.1108/ARCH-09-2021-0251

Ceschin, F., & Gaziulusoy, İ. (2019). *Design for sustainability: A multi-level framework from products to socio-technical systems.* Routledge. https://doi.org/10.4324/9780429456510

Charter, M. (2018). Introduction. In M. Charter (Ed.), *Designing for the Circular Economy* (pp.1-11). Routledge. https://doi.org/10.4324/9781315113067

Cradle to Cradle Products Innovation Institute (C2C). (2026). *C2C certified® full scope*. Retrieved July 21, 2026, from https://c2ccertified.org/the-standard/c2c-certified-full-scope

Crul, M. R. M., Diehl, J. C. & Ryan, C. (2009) *Design for sustainability: A stepby-step approach*. UNEP.

Demirbaş, O. O., & Demirkan, H. (2003). Focus on architectural design process through learning styles. *Design Studies, 24*(5), 437-456. https://doi.org/10.1016/S0142-694X(03)00013-9

Den Hollander, M. C., Bakker, C. A., & Hultink, E. J. (2017). Product design in a circular economy: Development of a typology of key concepts and terms. *Journal of Industrial Ecology, 21*(3), 517-525. https://doi.org/10.1111/jiec.12610

Design Council. (2003). *The double diamond.* Retrieved April 13, 2026, from https://www.designcouncil.org.uk/our-resources/the-double-diamond/

Dhaouadi, K., & Leclercq, P. (2022). Shaping sustainability in architectural education: The integrated design as a tool. *Journal of Design Studio, 4*(2), 217-226. https://doi.org/10.46474/jds.1218258

Ellen MacArthur Foundation (EMF). (2016). *The circular design guide.* Retrieved April 13, 2026, from https://www.ellenmacarthurfoundation.org/circular-design-guide/overview

Faludi, J., Acaroglu, L., Gardien, P., Rapela, A., Sumter, D., & Cooper, C. (2023). Sustainability in the future of design education. *She Ji: The Journal of Design, Economics, and Innovation, 9*(2), 157-178. https://doi.org/10.1016/j.sheji.2023.04.004

Green Product Award (GP-Award). (2025). *Concept award*. Retrieved April 13, 2026, from https://www.gp-award.com/en/gcaward

Green Product Award (GP-Award). (2026). *Criteria.* Retrieved July 21, 2026, from https://www.gp-award.com/en/criteria

Hasso Plattner Institute of Design at Stanford. (2010). *An introduction to design thinking process guide.* Retrieved April 13, 2026, from https://dschool_old.stanford.edu/sandbox/groups/designresources/wiki/36873/attachments/74b3d/ModeGuideBOOTCAMP2010L.pdf

Istanbul Mining and Metals Exporters Association (IMMIB). (2025). *Kategoriler*. Retrieved April 13, 2026, from https://www.tasarimyarismasi.com/yarismalar/yarisma-2025/kategoriler

iF Design. (2026). *iF design student award 2026*. Retrieved April 13, 2026, from https://ifdesign.com/en/if-design-student-award

Kandachar, P., & Halme, M. (Eds.). (2008). *Sustainability challenges and solutions at the base of the pyramid: Business, technology and the poor.* Greenleaf Publishing.

Karaca, C., & Küçüksayraç, E. (2026). Grow-it-yourself kits: Developing the tool for and tinkering with algae, bacteria and fungi. *Biotechnology Design*, *4*, e25. https://doi.org/10.1017/S2977905726100547

Kolb, D. A. (2015). *Experiential learning: Experience as the source of learning and development* (2nd ed.). Pearson Education.

Küçüksayraç, E., & Arıburun Kırca, L. N. E. (2020). Integrating sustainability into project-based undergraduate design courses. *International Journal of Sustainability in Higher Education*, *21*(2), 353-371. https://doi.org/10.1108/IJSHE-07-2019-0230

Küçüksayraç, E., Keskin, D., & Brezet, H. (2015). Intermediaries and innovation support in the design for sustainability field: Cases from the Netherlands, Turkey and the United Kingdom. *Journal of Cleaner Production*, *101*, 38-48. https://doi.org/10.1016/j.jclepro.2015.03.078

Larmer, J., Mergendoller, J., & Boss, S. (2015). *Setting the standard for project based learning: A proven approach to rigorous classroom instruction*. ASCD.

Lawton, J., & Judd, B. (2025). The MUDD program, UNSW: The centrality of transdisciplinary curricula in urban design studio (UDS): A phenomenographic exploration of factors impacting urban design studio curricula. *Journal of Design for Resilience in Architecture and Planning, 6*(Special Issue), 77-96. https://doi.org/10.47818/DRArch.2025.v6si196

Lilley, D. (2009). Design for sustainable behaviour: Strategies and perceptions. *Design Studies, 30*(6), 704-720.

Lockrey, S., & Bissett Johnson, K. (2013). Designing pedagogy with emerging sustainable technologies. *Journal of Cleaner Production, 61*, 70-79. https://doi.org/10.1016/j.jclepro.2013.05.005

Lockwood, T. (2007). Design value: A framework for measurement. *Design Management Review, 18*(4), 90-97. https://doi.org/10.1111/j.1948-7169.2007.tb00099.x

Manzini, E. (2009). *New design knowledge. Design Studies, 30*(1), 4_12. https://doi.org/10.1016/j.destud.2008.10.001

Manzini, E. & Vezzoli, C. (2002). *Product-service systems and sustainability: Opportunities for sustainable solutions.* UNEP

McDonough, W., & Braungart, M. (2002). *Cradle to cradle: Remaking the way we make things*. North Point Press.

Meyer, M. W. & Norman, D. (2020). Changing design education for the 21st century. *She Ji: The Journal of Design, Economics, and Innovation*, *6*(1), pp.13-49. https://doi.org/10.1016/j.sheji.2019.12.002

Norman, D. A. (1988). *The design of everyday things*. MIT Press.

Norman, D. A. (2024). *Design for a better world: Meaningful, sustainable, humanity centered*. MIT Press.

Roozenburg, N. F. M., & Eekels, J. (1995). *Product design: Fundamentals and methods*. Wiley.

Sanders, E. B. -N. (2017). Design research at the crossroads of education and practice. *She Ji: The Journal of Design, Economics, and Innovation*, *3*(1), 3-15.

Süner-Pla-Cerdà, S., Öztürk, E., & Ünlü, C. E. (2025). Towards an integrative model of blended design studios: A multiple case study across architecture, design and planning education. *Education and Information Technologies*, *30*(2), 2005-2039. https://doi.org/10.1007/s10639-024-12873-y

Thackara, J. (2005). *In the bubble: Designing in a complex world*. MIT Press.

Tukker, A. (2004). Eight types of product–service system: Eight ways to sustainability? Experiences from SusProNet. *Business Strategy and the Environment*, *13*(4), 246-260. https://doi.org/10.1002/bse.414

Tümtürk, O., Karakiewicz, J., Villoria, L. A., & Mah, D. (2025). The grounded projection: A reflective examination of urban design pedagogy at Melbourne School of Design. *Journal of Design for Resilience in Architecture and Planning, 6*(Special Issue), 97-132. https://doi.org/10.47818/DRArch.2025.v6si197

Uluoğlu, B. (2020). Design knowledge communicated in studio critiques. *Design Studies, 21,* 33-58.

United Nations (UN SDGs). (2015). *The 17 goals.* Retrieved April 13, 2026, from https://sdgs.un.org/goals

United Nations Environment Programme (UNEP). (2025). *Circularity*. Retrieved April 13, 2026, from https://www.unep.org/circularity

Van Boeijen, A., Daalhuizen, J., Zijlstra, J., & Van Der Schoor, R. (2013). *Delft design guide: Design strategies and methods*. BIS Publishers.

VentureWell. (2022). *Circular economy.* Retrieved July 21, 2026, from https://venturewell.org/tools_for_design/design-lifetime-sharing/

Vezzoli, C., Kohtala, C. & Srinivasan, A. (2014). *Product-service system design for sustainability*. Greenleaf.

Walker, S. (2023). *Design for resilience: Making the future we leave behind*. The MIT Press.

World Design Organisation (WDO). (2015). *About us.* Retrieved April 13, 2026, from https://wdo.org/about/

Yavuz Özgür, I., & Çalışkan, O. (2025). Constitutive conditions of transforming pedagogies in urban design: A critical reflection on METU MUD Studio (1996-2025). *Journal of Design for Resilience in Architecture and Planning, 6* (Special Issue), 133-167. https://doi.org/10.47818/DRArch.2025.v8si198

Yilmaz, T. & Kapkin, E. (2021). Mapping the intervention of sustainable design studio using multidimensional scaling and pathfinder networks. *International Journal of Sustainability in Higher Education*, *22*(2), 308-327.

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed). SAGE Publications.

Resume

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