



## **A PRISMA-Based Systematic Review of Technology, Sustainability, and Functional Diversity in City Center Land-Use Planning: Evidence from 50 Studies**



Marco Nagy Ragheb<sup>\*</sup>, Mohie Edeen Shalaby<sup></sup>, Ahmed M. Roshdy Radwan<sup></sup>

Faculty of Urban and Regional Planning, Cairo University, Giza 12613, Egypt

Corresponding Author Email: [marco\\_n\\_r@cu.edu.eg](mailto:marco_n_r@cu.edu.eg)

Copyright: ©2026 The authors. This article is published by IETA and is licensed under the CC BY 4.0 license (<http://creativecommons.org/licenses/by/4.0/>).

<https://doi.org/10.18280/ijstdp.210317>

### **ABSTRACT**

**Received:** 15 January 2026

**Revised:** 12 March 2026

**Accepted:** 20 March 2026

**Available online:** 31 March 2026

#### **Keywords:**

*city center, digital economy, land-use planning, mixed-use development, Preferred Reporting Items for Systematic Reviews and Meta-Analyses, resilient planning, smart city, sustainable planning*

The city center is undergoing profound transformations due to technological breakthroughs and socioeconomic shifts converge. However, there is no overarching synthesis of how these forces jointly reshape future land-use planning. This review fills that gap by systematically exploring the interaction among digitalization, sustainability imperatives, and economic realignments in city centers. Following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 protocols, we screened major academic databases and, through a multi-stage filtering process, distilled fifty peer-reviewed studies for thematic synthesis. Our analysis reveals a techno-optimistic slant: 48% of the studies emphasize data-driven planning with AI, IoT, and digital twins, while 44% foreground sustainability and resilience— although often without fully integrating socioeconomic equity. Mixed-use development emerges as a widely endorsed strategy (36% of studies), yet its vertical complexity and unintended externalities remain underexplored. Key obstacles include persistent data interoperability gaps, ethical challenges in deploying smart technologies, and fragmented governance frameworks that undermine implementation. We conclude that land-use planning is shifting toward dynamic, data-informed paradigms; however, a disconnect persists between the technological promise and its equitable, practical application. To bridge this divide, future research must prioritize longitudinal validation of predictive models, craft integrative frameworks that reconcile sustainability with governance, and rigorously address the ethical dimensions of urban digital tools to foster adaptive, inclusive, and sustainable city centers.

## **1. INTRODUCTION**

The study of future land-use planning in the city center has become increasingly vital as rapid urbanization, technological breakthroughs, and mounting environmental challenges are reshaping urban landscapes [1, 2]. Whereas traditional approaches once relied on rigidly defined zones for industry, housing, and commerce, contemporary paradigms prioritize digitalization and sustainability [2, 3]. This shift reflects the growing complexity of urban systems, which now embrace volumetric space utilization and mixed-use developments. Thus, there is an urgent need for novel planning frameworks that comprehensively integrate social, economic, and environmental dimensions [3, 4]. As more than two-thirds of the world's population is projected to live in cities by 2050, the need for planning frameworks that holistically integrate social, economic, and environmental goals is urgent [5, 6].

Despite a rich body of work on urban land use, critical gaps remain in our understanding of how emerging digital economies, climate pressures, and post-pandemic transformations jointly influence city-center dynamics [2, 7, 8]. Some studies celebrate the capacity of digital technologies to decouple economic growth from physical constraints, while

others highlight the challenge of updating land-use policies to keep pace with these rapid shifts [2, 8]. Yet few frameworks fully synthesize technological, environmental, and socioeconomic factors, leaving planners ill-equipped to anticipate conflicts or seize new opportunities [9, 10]. This disconnect threatens both sustainable development and equitable access to central urban resources [1, 11].

To address these deficiencies, this systematic review proposes a conceptual framework that brings together three core dimensions—digital transformation, sustainable urbanism, and land-use planning—to explore their combined impact on the future of city centers [2, 3, 5]. The model examines how the digital economy reshapes land valuation, how mixed-use and volumetric urbanism are redefining built form, and how smart technologies can support adaptive planning [4, 12]. By weaving these strands into a coherent structure, the framework offers a basis for analyzing their synergistic effects on urban strategy and design.

Our primary objective is to synthesize and critically evaluate contemporary research at the intersection of technological, environmental, and socioeconomic drivers [2, 8]. We aim to clarify emerging trends, pinpoint persistent challenges, and propose integrative approaches that promote

sustainable, resilient, and inclusive urban development [3, 5]. The goal is to transform fragmented findings into a unified perspective that can guide planners, policymakers, and scholars.

Methodologically, this review combines systematic literature searches, thematic synthesis, and conceptual mapping [8, 13]. We focused on recent empirical and theoretical studies addressing the crossroads of land-use planning, digital innovation, and sustainability in city centers. The results are organized into thematic clusters, providing a clear roadmap for understanding future trajectories and their practical implications for urban cores [2, 3, 5].

## 2. RESEARCH METHODOLOGY

The research follows a carefully planned design that combines sequential stages of systematic inquiry with rigorous analytical techniques. It began with an extensive literature search and screening—using both database queries and citation chaining—to assemble an initial pool of relevant publications. Applying Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 criteria, this collection was narrowed to 50 high-quality studies that satisfied strict relevance and quality thresholds.

At its core, the study employed a mixed-methods approach, integrating quantitative classification with qualitative interpretation. A predefined coding schema was applied across four key analytical dimensions—Technological Integration, Sustainability & Resilience, Functional Mix Diversity, and Adoption of Predictive Modeling. This multi-dimensional evaluation was further reinforced by content analysis for thematic extraction and systematic comparative analysis to uncover patterns and divergences. The analytical process was further enhanced by specialized research tools and techniques, notably bibliometric analysis for mapping scholarly trends and conceptual mapping for visualizing theoretical evolution. The synthesis culminated in a comprehensive Strengths, Weaknesses, Opportunities, Threats (SWOT) analytical framework, which enabled critical evaluation of the field's current state and future trajectories. This integrated methodological approach, combining systematic processes with multi-faceted analytical techniques, ensured the derivation of valid, reliable, and nuanced insights into the evolving landscape of urban planning research, directly facilitating the generation of the study's substantive findings and conclusions.

## 3. THEORETICAL BACKGROUND

### 3.1 Defining the city center

The city center - variously referred to as the Central Business District (CBD), downtown, or urban core - constitutes a dynamic and multifaceted spatial entity. More than just the historical or geographical heart of a city, it functions as the primary hub of urban concentration. It is defined by an unparalleled agglomeration of economic power, administrative authority, and cultural assets, which collectively produce distinct conditions of density, connectivity, and symbolic importance [2, 14]. Contemporary academic thought has moved beyond traditional frameworks that highlighted a singular, monocentric model, now

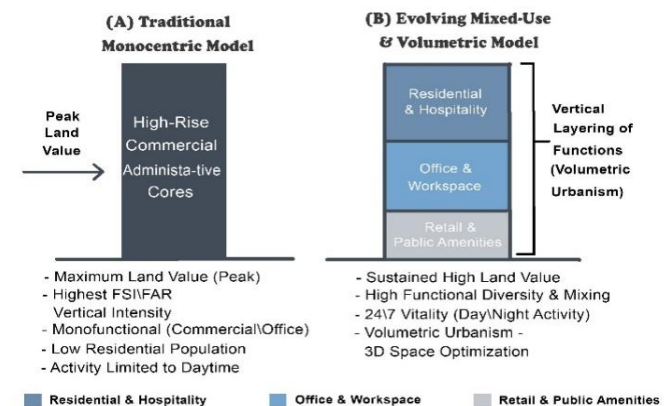
acknowledging its fluid and adaptive character in response to digital transformation, the rise of polycentric urban forms, and shifting socioeconomic dynamics.

### 3.2 Core characteristics of the city center

Drawing from urban planning, economic geography, and spatial theory, the city center can be delineated by the following interconnected characteristics:

#### 3.2.1 Peak value and intensity of land use

A defining feature of the city center is its premium land value, which drives the most intensive utilization of urban space. This is manifested not only horizontally but, more critically, through dense vertical construction, leading to high floor space index (FSI) or floor area ratio (FAR) values. The scarcity of land traditionally favors a concentration of commercial, retail, and administrative functions. However, contemporary urban paradigms are increasingly advocating for the integration of residential components into these areas to create mixed-use environments that sustain vitality throughout the day and night [3, 4]. Figure 1 contrasts (A) The traditional model shows peak land value driving high-rise, monofunctional commercial development. (B) The contemporary, sustainable model maintains high values and intensity (FSI/FAR) but achieves them through volumetric urbanism and vertical mixed-use layering, integrating residential, commercial, and public functions to create 24/7 vibrant city center.



**Figure 1.** Conceptual models illustrating the evolution of land use intensity and value in the city center

Source: Based on the studies [3, 4]

#### 3.2.2 Multifunctional and nodal character

Unlike specialized districts, the city center is defined by its functional diversity or functional mix. It serves as the primary node for:

**Economic Activity:** Concentrating corporate headquarters, high-order financial and professional services, and flagship retail [8].

**Administration and Governance:** Hosting key government institutions and civic buildings.

**Culture and Symbolism:** Featuring major cultural institutions (museums, theaters), historical landmarks, and public squares that constitute the city's identity and function as a central place for social interaction and congregation [15].

#### 3.2.3 High accessibility and multi-modal transit integration

The city center functions as the primary hub of a region's

transportation network. They are characterized by convergence of public transit lines (rail, metro, buses), major highways, and pedestrian infrastructure. This high level of accessibility is a fundamental driver of its agglomerative economies, making it the most convenient meeting point for the largest number of people [1, 16].

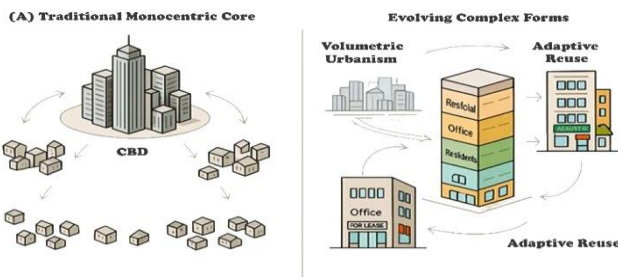
### 3.2.4 Dynamic morphology and evolving urban form

The physical form of the city center is not static. Scholarly work identifies a shift from traditional, densely built monocentric cores towards more complex forms, including:

**Polycentricity:** The decentralization of core functions into a network of urban centers and sub-centers within a metropolitan area [17].

**Volumetric Urbanism:** A growing focus on the three-dimensional use and analysis of space, moving beyond the horizontal plan to optimize vertical mixed-use and subsurface development [4].

**Adaptive Reuse:** The transformation of existing building stock (e.g., from obsolete office or retail space to residential or experiential uses) in response to economic shifts, such as those accelerated by the digital economy and the COVID-19 pandemic [7, 18] as shown in Figure 2.



**Figure 2.** Conceptual model of the dynamic evolution of urban Form in the city center

### 3.2.5 A zone of constant transformation and contestation

The city center is a primary site for negotiating urban futures. It is where pressures for technological modernization, climate resilience, social inclusivity, and economic competitiveness most acutely converge. This makes it a focal point for planning interventions, speculative investment, and debates over equity, access, and the right to the city [2, 19]. The integration of smart city technologies (e.g., IoT, digital twins) and sustainability frameworks are contemporary forces actively reshaping its characteristics and management [12, 20].

## 3.3 Theoretical evolution and frameworks for the city center planning

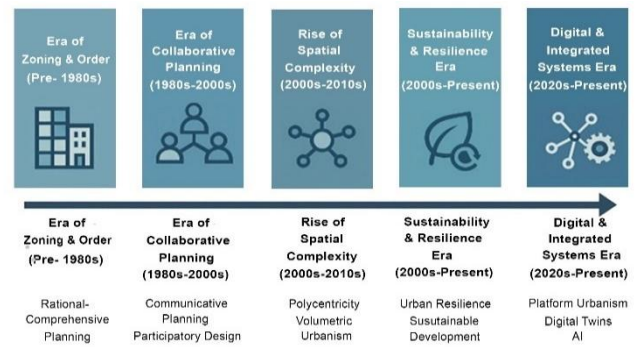
The evolution of land-use planning in the city center is underpinned by a dynamic interplay of theoretical paradigms that have shifted from rigid, static models to adaptive, multi-dimensional frameworks. This theoretical background outlines the core concepts that form the foundation for understanding the future trajectory of the city center, focusing on the transition from traditional spatial approaches to integrated socio-technical-ecological systems.

### 3.3.1 The shift from traditional to integrative planning theories

Historically, urban land-use planning was dominated by rational-comprehensive planning and Euclidean zoning, which advocated for the segregation of urban functions into distinct

zones (e.g., residential, commercial, industrial) to promote order, efficiency, and public health [16]. This modernist approach, influenced by figures like Le Corbusier, prioritized predictability and control over organic urban growth.

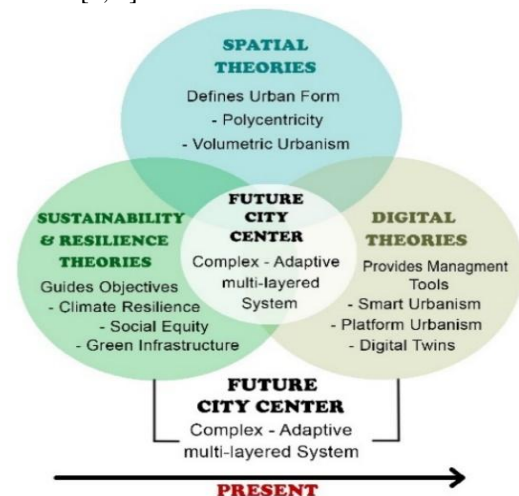
However, the limitations of these models—including urban sprawl, functional monotony, and auto-dependency—led to the rise of collaborative and communicative planning theories in the late 20th century. These theories, championed by scholars like Judith Innes and Patsy Healey, argue that planning is not a purely technical exercise but a social process involving negotiation, dialogue, and consensus-building among diverse stakeholders [21]. This theoretical shift is evident in contemporary emphases on community engagement and participatory design using digital platforms and virtual reality [17, 22] as shown in Figure 3.



**Figure 3.** The chronological shift in urban planning from separated zoning to multi-dimensional frameworks  
Source: By authors based on the research [2, 16, 17, 21, 22]

### 3.3.2 Sustainable urban development and resilience theory

Sustainable development (Brundtland Commission) is a key pillar in urban planning. In city centers, it evolved into urban sustainability and ecological urbanism, balancing environmental protection, economic vitality, and social equity [23]. Operationalized via green infrastructure, transit-oriented development (TOD), and compact forms to reduce environmental footprint and enhance climate resilience (Figure 4) [1]. Urban resilience theory views cities as complex adaptive systems that withstand, recover from, and reorganize after shocks like climate events or economic disruptions [24]. The literature emphasizes embedding resilience through adaptive land use and mixed-use development to buffer future uncertainties [2, 6].

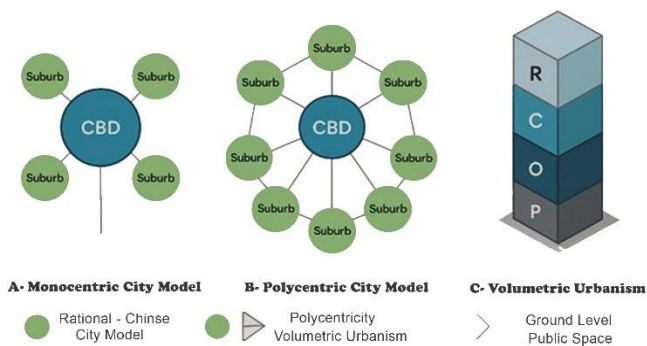


**Figure 4.** Integrated framework for future city center

### 3.3.3 The spatial turn: Polycentricity and volumetric urbanism

Spatial economic theories, such as the Monocentric City Model, have long explained urban structure based on a single CBD. This has been largely supplanted by theories of polycentricity, which describe urban regions with multiple, specialized centers [17]. This spatial restructuring is seen as a strategy to distribute economic activity, alleviate congestion, and foster balanced regional growth, a theme evident in modern master plans [17, 25].

A more recent theoretical advancement is volumetric urbanism, which challenges the traditional, two-dimensional (2D) "flat" understanding of land. It proposes a three-dimensional (3D) conception of urban space, recognizing that the vertical dimension—the density, overlap, and vertical layering of functions—is critical in high-density city center [4]. This theory provides a refined lens for analyzing and planning mixed-use developments and understanding the complex spatial-temporal dynamics of floor space use. As shown in Figure 5, the transition progresses from (A) Monocentric to (B) Polycentric models, culminating in the emergence of (C) Volumetric Urbanism with vertical functional integration.



**Figure 5.** Conceptual models of urban spatial structure  
Sources: Based on the studies [4, 17, 25]

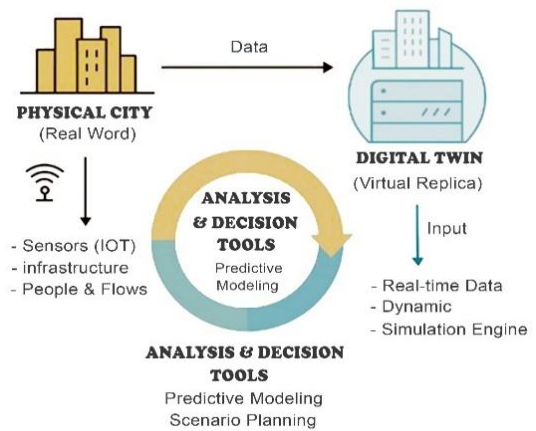
### 3.3.4 The digital revolution: Platform urbanism and the data-driven city

The infusion of digital technology has given rise to new theoretical frameworks. Smart Urbanism posits that data collected through Information and Communication Technologies (ICTs) and the Internet of Things (IoT) can optimize urban services and infrastructure [5, 26].

Building on this, the concept of platform urbanism examines how digital platforms (e.g., for mobility, hospitality, and work) are reshaping urban economies and land use patterns. This theory highlights a critical disruption: the decoupling of economic function from physical proximity, challenging traditional land valuation models based on location [8]. The digital economy alters demand for retail and office spaces while increasing pressure on residential and logistics functions, necessitating a theoretical revision of urban land economics [8, 18].

At the most advanced level, the theory of the Digital Twin – a dynamic, virtual replica of a physical city – represents a paradigm shift towards predictive and simulated planning. It allows for real-time monitoring, scenario modeling, and evidence-based decision-making, creating a closed-loop feedback system between the physical and digital worlds [8, 12]. This capability is pivotal in understanding and managing the urban transformations, where digital platforms decouple economic activities from physical proximity, thereby altering

traditional land use patterns and valuation as shown in Figure 6.



**Figure 6.** The disruptive mechanism of platform urbanism  
Sources: Based on [7, 8, 18]

The contemporary theoretical landscape for the city center land-use planning is no longer defined by a single doctrine but by a synthesis of these paradigms. The future city center is conceptualized as a complex, adaptive, and multi-layered system where:

Spatial theories. (Polycentricity, Volumetric Urbanism) define its form.

Sustainability and Resilience theories guide its environmental and social objectives.

Digital theories. (Smart Urbanism, platform urbanism, Digital Twins) provide the tools for its management and adaptation.

This integrated theoretical foundation is essential for analyzing the synergistic interplay between technological innovation, sustainability imperatives, and socioeconomic transformations.

## 4. LITERATURE SELECTION METHODOLOGY

This systematic literature review adheres to the PRISMA 2020 guidelines and is structured around three sequential phases: (1) identification and retrieval, (2) screening and evaluation, and (3) synthesis and presentation. The subsequent sections detail the application of this process.

### 4.1 Search strategy and reproducibility

The systematic search was conducted from 2–10 November 2025 across the following academic databases: Scopus and Web of Science (Core Collection).

#### Exact search strings per database:

- Scopus: TITLE-ABS-KEY ("city center" OR "downtown" OR "central business district" OR "urban core") AND ("land use" OR "land-use planning" OR "urban planning") AND (technology OR digital OR AI OR IoT OR "digital twin" OR sustainability OR resilience OR "mixed-use" OR "functional diversity").

- Web of Science (Core Collection): TS = ("city center" OR "downtown" OR "central business district" OR "urban core") AND ("land use" OR "land-use planning" OR "urban planning") AND (technology OR digital OR AI OR IoT OR "digital twin" OR sustainability OR resilience OR "mixed-

use" OR "functional diversity").

**Export format:** The results were exported in RIS format.

**De-duplication approach:** All records were imported into EndNote. Duplicates were removed using EndNote's automatic duplicate detection function, followed by manual verification by two authors. A total of 165 duplicates were removed.

**Automation tools:** The term "automation tools" in the PRISMA flow diagram (Figure 7) refers to the use of EndNote's Smart Groups to automatically flag records not meeting basic eligibility criteria (wrong publication type, no abstract available). This semi-automated process removed 47 records that were clearly ineligible. No fully automated study selection was performed. All final inclusion/exclusion decisions were made manually.

**Explicit inclusion criteria:**

1. Peer-reviewed journal articles or conference proceedings.
2. Focus on city centers, CBDs, or downtowns as the primary spatial unit.
3. Address at least two of the three core dimensions: (a) technological innovation/digital tools, (b) sustainability/climate resilience, or (c) functional diversity/mixed-use development.
4. Empirical (quantitative or qualitative), modeling-based, or conceptual studies with a clear methodological contribution.

**Explicit exclusion criteria:**

1. Editorials, book reviews, opinion pieces, or commentaries without original data or theoretical synthesis.
2. Studies focusing exclusively on suburban, rural, or non-urban areas.
3. Studies with no explicit link to land-use planning.
4. Duplicate publications of the same data set (only the most complete version was retained).

**Justification for the time window:** The search did not impose a strict lower bound to avoid missing foundational theoretical works [14, 16]. However, the screening prioritized recent empirical studies. The final set of 50 studies includes works from 1991 to 2025, with the majority (over 80%) published since 2015, ensuring both historical grounding and contemporary relevance.

#### 4.2 Literature screening and initial retrieval

The formulated search queries were executed across selected academic databases using the predefined inclusion and exclusion criteria. This initial screening and retrieval process yielded 568 candidate papers. For the complete inclusion and exclusion criteria, see Section 4.1.

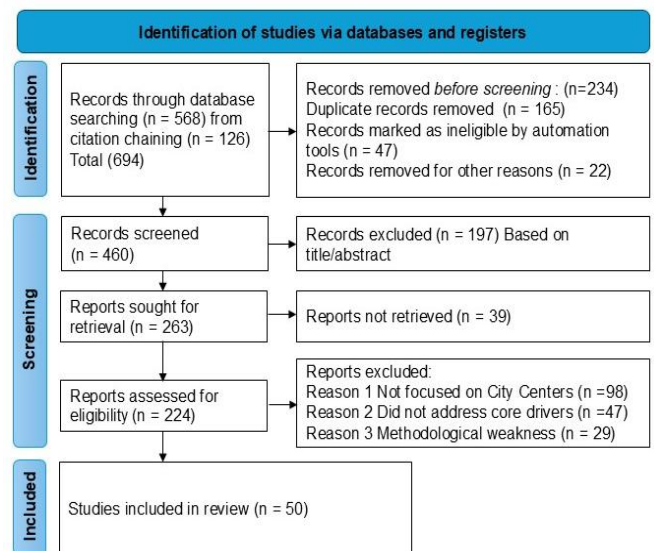
#### 4.3 Citation chaining for literature identification

To ensure coverage and identify seminal works, citation chaining was implemented through two complementary approaches "Backward Citation Chaining" Examining the reference lists of core papers to identify foundational studies. "Forward Citation Chaining" Tracking publications that cited the core papers to uncover debates and recent advancements. This process identified 126 relevant papers.

#### 4.4 Relevance assessment and final selection

The systematic search process yielded an initial pool of 694 candidate papers (568 from databases + 126 from citation

chaining). These records first underwent a pre-screening phase where 234 records were removed, primarily due to duplication (n = 165), ineligibility flagged by automation tools (EndNote Smart Groups) – see Section 4.1 (n = 47), and other reasons (n = 22). Consequently, 460 records were screened based on their titles and abstracts. This initial screening led to the exclusion of 197 records, leaving 263 reports for which the full text was sought. Of these, 39 reports could not be retrieved, resulting in 224 reports that underwent a full-text, in-depth assessment for eligibility. The application of specific exclusion criteria during this final stage led to the exclusion of 174 reports for the following reasons: not focused on city center/CBDs (n = 98), failure to address the core interlinked drivers of technological innovation, environmental sustainability, and economic transformation (n = 47), and methodological weaknesses (n = 29). This meticulous, multi-stage process refined the initial pool to a final cohort of fifty (50) high-quality studies that form the core evidence base for this systematic review as shown in Figure 7.



**Figure 7.** Stages of systematic literature review using the PRISMA method

## 5. RESULTS

### 5.1 Classification of the included studies

This systematic review analyzes 50 scholarly publications classified along three primary dimensions: study type, methodological approach, and geographical context. As visually summarized in Figure 8, the analysis reveals distinct patterns in the research landscape that inform this study's investigative focus as shown in.

**Study type:** Applied and empirical studies constitute 56% (n = 28) of the sample. Theoretical/conceptual papers account for 44% (n = 22).

**Methodological approach:** Modeling and simulation techniques (AI, GIS, digital twins) are used in 36% (n = 18) of studies. Case study analysis appears in 28% (n = 14), policy analysis in 20% (n = 10), and mixed methods in 16% (n = 8).

**Geographical context:** Global/comparative studies represent 28% (n = 14), Asia-Pacific 26% (n = 13), Europe 22% (n = 11), North America 14% (n = 7), and other regions 10% (n = 5).



transparency and replicability.

### 5.2.1 Coding procedure and operational definitions

A rigorous codebook with operational definitions for each classification was developed to ensure analytical consistency [27]. Before data extraction, a detailed coding manual was created. Each of the 50 studies was independently coded by two researchers (the authors). The analysis was conducted through a structured, iterative coding process, where each publication was systematically evaluated against four pre-defined analytical dimensions:

**Technological Integration Level:** High Integration: The study explicitly develops or applies artificial intelligence (AI), machine learning (ML), digital twins, Internet of Things (IoT), real-time data analytics, or predictive algorithms for land-use planning or urban management. Moderate Integration: The study uses geographic information systems (GIS), spatial simulations, virtual reality (VR), or scenario modeling without AI/ML components. Low Integration: The study is conceptual, policy-oriented, or qualitative, with no empirical implementation of digital tools.

**Sustainability and Resilience:** Comprehensive Integration: The study integrates environmental (e.g., green infrastructure, climate adaptation), social (e.g., equity, inclusion), and economic (e.g., viability, investment) sustainability indicators in a balanced manner. Conceptual Emphasis: The study discusses sustainability or resilience frameworks at a policy or theoretical level without empirical metrics or detailed indicators. Limited Focus: Sustainability is mentioned only peripherally, or the study focuses exclusively on economic or functional aspects without environmental or social considerations.

**Functional Mix Diversity:** Strong Emphasis: Mixed-use development is a central analytical focus, supported by quantitative spatial analysis (e.g., diversity indices, floor area ratios, volumetric analysis) or detailed empirical case studies. Moderate Emphasis: Mixed-use is conceptually endorsed or discussed in the context of TOD or urban vitality but lacks detailed spatial or quantitative evidence. Limited Emphasis: The study assumes monofunctional land use patterns (e.g., exclusively commercial or residential) or does not address functional diversity.

**Adoption of Predictive Modeling in Planning:** Studies were classified according to the degree to which they adopted predictive modeling approaches in their planning analysis, regardless of any reported accuracy metrics. The

classification levels were defined as follows: High Adoption: Studies that centrally employ AI/ML, digital twins, or scenario simulation for planning decisions. Moderate Adoption: Studies that use GIS-based simulation or scenario modeling without AI/ML. Limited Adoption: Studies that mention predictive modeling only conceptually or not at all.

It is important to note that this classification documents the presence and extent of adoption of predictive modeling in literature, not the empirical accuracy of any specific model. Systematic reviews are not designed to benchmark predictive model performance without standardized validation protocols, a limitation we acknowledge.

**Inter-rater reliability:** A random sample of 10 studies (20% of the total) was coded independently by both researchers. Cohen’s Kappa coefficients were calculated for each dimension:

Technological Integration:  $\kappa = 0.84$  (substantial agreement)

Sustainability & Resilience:  $\kappa = 0.79$  (substantial agreement)

Functional Mix Diversity:  $\kappa = 0.88$  (excellent agreement)

Adoption of Predictive Modeling in Planning:  $\kappa = 0.80$  (substantial agreement)

All disagreements were resolved through consensus discussion. The complete study-level coding matrix is provided as a supplementary file (see Appendix A).

**Quantitative Synthesis Methodology:** The quantitative synthesis was generated through a rigorous, multi-stage qualitative content analysis designed to ensure systematic, transparent, and replicable classification. After defining the four core analytical dimensions, a detailed codebook provided operational definitions, mutually exclusive classification levels, and explicit inclusion criteria with examples. An iterative full-text evaluation of all 50 studies was conducted against the codebook’s criteria. To minimize bias, a validation and reliability check was performed through independent coding of a subset by multiple researchers, with discrepancies reconciled by reference to operational definitions. Finally, studies were counted within each classification category and raw counts were converted into percentages of the total sample (N = 50).

The systematic classification of the 50 studies reveals a distinctly evolving paradigm in land-use planning for city centers, characterized by a strong techno-optimistic trajectory alongside persistent implementation challenges.

**Table 1.** Systematic classification of reviewed studies

Analytical Dimension	Classification Level	Number of Studies	Percentage	Key Characteristics & Exemplary References
Technological integration	High Integration	18	36%	AI, IoT, Digital Twins [12, 20].
	Moderate Integration	15	30%	GIS, VR, Simulations [28].
	Low Integration	17	34%	Policy, Conceptual Frameworks [7].
Sustainability & resilience	Comprehensive Integration	20	40%	Explicit environmental, social, economic focus [2].
	Conceptual Emphasis	18	36%	Policy frameworks, lacks empirical metrics [11].
	Limited Focus	12	24%	Peripheral to core economic/functional analysis.
Functional mix diversity	Strong Emphasis	22	44%	Essential for vibrant/resilient cores [3].
	Moderate Emphasis	18	36%	Conceptual or specific aspects (e.g., TOD).
	Limited Emphasis	5	10%	Monofunctional patterns.
Adoption of Predictive Modeling in Planning	High Adoption	15	30%	AI/ML, Neural Networks, Optimization [10].
	Moderate Adoption	20	40%	Scenario simulation, GIS-based models [29].
	Limited Adoption	10	20%	Qualitative, conceptual, no formal validation.

Table 1 presents the aggregated classification across the four analytical dimensions. As shown, high technological integration was observed in 18 studies (36%), while limited adoption of predictive modeling in planning appeared in 10 studies (20%). The full narrative synthesis allows clear identification of dominant trends and critical gaps without requiring the presentation of the complete coding matrix.

### 5.2.2 Technological integration levels

Of the 50 studies, 18 (36%) were classified as having high technological integration (AI, IoT, Digital Twins) [12, 20]; 15 (30%) as moderate integration (GIS, VR, simulations) [28]; and 17 (34%) as low integration (policy, conceptual frameworks) [7, 15].

### 5.2.3 Sustainability and resilience integration

Twenty studies (40%) were classified as having comprehensive integration of environmental, social, and economic indicators [2, 19]; 18 studies (36%) as conceptual or policy-level emphasis without robust empirical metrics [11, 30]; and 12 studies (24%) as limited focus.

### 5.2.4 Functional mix diversity

Twenty-two studies (44%) strongly emphasize mixed-use development [3, 31]; 18 studies (36%) have moderate or conceptual emphasis; 5 studies (10%) have limited emphasis; and 5 studies did not address functional mix diversity.

### 5.2.5 Adoption of predictive modeling in planning

Regarding the adoption of predictive modeling in planning, fifteen studies (30%) demonstrated high adoption of computational techniques (machine learning, neural networks, optimization) [10, 32]; twenty studies (40%) showed moderate adoption (scenario simulation, GIS-based models) [29]; and ten studies (20%) exhibited limited adoption, relying on qualitative or conceptual frameworks without empirical modeling [33].

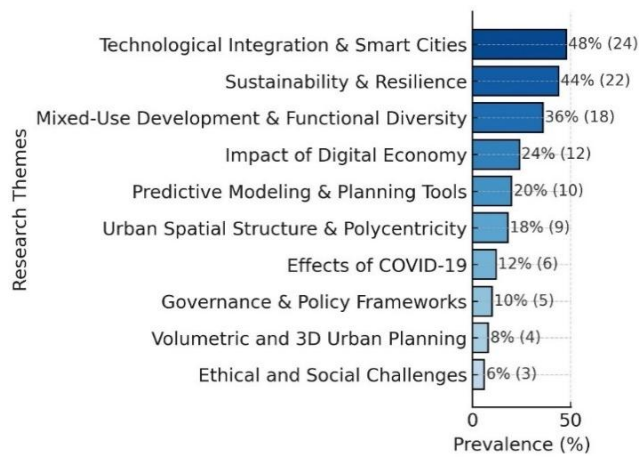
## 5.3 Prevalence of research themes

Contemporary literature on city center land-use planning coalesces around several interconnected thematic domains that reflect the field's dynamic evolution. The discourse is predominantly characterized by two powerful forces: the transformative potential of technological integration in reshaping urban functions, and the imperative of sustainability and resilience frameworks for addressing escalating environmental and social challenges. Within this context, mixed-use development and functional diversity have emerged as fundamental spatial strategies for cultivating vibrant, inclusive city centers. Concurrently, research increasingly examines the substantial impacts of digital economies on urban form, complemented by advances in predictive modeling that provide critical strategic foresight. This thematic convergence fundamentally illustrates the complex interplay between technological innovation, policy development, and socio-spatial dynamics in shaping the future urban landscape.

Figure 10 illustrates the percentage distribution of the dominant research themes across the reviewed literature. To systematically map the intellectual landscape of contemporary urban planning research, this section presents a systematic thematic analysis of the reviewed literature. As shown in Table 2, the following synthesis identifies and characterizes the dominant research themes that are shaping discourse on the future of city center. Through quantitative frequency analysis and qualitative content evaluation, this analysis delineates the core conceptual domains, their prevalence within the scholarly conversation, and their defining characteristics. This structured approach enables a comprehensive understanding of the field's current priorities, emerging trends, and the interconnections between different research foci.

**Table 2.** Dominant research themes in city center land-use planning literature

Theme	Prevalence	Core Focus & Characteristics
Technological integration & smart cities	24/50 (48%)	Digital transformation through AI, IoT, and digital twins enabling real-time analytics, scenario simulation, and data-driven governance for resilient urban design [2, 12, 20].
Sustainability & Resilience	22/50 (44%)	Integration of green infrastructure, climate adaptation, and social equity into land use frameworks, balancing ecological preservation with urban growth demands [6, 19, 34].
Mixed-Use development & functional diversity	18/50 (36%)	Vital role of mixed-use allocation in creating vibrant city center, with advanced spatial and volumetric analyses optimizing functional mix [3, 4, 10].
Digital economy impact	12/50 (24%)	Disruption of traditional land use paradigms through decoupling of physical proximity from economic functions, requiring adaptive regulatory frameworks [7, 8, 18].
Predictive modeling & planning tools	10/50 (20%)	Advanced computational techniques for urban forecasting, scenario testing, and strategic decision-making in sustainable development [10, 32, 35].
Urban spatial structure & polycentricity	9/50 (18%)	Evolution from monocentric to polycentric urban forms, distributing economic activity and fostering balanced regional growth [17, 25].
COVID-19 impacts	6/50 (12%)	Pandemic-induced functional shifts, commercial vacancies, and altered residential demand patterns requiring flexible planning responses [7, 18, 29].
Governance & policy frameworks	5/50 (10%)	Integrated governance approaches, regulatory innovation, and stakeholder collaboration for sustainable urban centers [25, 36, 37].
Volumetric & 3D urban planning	4/50 (8%)	Emerging three-dimensional analyses addressing density challenges and vertical mixed-use integration through volumetric urbanism [4, 38].
Ethical & social challenges	3/50 (6%)	Concerns regarding privacy, surveillance, and equity in smart technology deployment, necessitating balanced governance frameworks [8, 12, 20].



**Figure 10.** Distribution of dominant research themes across the reviewed literature

#### 5.4 Chronological distribution of research directions

To elucidate the chronological evolution of scholarly thought on city center land-use planning; as shown in Table 3, the literature is organized into distinct temporal phases. The following table delineates these sequential periods, summarizing the predominant research directions and thematic priorities that characterized each interval. This chronological framing allows for a clear understanding of how academic focus has shifted in response to technological advancements, societal challenges, and emerging urban paradigms.

**Table 3.** Chronological evolution of research directions in urban land-use planning

Year Range	Research Direction	Description
1991–2005	Foundational urban planning models	Research focused on integrated land use and transportation strategies, urban containment policies, and growth management programs to revitalize city center and manage congestion. Early modeling efforts explored the role of land-use models in strategic planning.
2014–2018	Participatory and transit-oriented planning	The emphasis shifted to innovative participatory tools such as virtual reality for public engagement and Transit-Oriented Development models promoting sustainable urban densification around transit hubs. Studies began exploring volumetric urbanism and mixed-use zoning.
2020–2022	Urban resilience and post-pandemic shifts	Investigations centered on the impacts of COVID-19 on downtown land use, with a focus on changes in commercial and residential real estate, vacancy trends, and adaptive reuse strategies. Sustainability and 15-minute city planning paradigms gained traction.
2023–2024	Smart cities, AI, and sustainability integration	A surge in research on smart city technologies, AI-enhanced GIS, digital twins, and IoT integration emerged to support dynamic, data-driven land-use planning. Studies explored mixed-use development,

2025	Advanced computational methods and digital economy	community participation, and sustainability frameworks to address urban challenges and climate resilience.
		The latest research advances computational intelligence algorithms for land-use allocation, investigates the disruptive influence of the digital economy on urban land value and function, and emphasizes synergistic AI and digital twin applications for environmentally sustainable smart city planning.

#### 5.5 Agreement and divergence across studies

To critically assess the coherence and contradictions within the extant literature, the following table (Table 4) provides a systematic comparison of scholarly perspectives across four pivotal planning criteria. It delineates the central points of agreement that form the dominant narrative, juxtaposed with significant points of divergence that reveal critical debates and limitations in the current body of knowledge. This comparative analysis highlights the nuanced and often context-dependent nature of urban planning paradigms.

**Table 4.** Summary of consensus and divergence

Criterion	Consensus Position (Number of Studies Agreeing)	Divergent Perspectives (Number of Studies)
Technological integration	Transformative potential of AI, IoT, digital twins (42/50)	Concerns about equity, data privacy, infrastructure readiness (15/50)
Sustainability & resilience	Embedding green infrastructure and climate adaptation (45/50)	Challenges in implementation and social equity integration (18/50)
Functional mix diversity	Benefits for vibrancy and resilience (40/50)	Negative externalities (traffic, exclusivity) (12/50)
Predictive model accuracy	Growing value of advanced models (35/50)	Limitations in data, complexity, policy integration (20/50)

Note: Numbers reflect explicit mention or clear implication in each study; not all studies addressed every criterion.

## 6. DISCUSSION

### 6.1 Interpretation of key findings

The results reveal several patterns that warrant interpretation. First, the high proportion of studies emphasizing technological integration (48%) and advanced digital tools (36% with high integration) indicates a prevailing orientation within the literature toward data-driven, technology-enabled planning. While the quantity of studies on AI, digital twins, and IoT is substantial, only 30% of studies demonstrated high adoption of predictive modeling (e.g., machine learning, neural networks, optimization), with 40% showing moderate adoption (scenario simulation, GIS-based models) and 20% limited adoption (conceptual frameworks). This distribution suggests a gap between technological promise and the *systematic, validated*

application of predictive tools—a gap further compounded by the absence of standardized benchmarking and longitudinal validation protocols across the reviewed literature.

Second, the near parity between comprehensive sustainability integration (40%) and conceptual-only emphasis (36%) points to a techno-optimistic slant in the literature: many studies assume that technological solutions will automatically deliver sustainability outcomes, without empirically testing social equity dimensions or governance mechanisms. Only 24% of studies explicitly addressed socioeconomic disparities in sustainability frameworks, and ethical challenges appeared in just 6% of the sample. This imbalance suggests that the field prioritizes environmental and technical aspects of sustainability over its distributive justice components.

Third, the strong consensus on mixed-use development (44% strong emphasis) coexists with limited attention to negative externalities (only 12% of studies raised concerns about traffic or social exclusion) and even less attention to vertical spatial dynamics (8% on volumetric urbanism). This divergence indicates that while functional diversity is widely endorsed as a normative goal, the operational knowledge required to implement it without adverse effects remains underdeveloped.

## 6.2 Systematic Strengths, Weaknesses, Opportunities, Threats analysis of literature

To critically evaluate the scholarly landscape, a systematic SWOT analysis was conducted across six pivotal dimensions of contemporary urban land-use planning. This analytical framework moves beyond mere description to provide a synthesized critique of the field's current capabilities and limitations. The following synthesis, presented in Table 5, is derived from a rigorous examination of the 50 studies included in this review, identifying recurrent strengths and exposing critical weaknesses that define the present state of research. This structured assessment serves to illuminate the dominant paradigm shifts and the persistent challenges that characterize the discourse on future city center.

### 6.2.1 Strengths, Weaknesses, Opportunities, Threats framework derivation and validation

The SWOT analysis was derived through a three-stage process:

**Inductive category generation:** Two researchers independently read all 50 included studies and extracted verbatim claims or recurring themes that could be classified as strengths, weaknesses, opportunities, or threats related to land-use planning in city centers. This yielded an initial pool of 124 extracted items.

**Thematic synthesis:** Extracted items were grouped into six thematic dimensions (Technological integration, Sustainability, Mixed-use development, Digital economy impact, Predictive modeling, Governance). Duplicate or overlapping items were merged.

**Validation through thematic saturation and team consensus:** After the initial extraction and synthesis, the research team conducted an iterative review of all items against the six dimensions. New items were added until thematic saturation was reached (no new codes emerged from three consecutive studies). The full research team (three members) then independently mapped 30% of randomly

selected items into categories; agreement reached 94%. The final SWOT structure was endorsed by team consensus.

This synthesis moves beyond a descriptive summary to present a systematic evaluation of the contemporary scholarly landscape. The analysis, structured through a rigorous SWOT framework, elucidates both the field's capabilities and its persistent challenges, revealing several overarching thematic tensions that define the current paradigm.

The most prominent finding is the field's significant technological ascendancy. There is a clear paradigm shift towards data-centric planning, marked by the robust integration of advanced digital tools—such as AI, IoT, and digital twins—for predictive modeling and real-time urban management. These technologies are positioned as central enablers of a more efficient and responsive planning future. However, this technological ambition is critically undermined by persistent implementation gaps. A salient disconnect exists between computational potential and on-the-ground execution.

Key weaknesses include unresolved ethical concerns over data use, a pervasive lack of longitudinal model validation, and significant difficulties in translating algorithmic insights into actionable, equitable policy. This is compounded by a distinct sustainability-governance divide; while sustainability and climate resilience are widely embraced as core principles, their implementation often prioritizes technological or environmental solutions at the expense of deeper socioeconomic inclusivity and effective governance frameworks.

Furthermore, the literature demonstrates a nuanced understanding of complex urban dynamics, particularly the impact of the digital economy and pandemic-induced shifts, which has spurred a focus on adaptive reuse and functional mix. Nonetheless, analyses in this domain are often nascent, lacking the long-term data required to fully comprehend and project these evolving trends.

In conclusion, the field finds itself at a crossroads, characterized by remarkable conceptual and technological advancements yet hampered by systemic implementation failures. The primary challenge identified is not a deficit of innovative tools, but rather the absence of holistic, transdisciplinary approaches. The overarching imperative is to bridge the gap between high-tech innovation and the nuanced realities of socio-political governance, thereby forging a path toward truly resilient, equitable, and implementable urban stewardship.

## 6.3 Comparison with previous literature

Work on the evolution of land-use planning in city center reveals a definitive trajectory from foundational, policy-centric models to increasingly complex, technology-driven, and sustainability-focused frameworks. The field's initial phase prioritized integrated land-use transportation, urban containment, and central business district revitalization. A pivotal transition occurred in the mid-2010s, marked by a growing emphasis on participatory methodologies and three-dimensional spatial modeling. The contemporary research landscape, particularly from 2020 onward, has been decisively shaped by the dual impact of the COVID-19 pandemic and the digital revolution, accelerating a focus on urban resilience, smart city paradigms, and the integration of artificial intelligence, IoT, and data-driven analytics to

address climate adaptation and socioeconomic transformations. The most recent scholarly directions point towards a mature integration of these elements, employing advanced computational methods and predictive analytics to navigate the complexities of the digital economy and climate

imperatives. This progressive evolution underscores a fundamental shift in the discipline- from reactive planning to proactive, predictive, and integrated urban management aimed at fostering resilient, inclusive, and adaptive city center.

**Table 5.** A systematic Strengths, Weaknesses, Opportunities, Threats analysis of contemporary urban land-use planning literature

Aspect	Strengths (S)	Weaknesses (W)	Opportunities (O)	Threats (T)	Supporting Evidence (References)
Technological integration & digital tools	Advanced adoption of AI, digital twins, and IoT for data-driven planning; enables real-time monitoring and predictive modeling for improved decision-making	Challenges in data availability, privacy, and ethical concerns; lack of longitudinal validation and data interoperability issues	Leveraging AI and digital twins for predictive urban management and optimized resource allocation; potential for integrating emerging technologies (e.g., Blockchain) for secure data management	Widening the "digital divide" between well-resourced and marginalized communities; risk of technological lock-in and vendor dependency, limiting flexibility	S: [2, 12, 20, 26, 28, 32] W: [8, 12, 20, 26, 39, 40] O: [12, 20, 32, 38, 41] T: [36, 39, 41]
Sustainability & resilience	Strong integration of green infrastructure and climate-adaptive strategies; empirical evidence from successful smart city initiatives	Under-addressed socioeconomic disparities and governance challenges; limited representation of implementation challenges in developing contexts	Promoting green infrastructure as a multi-functional asset for ecological, social, and economic benefits; aligning with global sustainability agendas (e.g., SDGs) to attract funding and political support	Escalating climate change impacts may outpace implementation of adaptive measures; risk of "green gentrification" where sustainability investments displace vulnerable populations	S: [2, 6, 19, 20, 22, 23, 42, 43] W: [11, 37, 39, 42] O: [2, 6, 23, 34, 43] T: [2, 11, 44]
Mixed-use development & functional diversity	Documented benefits for social interaction and economic vitality; advanced computational methods for optimization	Underexplored negative externalities like traffic and social exclusivity; inadequate capture of vertical spatial dynamics	Utilizing 3D volumetric modeling to optimize vertical mixed-use and address land scarcity; post-pandemic demand for live-work-play environments supports the mixed-use paradigm	Market forces favoring high-value commercial uses can undermine diversity of functions, leading to homogenization; inadequate regulatory frameworks may fail to manage land-use conflicts in dense mixed-use areas	S: [3, 10, 13, 31, 32, 45] W: [4, 13, 31, 44, 45] O: [4, 7, 13, 20, 38] T: [8, 31, 44, 46]
Impact of digital economy & COVID-19	Valuable insights into land use patterns and adaptive strategies; supports policy responses for urban adaptation	Geographically limited analyses with insufficient longitudinal data; nascent and fragmented policy frameworks	Accelerating adaptive reuse of underutilized commercial spaces (e.g., offices to residential); designing flexible zoning codes that can accommodate rapid and unforeseen economic shifts	Permanent reduction in demand for traditional commercial space leading to urban vacancies and fiscal stress; erosion of tax base in city centers due to decoupling of economic activity from physical space	S: [2, 7, 8, 18] W: [8, 18, 29, 36, 47] O: [7, 8, 18] T: [8, 18, 29]
Predictive modeling & scenario analysis	Wide adoption of advanced techniques for spatial forecasting; supports strategic planning and sustainable growth	Inadequate capture of socio-political complexity; limited integration into practical planning; data availability and quality constraints. Lack of standardized benchmarking prevents cross-study comparison	Enhancing public engagement through transparent and interactive scenario-planning tools; creating digital twins as a collaborative platform for interdisciplinary planning and stakeholder alignment. Development of standardized validation protocols	Over-reliance on models may lead to technocratic planning, marginalizing qualitative human factors; rapid obsolescence of models and tools due to fast-paced technological change. Risk of overclaiming predictive accuracy without standardized benchmarking	S: [9, 10, 13, 32, 35, 48] W: [33, 36, 38, 45] O: [12, 20, 22, 40] T: [33, 36, 39]
Governance & policy integration	Critical insights into governance frameworks and collaborative approaches; emphasis on multi-stakeholder engagement	Policy fragmentation and institutional inertia; gap in translating technological advances into equitable policy	Developing agile and adaptive governance models that can keep pace with technological and social change; leveraging digital platforms to foster more participatory and transparent governance (e-platforms, VR)	Siloed government institutions and bureaucratic inertia hindering integrated planning; policy capture by powerful interest groups, leading to inequitable outcomes	S: [19, 22, 25, 36, 49] W: [11, 36, 39, 42] O: [19, 22, 36, 42, 49] T: [11, 36, 39, 44]

## 6.4 Summary of consensus and divergence

The comparative analysis reveals four main areas of consensus alongside notable divergences, each with specific supporting sources.

First, regarding technological integration, there is widespread agreement on the transformative potential of digital technologies (AI, IoT, digital twins, GIS) for enhancing planning processes and smart city governance [2, 5, 12, 13, 20, 28, 36, 42, 43]. However, divergent perspectives raise concerns about equitable access, infrastructure readiness, data availability, and ethical risks including privacy and surveillance [12, 20, 39, 41]. These divergences are explained by differences in urban contexts (developed vs. developing), technological maturity, and socio-political frameworks influencing adoption and governance.

Second, on sustainability and resilience, a strong consensus exists on embedding sustainability through green infrastructure, climate adaptation, and social inclusiveness aligned with smart city concepts [1, 2, 6, 11, 19, 34, 42, 43, 50]. Nevertheless, questions persist about practical implementation challenges in resource-limited contexts and variations in incorporating social equity and cultural values [34, 37, 50]. Variations in local capacities, governance models, economic contexts, and methodological differences between conceptual frameworks and empirical studies account for these gaps.

Third, functional mix diversity is generally emphasized for its benefits to urban vibrancy, resilience, and efficient land use, supported by spatial and volumetric analyses [3, 4, 10, 15, 16, 32, 35, 47]. Conversely, concerns are raised about potential negative effects including increased traffic, social exclusivity, and disruption of existing land uses, alongside debate on local appropriateness [3, 32, 47]. Context-specific urban morphology, differing analytical scales, variations in implementation, and the influence of stakeholder priorities and market forces explain these divergences [51].

Fourth, regarding predictive model use, there is agreement on the growing utilization and value of advanced predictive models (AI-GIS, multi-objective optimization) for improving planning precision and adaptability [4, 10, 13, 28, 29, 32, 35, 45]. However, limitations are recognized in model complexity, data availability, challenges in capturing socioeconomic dynamics, and limited policy integration reducing generalizability [8, 28, 33]. Variability in data quality, geographic focus, model sophistication, and differences in incorporating behavioral or policy variables versus physical/spatial factors explain these divergences.

In summary, while the field converges on technology-driven, sustainability-oriented goals, the persistent disagreements—supported by distinct sets of references—highlight critical contextual and institutional barriers that future research must address.

## 6.5 Theoretical implications

- The synthesis of research findings signifies a fundamental paradigm shift in land-use planning theory, transitioning from traditional static models based on physical footprints toward dynamic, data-driven frameworks that integrate digital economy impacts and environmental constraints. This transformation challenges conventional urbanism assumptions by demonstrating the progressive erosion of physical spatial anchorage resulting from digitization and

climate pressures [2, 8].

- The incorporation of volumetric and three-dimensional spatial analysis into theoretical frameworks has expanded conceptual understandings of urban density and mixed-use development beyond conventional horizontal land allocation paradigms. This theoretical advancement highlights the complexity of vertical urbanism and underscores the necessity for multidimensional planning models [4, 13].
- Literature substantiates the growing theoretical emphasis on polycentric urban structures and functional diversity as strategic mechanisms for decentralizing economic activities and enhancing urban resilience. This theoretical development aligns with evolving master planning paradigms that seek to balance traditional centrality with distributed regional hubs [3, 17].
- Community engagement and participatory planning have been theoretically reinforced as essential components in shaping sustainable and inclusive city center. Emerging digital platforms and virtual reality technologies provide innovative theoretical frameworks for stakeholder involvement and social sustainability implementation [19, 22].
- The convergence of artificial intelligence, Internet of Things, and digital twin technologies introduces a new theoretical foundation for smart, adaptive, and predictive land use management. This integrated approach emphasizes the synergistic potential of technological integration to advance environmental sustainability and urban resilience [12, 20].
- Conventional land valuation and planning models face theoretical challenges as research demonstrates how digital economy disruptions decouple land value from physical proximity. These findings necessitate revised theoretical approaches that incorporate digital behavioral patterns and platform urbanism dynamics [8].

## 6.6 Practical implications

- Policymakers and urban planners should develop adaptive, data-informed land use regulations that anticipate reduced demand for conventional land uses due to digital transformation, thereby facilitating strategic reallocation of urban space for climate-resilient infrastructure and environmental adaptation [2, 8].
- The implementation of three-dimensional spatial modeling and volumetric urbanism methodologies enables more precise land use allocation and supports the design of vertically integrated mixed-use developments, effectively addressing urban density constraints while optimizing spatial efficiency [4, 13].
- Urban governance institutions should promote polycentric development frameworks to distribute economic activities across urban centers and regional hubs, alleviating congestion in central business districts while fostering balanced regional development [3, 17].
- Digital participatory platforms and virtual reality simulations can significantly enhance stakeholder engagement in planning processes, ensuring diverse community perspectives inform land use decisions and promoting socially equitable outcomes [19, 22].
- The integration of artificial intelligence, Internet of Things networks, and digital twin systems provides robust technical capacity for real-time urban analytics, scenario planning,

and predictive modeling, enabling more efficient infrastructure management and evidence-based resource distribution [12, 20, 52].

- Municipal authorities should reform land valuation methodologies and regulatory instruments to account for digital economy impacts on spatial patterns and property values, ensuring planning frameworks remain responsive to evolving urban market dynamics [8].

## 7. LIMITATIONS OF THE LITERATURE

This research, while providing a synthesis of urban land use literature, acknowledges several limitations inherent in its approach. As shown in Table 6, most of the reviewed literature is in English-language publications may introduce a cultural

and geographic Skew, potentially omit relevant studies and reinforce the existing geographic Skew found in the predominantly region-specific literature under review. Consequently, the generalizability of the findings is constrained.

The review is also shaped by the methodological constraints and data limitations prevalent in the primary studies, such as their reliance on simulations and cross-sectional data, which challenged efforts to derive robust, longitudinal insights. Furthermore, this study inherits literature’s narrow thematic focus on specific urban functions and, as a secondary analysis, could not address the lack of primary data to investigate critical gaps like community engagement or ethical concerns. Other potential contextual factors also limit the scope of the conclusions. This acknowledgment aims to contextualize the findings and highlight avenues for more comprehensive future research.

**Table 6.** Limitations of literature

Area of Limitation	Description of Limitation	Exemplary References
Geographic Skew	Several studies exhibit a geographic Skew, focusing predominantly on specific cities or regions, which limits the external validity and generalizability of findings to diverse urban contexts globally. This constrains the applicability of conclusions across different socioeconomic and cultural settings.	[8, 9]
Methodological constraints	Many papers rely on simulation models, case studies, or cross-sectional data, which may not capture long-term dynamics or causal relationships, thereby limiting the robustness of their conclusions and the generalizability of their findings. Additionally, the lack of standardized benchmarking across studies precludes any comparative judgment of predictive accuracy.	[4, 29, 35]
Data availability and quality	Limitations in data availability, granularity, and real-time access hinder comprehensive analysis and validation of urban land use models. Insufficient or incomplete datasets reduce the precision of spatial and functional analyses, impacting the validity of planning recommendations.	[38, 40]
Technological and implementation challenges	While many studies highlight innovative technological solutions, they often underemphasize practical challenges such as financial, policy, ethical, and governance barriers, which can impede real-world implementation and scalability of proposed urban planning strategies.	[12, 20, 50]
Limited longitudinal studies	The scarcity of longitudinal research tracking actual changes over time restricts understanding of evolving land use patterns and the sustained impact of interventions, thereby limiting the evidence base for long-term planning efficacy and the validation of predictive modeling adoption over time.	[8, 29]
Narrow focus on specific urban functions	Some literature concentrates on particular urban functions (e.g., commercial or residential) without fully integrating multifunctional or mixed-use perspectives, which limits holistic understanding of complex urban dynamics and interactions.	[3, 31, 44]
Insufficient community engagement analysis	Despite recognizing community participation's importance, few studies deeply analyze its influence on land use outcomes, limiting insights into social inclusiveness and stakeholder-driven planning processes.	[19, 22]
Ethical and privacy concerns underexplored	Emerging digital and data-driven urban planning approaches raise critical ethical and privacy issues that are insufficiently addressed, potentially undermining public trust and equitable urban development.	[12, 46]

## 8. GAPS AND FUTURE RESEARCH DIRECTIONS

As shown in Table 7, the literature reveals several critical research gaps that must be addressed to advance the field of urban land use and smart city planning. The most pressing gaps—rated as high priority—include the lack of longitudinal validation of predictive models, insufficient attention to socioeconomic disparities in sustainability frameworks, unresolved ethical and privacy concerns in digital twin and AI applications, the limited understanding of long-term digital economy impacts on land value and function, weak translation of technological advances into policy implementation, and the exclusion of marginalized populations from smart city planning. These gaps collectively hinder the reliability, equity,

and practical adoption of emerging technologies and governance models.

Medium-priority gaps concern vertical (3D) spatial dynamics in mixed-use planning and cross-boundary functional mix coordination, reflecting the need for more sophisticated spatial and institutional approaches. The table also highlights a missing comprehensive integration of environmental, social, and economic indicators, pointing toward the development of multi-criteria assessment tools. Addressing these gaps through the proposed future research directions—such as longitudinal multi-city studies, inclusive engagement frameworks, and interdisciplinary governance models—will be essential for building resilient, equitable, and evidence-based urban land use policies.

**Table 7.** Gaps, future research directions and research priority

Gap Area	Description	Future Research Rirections	Justification	Research Priority
Longitudinal validation of predictive models	Many advanced predictive models lack longitudinal validation to assess their reliability and generalizability over extended periods and across different urban contexts.	Conduct long-term empirical studies to validate AI, machine learning, and simulation models in diverse urban contexts, focusing on model reliability, adaptability, and the development of standardized benchmarking protocols that would enable meaningful cross-study comparisons in the future.	Without longitudinal validation and standardized benchmarking, confidence in model forecasts remains limited, and comparative judgments of predictive accuracy are not defensible—hindering practical adoption and policy integration.	High
Addressing socioeconomic disparities in sustainability frameworks	Sustainability strategies frequently overlook socioeconomic inequalities and governance challenges in city center.	Investigate multi-dimensional sustainability frameworks that explicitly incorporate equity, governance, and socioeconomic factors, especially in resource-constrained and rapidly urbanizing cities.	Ignoring socioeconomic disparities risks exacerbating urban inequities and undermines the effectiveness of sustainability initiatives [11, 42].	High
Vertical (3D) spatial dynamics in mixed-use planning	Most models inadequately capture vertical land use complexity critical in dense city center.	Advance 3D volumetric modeling techniques integrating vertical functional diversity and land use interactions, validated with real-world data from high-density urban environments.	Vertical spatial dynamics significantly affect land use compatibility and urban vitality but remain underexplored [3, 4].	Medium
Ethical and privacy concerns in digital twin and AI applications	Deployment of AI-powered digital twins raises unresolved ethical issues related to data privacy and equitable benefit distribution.	Conduct interdisciplinary research on governance frameworks, ethical standards, and privacy-preserving technologies tailored for urban digital twin implementations.	Addressing ethical challenges is essential for public trust and equitable adoption of smart city technologies [12, 20].	High
Long-term impacts of digital economy on land value and function	Current studies on digital economy effects are preliminary, with limited longitudinal and geographic scope.	Perform longitudinal, multi-city analyses to disentangle digital economy impacts on land value dynamics, functional mix, and urban spatial structure post-COVID-19.	Understanding persistent digital economy effects is critical for adaptive land use policies and urban resilience [8, 18, 29].	High
Bridging technological advances and policy implementation	There is a gap between innovative technological tools and their translation into actionable urban policies and governance.	Explore institutional barriers and develop integrative policy frameworks that facilitate the adoption of AI, IoT, and GIS tools in urban land use governance.	Effective urban transformation requires aligning technology with governance structures, which is currently insufficient [36].	High
Cross-boundary and multi-scale functional mix coordination	Functional mix planning often neglects cross-administrative boundaries and multi-scale spatial interactions.	Develop multi-scale, cross-jurisdictional planning models and cooperative governance mechanisms to optimize functional mix and urban regeneration across boundaries.	Effective functional mix requires coordination beyond municipal boundaries, which is rarely addressed in current literature [11].	Medium
Inclusion of marginalized populations in smart city planning	Disparities in technology access limit equitable community participation in smart city initiatives.	Design inclusive digital platforms and outreach strategies to engage marginalized groups in urban planning processes, ensuring equitable benefits from smart technologies.	Without inclusive engagement, smart city benefits risk reinforcing existing social inequalities [41, 50].	High
Comprehensive integration of environmental, social, and economic indicators	Most sustainability assessments are not holistic; they focus only on environmental OR economic aspects.	Develop integrated multi-criteria assessment tools combining environmental, social, and economic indicators for balanced urb		

**9. OVERALL SYNTHESIS AND CONCLUSION**

The literature on the future of land-use planning in the city center reveals a paradigm shift driven by the convergence of technological innovation, sustainability imperatives, and evolving socioeconomic dynamics. Digital technologies—including artificial intelligence, digital twins, IoT, and advanced spatial analysis tools—are being progressively integrated into planning frameworks, enabling real-time monitoring, predictive modeling, and scenario analysis that

enhance adaptive urban management. These tools provide planners with unprecedented capabilities to simulate urban growth trajectories, optimize land allocation, and respond proactively to changing functional requirements. However, significant challenges persist regarding data privacy, ethical implications, and the technical complexities of integrating heterogeneous data sources, which continue to hinder widespread implementation. Furthermore, despite the growing adoption of predictive models for forecasting spatial and functional transformations, their incorporation into practical

planning processes and policy formulation remains inconsistent, highlighting enduring institutional and technical barriers.

Sustainability and resilience principles have emerged as central themes, with numerous studies advocating for green infrastructure implementation, climate-adaptive land use strategies, and mixed-use development as essential approaches for creating environmentally sound and socially resilient city center. Literature consistently emphasizes the necessity of aligning ecological objectives with social equity considerations and economic viability. Nevertheless, substantial gaps remain in addressing socioeconomic disparities and governance limitations that impede equitable implementation, particularly in rapidly urbanizing regions and resource-constrained contexts [53]. Mixed-use development is widely endorsed as a crucial strategy for enhancing urban vitality and functional diversity, effectively balancing residential, commercial, and public space requirements. However, the intricate task of managing complementary uses to mitigate potential negative externalities—such as traffic congestion or social exclusion—demands more sophisticated approaches, especially in understanding and managing vertical spatial relationships within high-density urban environments.

Community engagement is increasingly recognized as fundamental to inclusive and responsive planning, with innovative participatory mechanisms including virtual reality platforms and digital tools substantially enhancing stakeholder collaboration. Despite this recognition, the practical application of participatory methodologies remains irregular, frequently constrained by accessibility limitations and the absence of comprehensive frameworks for systematically incorporating community input into data-informed planning processes. Concurrently, digital economy transformations and pandemic-induced adaptations have fundamentally disrupted conventional land use and valuation paradigms, accelerating trends toward remote work and digital commerce that progressively decouple urban functions from physical proximity. While these disruptions present opportunities for adaptive reuse and flexible planning approaches, their long-term implications remain uncertain, exacerbated by geographical and temporal limitations in current research.

In conclusion, the future trajectory of urban land-use planning is being shaped by the dynamic interplay of sophisticated technological tools, sustainability requirements, socioeconomic transformations, and participatory governance mechanisms. Realizing resilient, inclusive, and environmentally responsible city center will necessitate overcoming persistent data and institutional challenges, promoting equitable community involvement, and effectively integrating advanced predictive analytics with practical policy frameworks. This comprehensive approach provides valuable guidance for policymakers, planning professionals, and researchers navigating the complexities of urban transformation toward sustainable and adaptive city center that can respond to emerging challenges and opportunities.

## ACKNOWLEDGMENT

We would like to express our sincere gratitude to Dr. Mahmoud Mabrouk, the Faculty of Urban and Regional Planning, Cairo University, for his technical and linguistic review of the research: <https://orcid.org/0000-0003-1148-4920>. The authors thank their native English-speaking

colleagues for their careful language proofreading of the revised manuscript.

## REFERENCES

- [1] Hameed, A.A.S. (2021). Urban and regional planning strategies to achieve sustainable urban development: (Subject review). *International Journal of Advanced Science and Research Engineering*, 7(3): 22-27. <https://doi.org/10.31695/IJASRE.2021.33980>
- [2] Özdilek, Ü. (2025). Digitally melting cities under climate stress. *Discover Cities*, 2: 60. <https://doi.org/10.1007/s44327-025-00099-7>
- [3] Crosas, C., Gómez-Escoda, E., Villavieja, E. (2024). Interplay between land use planning and functional mix dimensions: An assemblage approach for metropolitan Barcelona. *Sustainability*, 16(17): 7734. <https://doi.org/10.3390/su16177734>
- [4] Hsu, Y.Y., Han, H. (2024). Toward volumetric urbanism: Analysing the spatial-temporal dynamics of 3d floor space use in the built environment. *Environment and Planning B: Urban Analytics and City Science*, 52(5): 1181-1196. <https://doi.org/10.1177/23998083241286592>
- [5] Benini, S.M., da Silva, A.L.C., de Godoy, J.A.R., Palmisano, A. (2024). Smart cities for urban planning: A bibliometric-conceptual analysis. *International Journal of Business and Management*, 19(6): 92-108. <https://doi.org/10.5539/ijbm.v19n6p92>
- [6] Raghubanshi, A.S. (2024). Sustainable urban planning: A comparative study of green city initiatives around the world. *Journal of Sustainable Solutions*, 15(3): 18-23. <https://doi.org/10.36676/j.sust.sol.v1.i3.16>
- [7] Hutson, N., Orlando, A.W. (2023). The effects of COVID-19 on downtown land use: Evidence from four U.S. Cities. *Journal of Urban Affairs*, 47(2): 547-565. <https://doi.org/10.1080/07352166.2023.2195665>
- [8] Harun, I., Yigitcanlar, T. (2025). Urban land use and value in the digital economy: A scoping review of disrupted activity. *Land*, 14(8): 1647. <https://doi.org/10.3390/land14081647>
- [9] Henriquez, C., Morales, M., Quense, J., Hidalgo, R. (2022). Future land use conflicts: Comparing spatial scenarios for urban-regional planning. *Environment and Planning B: Urban Analytics and City Science*, 50(2): 332-349. <https://doi.org/10.1177/23998083221111404>
- [10] Aosaf, S., Nayeem, M.A., Haque, A., Rahman, M.S. (2025). Computational intelligence based land-use allocation approaches for mixed use areas. *arXiv preprint arXiv:2508.15240*. <https://doi.org/10.48550/arxiv.2508.15240>
- [11] Khamdamov, S.J., Usmanov, A. (2024). Sustainable cities and communities: Urban planning and development strategies. *Journal of Artificial Intelligence and Digital Economy*, 1(7): 76-81. <https://doi.org/10.61796/jaide.v1i7.794>
- [12] Hooli, M. (2025). Digital twins and urban planning: Designing smarter, more inclusive cities. *European Journal of Computer Science and Information Technology*, 13(44): 104-112. <https://doi.org/10.37745/ejsit.2013/vol13n44104112>
- [13] Dong, W.X., Wu, N.N., Xiang, G.F., Wu, X.J., Li, J.X. (2025). Spatial data analysis and urban functional zoning

- optimization in smart city development. *International Journal of High Speed Electronics and Systems*, 35(4): 2540634. <https://doi.org/10.1142/s0129156425406345>
- [14] Hall, T. (1998). *Urban Geography*. Routledge. <https://www.muthar-alomar.com/wp-content/uploads/2020/02/Urban-Geography.pdf>.
- [15] Mensing, K., Anders, U., Fanelli-Falcke, J., Hauschild, A., et al. (2020). Zukunft der (stadt-)zentren ohne handel? Neue impulse und nutzungen für zentren mit zukunft. *Akademie Fürraumentwicklung in Derleibniz-Gemeinschaft*. <https://d-nb.info/1213315859/34>.
- [16] Cervero, R. (1991). Congestion relief: The land use alternative. *Journal of Planning Education and Research*, 10(2): 119-130. <https://doi.org/10.1177/0739456X9101000209>
- [17] Wu, C., Wang, M.S., Wang, J., Smith, D., Kraak, M.J. (2024). 'Local hubs and global gateways': Understanding the impact of Singapore's master plan on urban polycentricity. *Environment and Planning B: Urban Analytics and City Science*, 52(4): 789-803. <https://doi.org/10.1177/23998083241267070>
- [18] Vigiola, G.Q., Cilliers, J., Lozano-Paredes, L.H. (2022). Reimagining the future of the Sydney CBD: Reflecting on COVID-19-driven changes in commercial and residential property trends. *Urban Planning*, 7(3): 49-62. <https://doi.org/10.17645/up.v7i3.5298>
- [19] Pozoukidou, G., Angelidou, M. (2022). Urban planning in the 15-minute city: Revisited under sustainable and smart city developments until 2030. *Smart Cities*, 5(4): 1356-1375. <https://doi.org/10.3390/smartcities5040069>
- [20] Bibri, S.E., Huang, J., Jagatheesaperumal, S.K., Krogstie, J. (2024). The synergistic interplay of artificial intelligence and digital twin in environmentally planning sustainable smart cities: A comprehensive systematic review. *Environmental Science & Ecotechnology*, 20: 100433. <https://doi.org/10.1016/j.ese.2024.100433>
- [21] Forester, J. (1982). Planning in the face of power. *Journal of the American Planning Association*, 48(1): 67-80. <https://doi.org/10.1080/01944368208976167>
- [22] Stauskis, G. (2014). Development of methods and practices of virtual reality as a tool for participatory urban planning: A case study of Vilnius city as an example for improving environmental, social and energy sustainability. *Energy, Sustainability and Society*, 4: 7. <https://doi.org/10.1186/2192-0567-4-7>
- [23] Cieszewska, A. (2000). Green urbanism: Learning from European cities [Review of the book *Green Urbanism: Learning from European cities*, by T. Beatley]. *Landscape and Urban Planning*, 51(1): 64-65. [https://doi.org/10.1016/S0169-2046\(00\)00074-8](https://doi.org/10.1016/S0169-2046(00)00074-8)
- [24] 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>
- [25] Dawkins, C.J., Nelson, A.C. (2003). State growth management programs and central-city revitalization. *Journal of the American Planning Association*, 69(4): 381-396. <https://doi.org/10.1080/01944360308976326>
- [26] Zanella, A., Bui, N., Castellani, A., Vangelista, L., Zorzi, M. (2014). Internet of Things for smart cities. *IEEE Internet of Things Journal*, 1(1): 22-32. <https://doi.org/10.1109/JIOT.2014.2306328>
- [27] Lungu, M. (2022). The coding manual for qualitative researchers. *American Journal of Qualitative Research*, 6(1): 232-237. <https://doi.org/10.29333/ajqr/12085>
- [28] Anwar, M.R., Sakti, L.D. (2024). Integrating artificial intelligence and environmental science for sustainable urban planning. *IAIC Transactions on Sustainable Digital Innovation (ITSDI)*, 5(2): 179-191. <https://doi.org/10.34306/itsdi.v5i2.666>
- [29] Buda, E., Broitman, D., Czamanski, D. (2023). Land value dynamics and the spatial evolution of cities following COVID 19 using big data analytics. *The Annals of Regional Science*, 70: 429-445. <https://doi.org/10.1007/s00168-022-01153-7>
- [30] Giddings, B., Rogerson, R.J. (2022). *The Future of the City Centre: Global Perspectives (1st ed.)*. Routledge. <https://doi.org/10.4324/9781003141198>
- [31] Heptig, M. (2023). Die mischung macht's? Das shopping-center wird zum mixed-use-center. *Standort*, 47: 237-246. <https://doi.org/10.1007/s00548-023-00877-8>
- [32] He, Y., Yuan, H., Yao, Q., Wang, Z.L. (2021). Research and exploration of land use in core area of urban central rail transit station based on AI technology. In *2021 4th International Conference on Artificial Intelligence and Big Data (ICAIBD)*, Chengdu, China, pp. 645-650. <https://doi.org/10.1109/ICAIBD51990.2021.9459099>
- [33] Couclelis, H. (2005). "Where has the future gone?" Rethinking the role of integrated land-use models in spatial planning. *Environment and Planning A*, 37(8): 1353-1371. <https://doi.org/10.1068/a3785>
- [34] Lim, S.B., Abdullah, J., Abdul Rashid, M.F., Danial, M.H., Low, S.P. (2024). Sustainable-smart-healthy development framework for urban social spaces imaginary: A review. *Environment-Behaviour Proceedings Journal*, 9(30): 189-194. <https://doi.org/10.21834/e-bpj.v9i30.6218>
- [35] Bittner, O., Burian, J. (2024). Modelling future urban scenarios of land suitability: A case study of Jihlava city. *International Journal of Digital Earth*, 17(1): 2433613. <https://doi.org/10.1080/17538947.2024.2433613>
- [36] Jagtap, R.D., Singh, D.P., Singh, E., Shinde, P. (2024). The role of technology to enhance city development by optimizing strategy formulation and implementation. *Current Approaches in Engineering Research and Technology* 1: 139-156. <https://doi.org/10.9734/bpi/caert/v1/3557G>
- [37] Rajendran, L.P., Odeleye, N.D., Can, A. (2025). *Resilient Cities in the Global South: Rethinking Informality in Urban Planning and Design (1st ed.)*. Routledge. <https://doi.org/10.4324/9781003336709>
- [38] Pasupuleti, M.K. (2024). *GeoDynamics: Innovating urban spaces with GIS and remote sensing technologies*. In *GIS Horizons: Mapping the Future with GIS, Remote Sensing & Urban Dynamics*, pp. 316-335. <https://doi.org/10.62311/nesx/97896>
- [39] Chen, L.H. (2025). Smart cities and social equity: A review of digital urban governance in Southeast Asia. *International Journal of Social Science and Applied Technology*, 1(1): 1-11. <https://doi.org/10.64391/ijssat.v1i1.001>
- [40] Shariatpour, F., Behzadfar, M. (2024). A data-driven interactive system for smart urban planning and design. *International Journal of Digital Innovation in the Built Environment*, 12(1): 1-23. <https://doi.org/10.4018/ijdice.361591>
- [41] Wibowo, A., Amar, M.Y., Mardiana, R., Sobarsyah, M.,

- Sabbar, S.D. (2024). Strategic planning for the development of a smart city in Tangerang, Indonesia: Integrating technology and innovation in urban development. *Journal of Infrastructure, Policy and Development*, 8(9): 5885. <https://doi.org/10.24294/jipd.v8i9.5885>
- [42] Putra, A.A., Makmur, M., Takdir, R.A., Wibowo, A.H., Ladianto, A.J., Munansar, Wulandari, N.R., Nugraha, F.W. (2025). Towards a sustainable city: Strategic approach to smart city development. *Future Cities and Environment*, 11: 1-14. <https://doi.org/10.70917/fce-2025-020>
- [43] Chen, S.C.S. (2024). Planning and development of smart cities based on the concept of sustainable development. *Advances in Economics, Management and Political Sciences*, 96(1): 73-80. <https://doi.org/10.54254/2754-1169/96/2024mur0115>
- [44] Lees, L. (2008). Gentrification and social mixing: Towards an inclusive urban renaissance? *Urban Studies*, 45(12): 2449-2470. <https://doi.org/10.1177/0042098008097099>
- [45] Liu, L., Huang, H., Yang, J.L. (2024). Enhancing detailed planning from functional mix perspective with spatial analysis and multiscale geographically weighted regression: A case study in shanghai central region. *Land*, 13(12): 2154. <https://doi.org/10.3390/land13122154>
- [46] Widener, M.N. (2015). Begone, Euclid!: Leasing custom and zoning provision engaging retail consumer tastes and technologies in thriving urban centers. *Pace Law Review*, 35(3): 834-886. <https://doi.org/10.58948/2331-3528.1897>
- [47] Evans-Cowley, J. (2003). A new land use in downtown: How cities are dealing with telecom hotels. *Journal of Urban Affairs*, 25(5): 551-570. <https://doi.org/10.1111/j.1467-9906.2003.00002.x>
- [48] Wei, H.Y., Wostenholme, L.C., Carruthers, J.I. (2021). Planning and markets at work: Seattle under growth management and economic pressure. *Sustainability*, 13(14): 7634. <https://doi.org/10.3390/su13147634>
- [49] Marsal-Llacuna, M.L., Colomer-Llinàs, J., Meléndez-Frigola, J. (2015). Lessons in urban monitoring taken from sustainable and livable cities to better address the Smart Cities initiative. *Technological Forecasting and Social Change*, 90: 611-622. <https://doi.org/10.1016/j.techfore.2014.01.012>
- [50] Liu, K.C., Yoon, M.H. (2024). Research on urban renewal design in the context of the future community concept. *Sustainability in Environment*, 9(4): 6-23. <https://doi.org/10.22158/se.v9n4p6>
- [51] Udapitiya, G.A.M.A.S.B., Rathnayake, R.M.T., Sylva, K.K.K. (2018). Land-use planning model: A case study on transit-oriented development (TOD). In *ICSBE 2018. Lecture Notes in Civil Engineering*, pp. 183-192. [https://doi.org/10.1007/978-981-13-9749-3\\_17](https://doi.org/10.1007/978-981-13-9749-3_17)
- [52] Aidaoui, A., Dechaicha, A., Alkama, D., Menai, I., Salah, H.S. (2024). Mapping tomorrow's cities: GeoAI strategies for sustainable urban planning and land use optimization. *Journal of Contemporary Urban Affairs*, 8(1): 158-176. <https://doi.org/10.25034/ijcua.2024.v8n1-9>
- [53] Feng, Y.F., Wang, Z.K. (2024). Navigating the future of urban environments: A comprehensive analysis of contemporary urban planning. *Applied and Computational Engineering*, 65: 320-325. <https://doi.org/10.54254/2755-2721/65/20240524>

## APPENDIX

**Appendix (A).** The complete study-level coding matrix

Authors (Year)	Full title	Technological Integration Level	Sustainability & Resilience	Functional Mix Diversity	Consideration of Predictive Modeling in Planning
Hameed (2021) [1]	Urban and regional planning strategies to achieve sustainable urban development	Low (no digital tools, policy focus)	Conceptual (env. sustain., no metrics)	Moderate (advocates integrated land use)	Limited (conceptual framework)
Özdilek (2025) [2]	Digitally melting cities under climate stress	High (real-time data & digital frameworks)	Comprehensive (climate resilience & green infra)	Strong (repurposing land for mixed uses)	High (spatio-temporal big data modeling)
Crosas, C. et al. (2024). [3]	Interplay between land-use planning and functional mix dimensions: An assemblage approach for metropolitan Barcelona	Moderate (GIS & morphological analysis)	Comprehensive (social & env. sustainability)	Strong (detailed mixed-use planning)	Moderate (qualitative & quantitative spatial eval)
Hsu and Han (2024) [4]	Toward volumetric urbanism: Analysing the spatial-temporal dynamics of 3d floor space use in the built environment	Moderate (3D spatial modeling & simulation)	Conceptual (urban density & volumetric sustain.)	Strong (vertical mixed-use floor space)	High (Voxel Automata & Markov models)
Benini et al. (2024) [5]	Smart cities for urban planning: A bibliometric-conceptual analysis	Moderate (bibliometric, not direct application)	Conceptual (env. & social sustain., no metrics)	Moderate (technology-enabled mixed-use)	Limited (identifies trends, no direct prediction)
Raghubans (2024) [6]	Sustainable urban planning: A comparative study of green city initiatives around the world	Moderate (comparative study of green cities)	Comprehensive (sustainability & community engage.)	Moderate (supports mixed-use for resilience)	Limited (case study analysis)
Hutson and	The effects of covid-19 on	Low (economic	Conceptual (urban	Moderate	Limited (descriptive

Orlando (2023) [7]	downtown land use: Evidence from four u.s. Cities	& policy analysis)	resilience, no metrics)	(functional shifts in downtown)	trend analysis)
Harun and Yigitcanlar (2025) [8]	Urban land use and value in the digital economy: A scoping review of disrupted activity	High (systematic review of digital economy)	Conceptual (env. & social challenges)	Moderate (functional mix changes due to digital)	High (synthesizes empirical & theoretical insights)
Henriquez et al. (2022) [9]	Future land use conflicts: Comparing spatial scenarios for urban-regional planning	Moderate (GIS & scenario modeling)	Conceptual (sustainable land use, no metrics)	Moderate (urban & peri-urban mixed-use conflicts)	High (scenario-based spatial simulation)
Aosaf et al. (2025) [10]	Computational intelligence based land-use allocation approaches for mixed use areas	High (computational intelligence algorithms)	Moderate (improves land-use compatibility)	Strong (optimizes allocation of mixed land-uses)	High (optimization metrics HV, GD)
Khamdamov and Usmanov (2024) [11]	Sustainable cities and communities: Urban planning and development strategies	Moderate (sustainable urban development strategies)	Comprehensive (green infrastructure & inclusive housing)	Moderate (promotes functional diversity)	Limited (conceptual, no specific tools)
Hooli (2025) [12]	Digital twins and urban planning: Designing smarter, more inclusive cities	High (AI-powered digital twins)	Comprehensive (env. & social sustain. through modeling)	Strong (supports mixed-use planning)	High (AI-driven scenario testing & predictive analytics)
Dong et al. (2025) [13]	Spatial data analysis and urban functional zoning optimization in smart city development	High (AI & machine learning for zoning)	Conceptual (integrates env. & socioeconomic variables)	Strong (optimizes functional zoning for sustainability)	High (advanced machine learning spatial predictions)
Hall (1998) [14]	Urban Geography	Low (predates smart tech, theoretical)	Conceptual (ecological footprint, green projects)	Strong (critiques single-use zoning, mixed-use areas)	Moderate (qualitative, context-specific)
Mensing et al. (2020) [15]	Zukunft der (stadt-)zentren ohne handel? Neue impulse und nutzungen für zentren mit zukunft	Low (policy & planning recommendation s)	Conceptual (social inclusiveness, no metrics)	Strong (promotes complementary uses alongside retail)	Limited (qualitative policy analysis)
Cervero (1991) [16]	Congestion relief: The land use alternative	Low (no digital tools, conceptual)	Conceptual (sustainable site design & mixed-use)	Strong (promotes densification & mixed-use for mobility)	Limited (conceptual, no formal models)
Wu et al. (2024) [17]	'Local hubs and global gateways': Understanding the impact of singapore's master plan on urban polycentricity	Moderate (master plan data & spatial network)	Conceptual (polycentricity for resilience, no metrics)	Moderate (functional decentralization & mixed-use hubs)	Moderate (scenario simulation of floor space & commuting)
Vigiola et al. (2022) [18]	Reimagining the future of the sydney CBD: Reflecting on covid-19-driven changes in commercial and residential property trends	Moderate (property trend data analysis)	Conceptual (sustainability challenges, no metrics)	Moderate (shifts in commercial & residential mix)	Limited (empirical trends, limited forecasting)
Pozoukidou and Angelidou (2022) [19]	Urban planning in the 15-minute city: Revisited under sustainable and smart city developments until 2030	Moderate (intelligence-driven planning & digital tools)	Comprehensive (sustainable & inclusive neighborhood design)	Strong (advocates mixed-use neighborhoods for proximity)	Limited (conceptual rather than quantitative)
Bibri et al. (2024) [20]	The synergistic interplay of artificial intelligence and digital twin in environmentally planning sustainable smart cities: A comprehensive systematic review	High (integrates AI, IoT, digital twins)	Comprehensive (env. sustainability & data-driven planning)	Moderate (supports mixed-use through smart tech)	High (comprehensive review of advanced predictive models)
Stauskis (2014) [22]	Development of methods and practices of virtual reality as a tool for participatory urban planning: A case study of vilnius city as an example for improving environmental, social and energy sustainability	Moderate (VR for participatory planning)	Comprehensive (env. & social sustainability)	Moderate (supports sustainable urban design)	Limited (VR simulation to improve outcomes)
Cieszewska (2000) [23]	Green Urbanism: Learning from European Cities	Low (policy framework, no digital tools)	Comprehensive (sustainability metrics & progress)	Moderate (compact neighborhoods with housing, commerce)	Limited (no focus on predictive modeling)
Dawkins and Nelson (2003) [25]	State growth management programs and central-city revitalization	Low (policy analysis only)	Conceptual (residential construction)	Moderate (spatial distribution of urban functions)	Moderate (panel data regression for spatial analysis)

			distribution)		
Zanella et al. (2014) [26]	Internet of Things for Smart Cities	Moderate (IoT weak applied to planning)	Limited (no explicit sustain. metrics)	Moderate (multiple services implying mix)	Limited (focus on real-time monitoring, not prediction)
Anwar and Sakti (2024) [28]	Integrating artificial intelligence and environmental science for sustainable urban planning	High (AI-enhanced GIS tools)	Comprehensive (env. indicators & sustainability)	Moderate (land use diversity linked to env. outcomes)	High (machine learning improves urban growth forecasts)
Buda et al. (2023) [29]	Land value dynamics and the spatial evolution of cities following covid 19 using big data analytics	Moderate (big data analytics for land value)	Conceptual (post-COVID resilience, no metrics)	Moderate (land value dynamics affecting functional mix)	High (calibrated forecasting models with scenario simulation)
Giddings and Rogerson (2022) [30]	The City Centre. The Future of the City Centre: Global Perspectives	Low (conceptual discussion)	Conceptual (social & economic resilience)	Strong (evolving functional diversity in city centers)	Limited (theoretical, no predictive modeling)
Heptig (2023) [31]	Die Mischung macht's? Das Shopping-Center wird zum Mixed-Use-Center	Moderate (expert interviews & lit review)	Conceptual (reduced vacancy & resource use)	Strong (mixed-use shopping centers & urban vitality)	Limited (qualitative assessment, no formal models)
He et al. (2021) [32]	Research and Exploration of Land Use in Core Area of Urban Central Rail Transit Station Based on AI Technology	High (AI & neural networks for land use)	Moderate (sustainable development around transit)	Strong (transit-oriented mixed-use land use)	High (BP & deep neural networks for simulation accuracy)
Couclelis (2005) [33]	"Where has the future gone?" Rethinking the role of integrated land-use models in spatial planning	Low (conceptual, no digital tools)	Conceptual (strategic planning for sustain., no metrics)	Moderate (conceptual discussion of land-use integration)	Moderate (reviews modeling roles, no specific accuracy data)
Lim et al. (2024) [34]	Sustainable-Smart-Healthy Development Framework for Urban Social Spaces Imaginary: A Review	Moderate (sustainable-smart-healthy framework)	Comprehensive (cultural & intangible sustainability values)	Moderate (supports mixed-use social urban environments)	Limited (conceptual framework, no predictive modeling)
Bittner and Burian (2024) [35]	Modelling future urban scenarios of land suitability: A case study of Jihlava city	Moderate (multicriteria analysis for land suitability)	Conceptual (supports sustainable expansion, no metrics)	Moderate (land suitability for mixed urban uses)	High (Urban Planner methodology for predictive modeling)
Jagtap et al. (2024) [36]	The Role of Technology to Enhance City Development by Optimizing Strategy Formulation and Implementation	High (GIS & MIS for strategy)	Conceptual (bridging policy & practice, no metrics)	Moderate (supports mixed-use through planning processes)	Moderate (reviews technological tools for monitoring)
Rajendran et al. (2025) [37]	Resilient Cities in the Global South: Rethinking Informality in Urban Planning and Design	Moderate (mentions tech in governance)	Comprehensive (social & spatial resilience)	Moderate (informal urbanism generates mixed-use)	Limited (qualitative, context-sensitive understanding)
Pasupuleti (2024) [38]	GeoDynamics: Innovating urban spaces with GIS and remote sensing technologies	High (GIS & remote sensing)	Conceptual (env. monitoring & resilience)	Moderate (supports mixed-use through spatial data)	High (advanced spatial data analysis & visualization)
Chen, L.H. (2025) [39]	Smart cities and social equity: A review of digital urban governance in Southeast Asia	High (examines high but uneven integration)	Limited (sustainability sidelined by economic growth)	Limited (does not explicitly address functional mix)	Limited (critiques data-driven governance, no prediction)
Shariatpour and Behzadfar (2024) [40]	A data-driven interactive system for smart urban planning and design	High (data-driven interactive system)	Moderate (supports smart, sustainable development)	Moderate (facilitates mixed-use with real-time data)	High *(real-time 3D visualization & dynamic reporting)*
Wibowo et al. (2024) [41]	Strategic planning for the development of a smart city in tangerang, indonesia: Integrating technology and innovation in urban development	High (blockchain & IoT in strategic planning)	Moderate (sustainable development & quality of life)	Moderate (mixed-use through technology-enabled services)	Limited (survey data, limited predictive modeling)
Putra et al. (2025) [42]	Towards a sustainable city: Strategic approach to smart city development	High (smart city strategies integrating tech & policy)	Comprehensive (env. sustainability & social inclusion)	Moderate (mixed-use through ICT & governance)	Limited (case studies & expert interviews, no formal models)
Chen (2024) [43]	Planning and development of smart cities based on the concept of sustainable development	High (ICT-based smart city planning)	Comprehensive (energy, environment, social	Moderate (mixed-use & smart land-use planning)	Limited (case study-based, no advanced predictive modeling)

Lees (2008) [44]	Gentrification and social mixing: Towards an inclusive urban renaissance?	Low (social & policy dynamics, not tech)	equity) Conceptual (gentrification undermines community, no metrics)	Strong (critiques policies promoting social & functional mix)	Limited (qualitative critical policy analysis)
Liu et al. (2024) [45]	Enhancing detailed planning from functional mix perspective with spatial analysis and multiscale geographically weighted regression: A case study in shanghai central region	Moderate (spatial analysis with MGWR)	Conceptual (links functional mix to population)	Strong (detailed functional mix analysis at multiple scales)	Moderate (MGWR for spatial predictive insights)
Widener (2015) [46]	Begone, Euclid!: Leasing Custom and Zoning Provision Engaging Retail Consumer Tastes and Technologies in Thriving Urban Centers	Moderate (discusses technology impacts on retail)	Conceptual (social integration & urban vitality)	Strong (mixed-use retail & public space integration)	Limited (qualitative analysis, no predictive modeling)
Evans-Cowley (2003) [47]	A new land use in downtown: How cities are dealing with telecom hotels	Low (policy responses, no digital tools)	Limited (no sustain. focus)	Moderate (new land use for telecom facilities)	Limited (descriptive policy analysis)
Wei et al. (2021) [48]	Planning and markets at work: Seattle under growth management and economic pressure	Moderate (GIS & discrete choice models)	Conceptual (sustainable urban village policies)	Moderate (redevelopment intensity in mixed-use areas)	Moderate (discrete choice modeling for redevelopment prediction)
Marsal-Llacuna et al. (2015) [49]	Lessons in urban monitoring taken from sustainable and livable cities to better address the Smart Cities initiative	Moderate (sensors, IoT – conceptual, not applied)	Comprehensive (synthetic indices PCA for sustainability)	Moderate (multi-domain urban indicators)	Limited (focus on real-time monitoring, not prediction)
Liu and Yoon (2024) [50]	Research on urban renewal design in the context of the future community concept	High (smart technologies & participatory design)	Comprehensive (eco-friendly design & social inclusiveness)	Moderate (promotes mixed-use for economic vitality)	Limited (data tables for empirical validation)
Udapitiya et al. (2018) [51]	Land-use planning model: A case study on transit-oriented development (TOD)	Moderate (qualitative interviews for TOD model)	Comprehensive (sustainability through transit-oriented design)	Strong (mixed-use development near transit)	Limited (conceptual TOD model, no quantitative validation)
Aidaoui et al. (2024) [52]	Mapping Tomorrow's Cities: GeoAI Strategies for Sustainable Urban Planning and Land Use Optimization	High (GeoAI & remote sensing)	Comprehensive (env. sustainability & inclusive growth)	Moderate (monitors land use & functional diversity)	High (AI for predictive landscape & urban planning)
Feng and Wang (2024) [53]	Navigating the future of urban environments: A comprehensive analysis of contemporary urban planning	Moderate (comprehensive planning analysis)	Conceptual (resilience & sustainability principles)	Moderate (supports mixed-use & human-centric design)	Limited (theoretical, no specific predictive tools)