



Artificial Intelligence, Architecture, and Urban Sustainability: A Systematic Review with a Speculative Design Approach

Yapay Zeka, Mimarlık ve Kentsel Sürdürülebilirlik: Spekülatif Tasarım Yaklaşımıyla Sistematik Bir İnceleme

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ABSTRACT

This study presents a systematic literature review that examines the integration of artificial intelligence (AI) technologies into the disciplines of architecture and urban planning, within the context of sustainable cities. In this review conducted in accordance with the PRISMA protocol, 11 academic publications were evaluated through keywords identified in the Web of Science and Scopus databases. The literature has been examined under five thematic headings: AI applications in urban planning processes, Decision support systems and scenario development, Social participation and governance, Conceptual- speculative approaches, and the Sustainability perspective. Methodologically, the study has focused on both technical applications and social and ethical dimensions with an interdisciplinary approach. The literature shows that AI is effective in areas such as data-intensive decision-making, multi-scenario analysis, and performance optimization in planning and design processes. However, significant gaps still exist in the areas of social engagement, ethical responsibility, and stakeholder diversity. The speculative design approach, on the other hand, has the potential to go beyond current practices by combining possible future scenarios shaped by AI with architectural and urban visions. In this context, the study poses the following fundamental research questions: (1) How are AI technologies integrated into the fields of architecture and urban planning? (2) What themes are prominent at the intersection of AI and speculative design? (3) How are AI applications evaluated in terms of social participation and ethical governance with respect to sustainable city goals? These questions provide an essential framework for forward-looking creative and critical urban design approaches. This review addresses a notable gap in the literature by examining the role of AI in sustainable urban design, providing insights into underexplored areas such as participatory governance and ethical AI practices. The findings contribute to both academia and practice by highlighting how AI-driven approaches can enhance sustainable city planning and by identifying areas where further innovation is needed, thereby informing future design strategies.

Keywords: Artificial Intelligence, Decision Support Systems, Smart Cities, Speculative Design, Sustainable Urban Planning

Öz

Bu çalışma, yapay zekâ (YZ) teknolojilerinin sürdürülebilir şehirler bağlamında mimarlık ve şehir planlama disiplinlerine entegrasyonunu inceleyen sistematik bir literatür taraması sunmaktadır. PRISMA protokolüne uygun olarak yürütülen bu taramada, Web of Science ve Scopus veritabanlarında belirlenen anahtar kelimeler aracılığıyla 11 akademik yayın değerlendirilmiştir. Literatür beş tematik başlık altında incelenmiştir: Kentsel planlama süreçlerinde YZ uygulamaları, Karar destek sistemleri ve senaryo geliştirme, Sosyal katılım ve yönetim, Kavramsal-spekülatif yaklaşımlar ve Sürdürülebilirlik perspektifi. Yöntemsel olarak çalışma, disiplinlerarası yaklaşımla hem teknik uygulamalara hem de sosyal ve etik boyutlara odaklanmıştır. Literatür, YZ'nin planlama ve tasarım süreçlerinde veri yoğun karar alma, çoklu senaryo analizi ve performans optimizasyonu gibi alanlarda etkili olduğunu göstermektedir. Bununla birlikte, sosyal katılım, etik

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sorumluluk ve paydaş çeşitliliği konularında hâlen önemli boşluklar bulunduğu görülmektedir. Spekülatif tasarım yaklaşımı ise, mevcut uygulamaların ötesine geçerek YZ ile şekillenen olası gelecek senaryolarını mimari ve kentsel vizyonlarla birleştirme potansiyeli taşımaktadır. Bu bağlamda çalışma, şu temel araştırma sorularını yöneltmektedir: (1) YZ teknolojileri mimarlık ve şehir planlama alanlarında hangi yöntemlerle entegre edilmektedir? (2) YZ ve spekülatif tasarım kesişiminde hangi temalar ön plana çıkmaktadır? (3) YZ uygulamaları sürdürülebilir şehir hedefleri açısından sosyal katılım ve etik yönetim ekseninde nasıl değerlendirilmektedir? Bu sorular, geleceğe dönük yaratıcı ve eleştirel şehir tasarımı yaklaşımları için önemli bir çerçeve sunmaktadır. Bu inceleme, sürdürülebilir kentsel tasarımda yapay zekânın rolünü inceleyerek literatürdeki önemli bir boşluğu ele almakta, katılımcı yönetim ve etik yapay zekâ uygulamaları gibi az araştırılmış alanlara dair içgörüler sunmaktadır. Bulgular, yapay zekâ destekli yaklaşımların sürdürülebilir şehir planlamasını nasıl geliştirebileceğini vurgulayarak hem akademiye hem de uygulamaya katkıda bulunmakta ve daha fazla yeniliğe ihtiyaç duyulan alanları belirleyerek gelecekteki tasarım stratejilerine öneriler sunmaktadır.

Keywords: Keyword, Keyword, Keyword, Keyword, Keyword

INTRODUCTION

In the 21st century, where urbanization is accelerating, the sustainability issues faced by cities are more complex and multidimensional than ever. The 11th of the United Nations' Sustainable Development Goals (SDG 11) aims to make cities and human settlements "inclusive, safe, resilient, and sustainable." The projection that 66% of the world's population will live in cities by 2030 underscores the critical importance of sustainable urban development for the future of humanity. In this context, challenges such as climate change, rapid population growth, infrastructure deficiencies, housing issues, and urban inequalities emerge as urgent areas for solution for urban planners and architects (United Nations, 2015, 2018, 2022).

On the other hand, advancements in artificial intelligence (AI) technologies over the past decade offer new opportunities for planning, designing, and managing cities (Wang et al., 2023; Qian et al., 2023). AI, along with digital technologies such as big data analytics, machine learning, and the Internet of Things (IoT), is emerging as a crucial tool in optimizing urban systems and developing innovative solutions. For example, AI-supported systems can reduce traffic congestion by optimizing traffic flow in real-time and can shorten travel times by increasing the efficiency of public transportation. In energy infrastructure, artificial intelligence can significantly reduce energy consumption by dynamically adjusting lighting and heating in buildings, contributing to more sustainable urban energy systems through the integration of renewable energy sources and demand forecasting (Das, 2025). Similarly, in smart waste management, sensor and AI-supported systems aim to optimize garbage collection routes and reduce resource waste and environmental pollution (Ghahramani et al., 2021; Alsabt et al., 2024).

However, the real impacts of artificial intelligence on the sustainability of cities and the transformation it brings to the field of architecture remain an open-ended topic of ongoing research. The literature highlights the potential benefits of AI for sustainable cities, but also notes that the social and spatial impacts of these technologies are not yet fully understood. Gupta and Degbelo (2022) emphasized that studies examining the contributions of artificial intelligence to SDG 11 are sparse and scattered, notably lacking multi-stakeholder and citizen-participatory approaches. It is stated that current research largely focuses on technical issues, with social impacts, participation opportunities, and knowledge sharing dimensions being sidelined. This suggests that there is a need for more interdisciplinary efforts to understand the urban applications of artificial intelligence comprehensively.

At this point, the perspective of architecture and design disciplines comes into play. Architecture is concerned not only with the aesthetic and technical design of buildings but also with the conceptualization of spaces that shape human experience. The integration of AI technologies into architectural practices creates new possibilities and questions in design processes. For example, advanced architecture firms are using AI-supported generative design tools to optimize complex forms, minimizing material usage and maximizing structural performance. The Daedalus Pavilion,

designed by the London-based AI Build initiative in collaboration with ARUP engineers, is a concrete example of this: This five-meter-high lattice structure was designed using generative algorithms and constructed in three weeks using robotic arms and biodegradable materials (Figure 1). The result is a sustainable design prototype that maximizes material efficiency and allows for the quick realization of complex geometry. Similarly, the Edge office building in Amsterdam is considered one of the world's "smartest" buildings, providing a dynamic environment that adapts to users thanks to AI, while reducing energy consumption by 70% compared to traditional buildings (Figure 2). Examples like these demonstrate that artificial intelligence can play a groundbreaking role in architectural design and building operation processes.

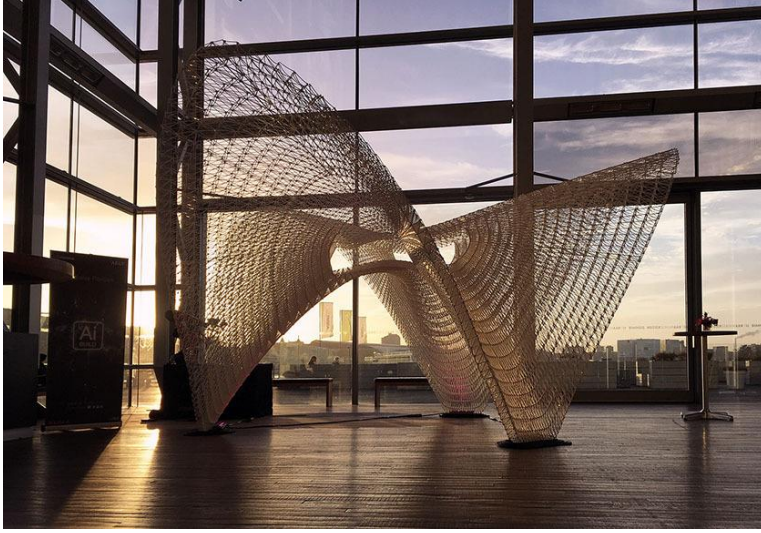


Figure 1. Daedalus Pavilion <https://www.archdaily.com/936999/pioneers-6-practices-bringing-ai-into-architecture>



Figure 2. The Edge Office Building, Amsterdam <https://www.archdaily.com/785967/the-edge-plp-architecture>

However, when addressing the impacts of artificial intelligence on architecture and urban design, it is insufficient to limit consideration to current applications. The speculative design approach comes into play precisely at this point, allowing us to ask the question "what if it were like this?" and to imagine possible future scenarios. As Anthony Dunne and Fiona Raby (2013) have noted, speculative

design is employed to explore various future possibilities and to initiate discussions about the types of futures we prefer (or wish to avoid), as opposed to traditional forecasting or trend extrapolation. This approach views design not only as a means to create objects but also as a tool to generate ideas, testing the social and ethical impacts of technology through imagination. In the fields of architecture and urban planning, speculative design also offers the opportunity to experimentally explore the future of urban life, spatial arrangements, and design practices through both utopian and dystopian scenarios. For example, the "Regenerative Futures" competition, organized by the design laboratory Space10 in 2022, provided a platform for designers to reimagine sustainable homes and neighborhoods of the future using generative artificial intelligence tools (SPACE10, 2022). Such studies can provide critical insights to today's decision-makers by materializing urban future visions shaped by artificial intelligence.

This article aims to examine the impact of artificial intelligence (AI) technologies on urban sustainability from the perspective of architecture and urban planning, through a systematic literature review. In support of this primary objective, the intersections of AI with speculative design approaches and the social participation and ethical governance dimensions of AI applications are also addressed as secondary aims. The study examines prominent research and exemplary applications in the existing literature, while also developing forward-looking projections to initiate a discussion on the question, "What kind of city do we want?" in the context of artificial intelligence.

In the absence of a predefined hypothesis, this study is guided by a set of structured research questions. The primary research question asks: (1) How are AI technologies integrated into the fields of architecture and urban planning for sustainable cities? Supporting this inquiry, the study explores the following sub-questions: (a) Which themes are prominent at the intersection of AI and speculative design? (b) How are AI applications evaluated in terms of social participation and ethical governance in line with sustainable city goals?

It aims to provide a new theoretical contribution to the literature by blending the disciplines of architecture, urban planning, computer science, and ethics with an interdisciplinary perspective. Building on these objectives, the following sections elaborate on the theoretical framework, present the research questions and methods, and finally evaluate the relevant literature.

1. Theoretical Framework

In this section, key concepts, debates, and disciplinary perspectives that frame the relationship between artificial intelligence, sustainable urbanism, and design are outlined to provide the conceptual basis for the subsequent analysis.

Cities are complex systems facing multifaceted sustainability challenges in the 21st century. The United Nations' Sustainable Development Goal 11 calls for urban environments to be "inclusive, safe, resilient, and sustainable". Achieving this involves not only environmental targets but also social inclusivity, economic vitality, and good governance. With an estimated 66% of the world's population projected to live in cities by 2030, sustainable urban development has become increasingly critical. Addressing these challenges demands interdisciplinary approaches that bridge technology, urban planning, and social dimensions. In recent decades, the concept of the smart city has emerged as a paradigm for leveraging digital technologies, particularly artificial intelligence (AI), to enhance urban services and improve quality of life. Smart cities integrate sensors, data analytics, and connectivity to optimize infrastructure and governance. AI functions as the "brain" of these systems, enabling real-time data processing, forecasting, and intelligent decision support across various urban domains. Its contributions span transportation management, energy efficiency, waste reduction, and participatory planning, illustrating AI's potential to advance urban sustainability. At the same time,

researchers emphasize that sustainability must encompass social and ethical dimensions alongside technical efficiency. This requires integrating community engagement, equity, and governance into the discussion of AI-driven smart cities. The theoretical framework of this study situates AI within the broader context of sustainable urbanism and architectural innovation, while critically examining participatory and speculative dimensions that address the future implications of these technologies.

AI applications in urban infrastructure have already shown tangible benefits. For example, AI-driven traffic optimization has alleviated congestion in cities like Hangzhou: the City Brain project by Alibaba analyzes live traffic data and dynamically adjusts traffic lights, reportedly improving vehicle speeds by 15% and significantly reducing accidents. Before City Brain's implementation, Hangzhou ranked among China's most congested cities; afterward, it experienced a dramatic drop in congestion rankings. In the building sector, intelligent control systems use AI to cut energy consumption. The Edge building in Amsterdam, often hailed as "the world's smartest building," uses AI to continuously adjust lighting and HVAC based on occupancy and weather, achieving up to 70% energy savings compared to conventional buildings. AI is also being applied to resource management challenges. Smart waste collection systems utilize machine learning to optimize garbage truck routes by analyzing sensor data on bin fill levels, thereby minimizing fuel use and emissions. In Rwanda, autonomous drones guided by AI deliver medical supplies to remote areas, demonstrating innovative solutions for public services. These examples demonstrate how AI can help cities become more efficient, resilient, and livable, aligning with the objectives of SDG 11. However, technological solutions alone are not a panacea; their success depends on addressing social and governance factors. In urban planning, AI offers powerful tools for scenario analysis and decision support. Planners can simulate the long-term impacts of policies (e.g., adding a new transit line) on factors such as traffic, property values, or emissions using AI models that account for complex variables. AI can also enhance participatory planning by providing data-driven visualizations and interactive platforms for public feedback. For instance, cities like London are experimenting with open-data platforms and AI tools to let citizens contribute to planning decisions, which can increase transparency and align urban development with community needs. Crucially, these participatory AI applications can improve citizens' data literacy and integrate qualitative insights, addressing a key facet of smart cities that has often been overlooked. However, they also surface important ethical and political concerns. AI-enabled urban management raises questions about privacy, surveillance, and algorithmic bias. When vast amounts of urban data are consolidated, ensuring the privacy and data justice for citizens becomes paramount. Likewise, the transparency and accountability of AI-driven decisions are necessary for public trust. Without careful governance, innovative city systems might erode civil liberties or entrench existing inequalities. Thus, balancing efficiency with ethics is indispensable - a theme that runs through contemporary debates on AI in the urban context.

The examples above demonstrate AI's capacity to help realize cities' sustainability goals in domains ranging from mobility to energy. At the same time, they reveal a tension between technological optimism and social caution. Scholars have noted that current research on AI for sustainable cities remains fragmented and largely technocentric, often neglecting multi-stakeholder perspectives and social impacts. Gupta and Degbelo (2022) note that studies on AI's contributions to SDG 11 are sparse and scattered, with participatory and citizen-focused approaches notably underrepresented. In other words, much of the literature emphasizes technical solutions but sidelines questions of community engagement, equity, and governance. This suggests a need for more integrative and critical frameworks to understand the role of AI in urban sustainability. The discipline of architecture offers an important complementary

perspective. Architecture is not only concerned with the form and performance of buildings, but also with the experiential and conceptual dimensions of space that shape human life. In recent years, AI has begun to revolutionize architectural practice, introducing new methods for designing and constructing the built environment. AI-assisted design tools enable architects to analyze data and generate complex forms with unprecedented speed and ease. These tools are affecting all stages of the design process, from initial massing studies to detailed optimization. Integrating AI into architectural workflows creates opportunities to advance sustainability (for instance, by optimizing energy efficiency or material usage) but also prompts reflection on the changing role of the architect and the creativity of the design process.

One area where AI has made striking inroads is generative design. Machine learning models, especially generative adversarial networks (GANs) and evolutionary algorithms, can serve as creative partners in form-finding. For example, architect and researcher Stanislas Chaillou developed a deep learning system to generate housing floor plans that meet functional requirements. By training GANs on a large dataset of architectural layouts, the system learned to produce viable floor plan alternatives in a matter of seconds. Chaillou's prototype could output hundreds of plan variations that satisfy given constraints, allowing designers to explore a vast design space in early project stages. This suggests a future in which architects, aided by AI, can rapidly iterate through options and refine designs with greater information. Figure 3 shows an example of AI-generated floor plan layouts: the model receives a basic input (such as a building footprint with desired openings) and autonomously generates plausible room configurations, which can then be compared to human-designed solutions for reference. Floor plan alternatives generated by a deep learning model (Chaillou, 2019) illustrate AI's ability to produce diverse layout options from the same initial constraints. Such generative approaches highlight AI's potential to augment human creativity, automating routine aspects of design and unveiling novel solutions that a designer might not have conceived manually.

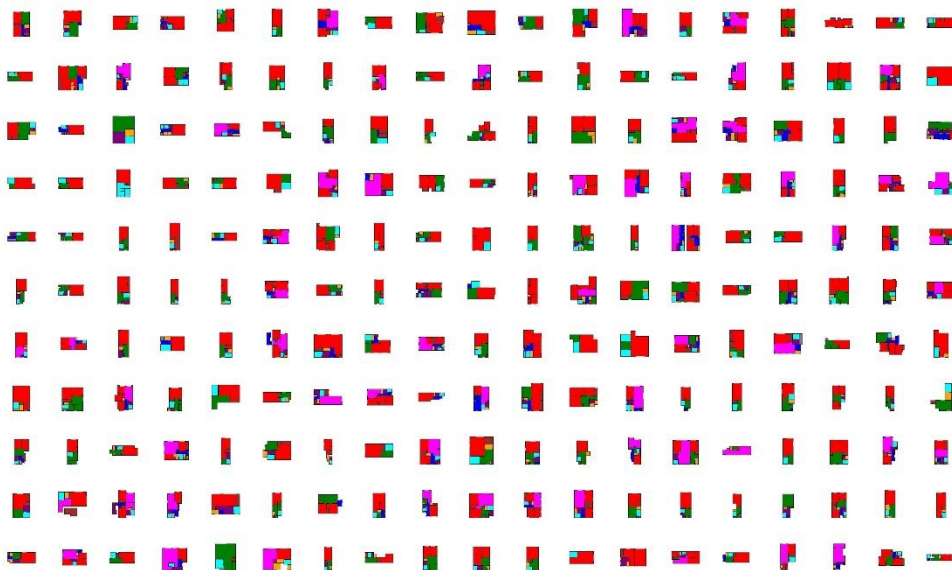


Figure 3. Floor Plan Alternatives Generated Using Deep Learning and GAN (Chaillou, 2019).

Beyond form generation, AI plays a crucial role in performance optimization in architecture. Designers can utilize AI-based simulation and optimization algorithms to address complex problems, such as energy efficiency, structural stability, and thermal comfort. Traditionally, testing thousands of design permutations (for instance, facade configurations to maximize daylight or natural ventilation)

would be prohibitively time-consuming. AI can drastically accelerate this process: neural networks and evolutionary algorithms quickly learn the relationships between design parameters (such as window size, material, and orientation) and performance outcomes (including energy use, daylight levels, and cost). This allows near real-time feedback on how design choices impact a building's life-cycle sustainability. A recent systematic review (Li et al., 2024) reported that AI has become a transformative tool for optimizing sustainable building design, with many studies focusing on energy and material optimization. In effect, AI algorithms can sift through a vast solution space to identify design alternatives that minimize carbon footprint or operational costs, supporting architects in making evidence-based decisions for sustainability. Another frontier is the application of AI in construction and fabrication. On-site robotics guided by AI are enabling new construction techniques that improve efficiency and precision. The Daedalus Pavilion project, for example, demonstrated an AI-driven construction process: robotic arms equipped with sensors assembled a complex structure. At the same time, an AI system detected errors in real-time and adjusted subsequent steps to correct them. This adaptive, self-correcting construction hints at the future "autonomous construction site" with minimal waste and reduced human error. AI is also used to optimize construction scheduling and logistics. By analyzing data from past projects, machine learning models can predict potential delays or supply chain disruptions, allowing project managers to proactively mitigate issues. These applications contribute to more sustainable construction practices by improving resource management and reducing overruns. Furthermore, AI is reshaping collaboration and knowledge management in architectural practice. Large firms have begun developing AI systems to capture and reuse knowledge from past projects. For instance, the innovation unit GXN of 3XN Architects analyzed years of design data to identify where AI could add the most value: in research (information gathering), design iteration, and organizational knowledge transfer. The resulting AI tools enable architects to quickly retrieve precedents, verify regulations, or learn from previous designs, effectively creating a shared, intelligent knowledge base. Natural language processing-based assistants (powered by large language models) are also emerging to support architects in drafting and problem-solving. As architects increasingly rely on AI as a "co-pilot" in the creative process, questions arise about authorship, originality, and ethics in the design field. If an AI generates a substantial portion of a design, who is the author? How do we ensure the originality and cultural relevance of designs in an age of algorithmic assistance? These questions echo broader ethical and professional debates. Notably, many architects are embracing AI as a means to enhance creativity rather than replace it. Cutting-edge studios (e.g., Zaha Hadid Architects) are already using AI image generators like MidJourney and DALL-E to explore imaginative concepts and aesthetics during the early design phase. This integration of human and machine creativity holds promise for more innovative and responsive architecture, but it also underscores the need for critical reflection on technology's role in design.

In summary, AI is catalyzing radical transformations in how we design, build, and manage architecture. It enables more data-driven, adaptive, and high-performing designs that align with sustainability goals. At the same time, these technological opportunities bring new responsibilities. Architects and planners must grapple with ethical considerations - from ensuring equitable and inclusive use of AI, to maintaining agency and critical oversight over algorithmic outputs (avoiding a blind reliance on "black box" solutions). This is where the concept of speculative design becomes highly relevant as a theoretical lens. Speculative design offers a framework for exploring and envisioning the broader implications of emerging technologies, including their political and ethical dimensions, rather than merely addressing immediate technical issues. By projecting forward and posing "what if?" scenarios, speculative design encourages a more reflective and pluralistic approach to the future of AI in the built environment.

Speculative design is an approach within design research that utilizes imagination and storytelling to explore potential futures and stimulate critical discussion. As defined by Dunne and Raby (2013), design can function as a tool not only to create products but to generate ideas and provoke debate. Rather than extrapolating existing trends, speculative design constructs hypothetical scenarios—often through conceptual prototypes, fictions, or scenarios—that ask questions about how technology and society might intersect in years to come. The goal is not to predict the future accurately, but to challenge assumptions and broaden the discourse about what kind of future is desirable. By presenting artifacts or narratives from a speculative future, designers invite the public to reflect on present-day values and choices. For example, Dunne and Raby famously envisioned provocative devices, such as a “phantom limb sensation recorder” or proposals for feeding pets with artificial meat. Such concepts may seem absurd, but they compel us to examine the ethical and societal ramifications of technological progress (in those cases, questioning the relationship between technology, the human body, and nature). The motto of this approach could be summarized as “What if...?”: by asking open-ended questions, speculative design opens up a space to debate preferable vs. undesirable futures. Importantly, speculative design has strong roots in critical design and often carries a political or ethical critique implicitly. It brings to light power structures, environmental concerns, and human values that purely technical or market-driven perspectives might otherwise overshadow. This makes it an apt approach to integrate into our exploration of AI in architecture and urbanism, which similarly demands grappling with normative questions (e.g., whose needs are prioritized by AI-driven cities? Who is excluded? How do we govern these technologies?).

Historically, speculative design has had a presence in architecture and urban planning, often through visionary concepts and experimental projects. Architectural educators frequently encourage “paper architectures” or studio projects that imagine future cities transformed by new technologies. These visions range from utopian eco-cities to dystopian megastructures. A notable example comes from the avant-garde collective Archigram in the 1960s, which produced radical proposals, such as the Walking City - a vision of giant, mobile robotic habitats roaming the world. In an era with far more primitive technology, Archigram’s members anticipated themes of extreme modularity, mobility, and high-tech urbanism that resonate with today’s discussions. Figure 4 illustrates Archigram’s concept of the Walking City: a group of insect-like megastructures striding across an urban skyline, intended as a provocative statement on nomadic infrastructure and the obsolescence of traditional city forms.

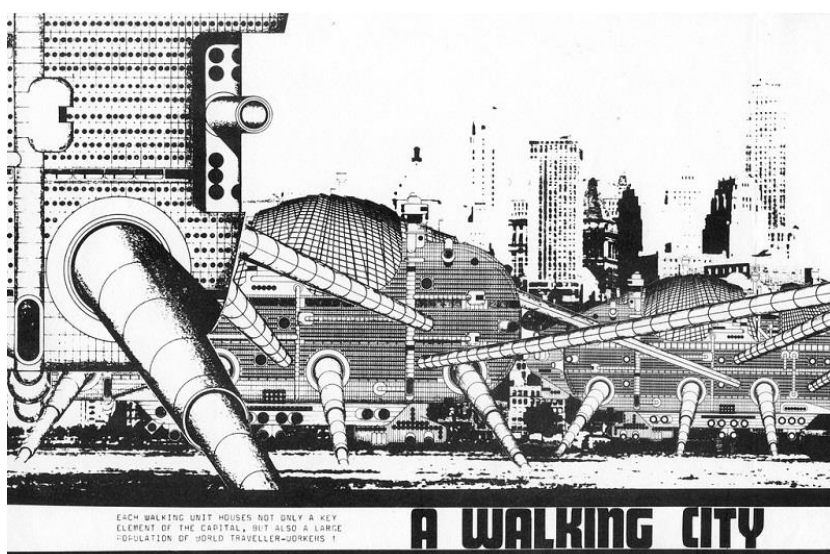


Figure 4. Walking City Representation of Archigram (Designing Buildings Wiki, 2019)

Archigram's "Walking City" concept (Ron Herron, 1964) envisioned mobile, intelligent buildings challenging the static nature of cities. By presenting such extreme scenarios, Archigram invited society to question the conventions of urban design and the political power embedded in immobile architecture. Their speculative drawings (though never built) left a lasting impact on architectural theory. Today, with the advent of AI, augmented reality, and biotechnology, the scope for architectural speculation has dramatically expanded. Designers can now not only imagine new architectural forms, but also complex systems that incorporate algorithms, data, and even non-human species into the urban fabric. Contemporary speculative projects increasingly address themes like multispecies cohabitation, data governance, and post-human aesthetics, reflecting an understanding that sustainability and ethics in future cities must extend beyond human-centered concerns.

Recent work demonstrates how speculative design can intersect with concerns of sustainability and social justice. For instance, Edwards and Pettersen (2023) describe a project in which architecture students developed visions of multispecies, sustainable cities through speculative design exercises. These visions expanded the notion of sustainability to include ecosystems and non-human life, proposing urban futures that prioritize biodiversity and "just" transitions for all living beings. Such explorations underscore that speculative design is not merely fanciful but can contribute to reframing real-world objectives, such as sustainability, in more holistic terms. They encourage architects and planners to think beyond incremental improvements and consider transformative possibilities (and pitfalls) at the systemic level. Crucially, speculative design can also incorporate the ethical and political dimensions of AI in cities. By crafting scenarios where, for instance, an AI-controlled city administration goes awry, or where citizens reclaim agency through new participatory technologies, designers can critically examine issues of governance, equity, and human rights in a futuristic context. In doing so, speculative design serves as a bridge between technical development and societal dialogue, ensuring that as we integrate AI into our cities and buildings, we continually ask who benefits, who might be marginalized, and how we can steer technology toward inclusive ends.

One emerging area at the intersection of AI and speculative design is the use of AI as a medium to generate speculative scenarios. Interestingly, AI itself can assist in visualizing futures, for example, by producing hyper-realistic images of hypothetical buildings or city scenes. A recent literature review by Østvold, Paulsen, and Trondsen (2024) examined current projects uniting AI with speculative design. They found three prominent themes: (1) the use of AI image generation (tools like DALL-E or MidJourney) to create visionary architectural images, (2) AI as an enabler of accessibility - helping non-experts participate in design speculation by generating ideas from simple inputs, and (3) employing AI to simulate future scenarios for cities (for instance, algorithmically forecasting urban changes and visualizing them). These trends show that AI is not only an object of speculation but also a tool for speculation. Designers can quickly prototype future visions with the help of AI, from fantastical cityscapes to interactive urban narratives. However, the same review also sounded a note of caution: some practitioners reported that AI-generated designs can feel "uninspired" or lacking in contextual depth. The ease and speed of producing imagery with AI do not automatically guarantee meaningful speculation; in fact, there is a risk of superficial futurism - glossy visuals without critical substance. This underscores the fact that human creativity and cultural insight remain crucial. AI might provide the palette of possibilities, but designers must imbue those with context, critique, and nuance. Otherwise, speculative projects could remain at the level of novelty and fail to engage with more profound questions. In sum, while AI expands the horizons of speculative design, it also requires us to be even more reflective about the values and assumptions embedded in the outputs.

In light of the above theoretical context, it becomes evident that a more integrated scholarly perspective is needed. AI's integration into sustainable cities and architecture involves technical innovation, but equally, it raises participatory, ethical, and even philosophical questions. The literature to date, however, often treats these facets in isolation: engineering studies advance AI applications, urban studies call for inclusivity, and design research explores speculation - rarely are these threads woven together. This study posits that bridging these domains is essential to fully understand the potential and pitfalls of AI in our built environment. There is a clear scholarly gap in the lack of a holistic synthesis of how AI technologies intersect with sustainable architecture, urban planning, and forward-looking design thinking. To address this gap, the present work adopts a systematic review methodology to collect and analyze existing knowledge across disciplines. By reviewing the state of the art, we aim to identify patterns, tensions, and opportunities that might not be visible within siloed discussions. In particular, this study focuses on the convergence of AI applications with the ideals of sustainable urbanism, the practice of architecture, and the notions of participatory and speculative design.

Accordingly, the research is guided by one primary question and two subsidiary questions that together cover this convergence. The primary research question asks:

RQ1: In which application areas, and through what methods, are AI technologies being integrated into architecture and urban planning in the context of sustainable cities?

This broad question examines how AI is actually being used at the intersection of these fields - from planning support systems to architectural design tools - and what that reveals about current priorities and approaches. Building on this, the first sub-question delves into a specific cutting-edge domain:

RQ2: What themes emerge at the intersection of artificial intelligence and speculative design in the current literature, and how do these themes impact architectural and urban visions for the future?

This question probes how AI and speculative design together are shaping new narratives or prototypes for the future city, and it seeks to categorize the dominant ideas (for example, AI-driven visual creativity, new design processes, or conceptual explorations of AI's societal role). It also invites reflection on what these speculative themes imply for the direction of architecture and urbanism - are they pushing toward utopian ideals, dystopian warnings, or radical redefinitions of practice? The second sub-question addresses the crucial social dimension often underrepresented in technical discussions:

RQ3: How are AI applications in architecture and urban planning evaluated in terms of social participation, ethical responsibility, and multi-stakeholder governance in the literature, in line with sustainable urban development goals?

Through this question, we investigate to what extent and in what ways researchers have assessed AI-driven projects on criteria like public engagement, equity, transparency, and ethics. It examines whether scholarly discourse is critically engaging with issues such as data governance frameworks, the inclusion of diverse stakeholders, the avoidance of bias, and alignment with public values when implementing AI in urban contexts. Essentially, RQ3 asks: are we integrating AI responsibly and democratically in our cities, and what frameworks or gaps exist in that regard? By structuring the inquiry around a central question (the technical and practical integration of AI) and focused sub-questions (covering futuristic/speculative themes, as well as ethical/governance aspects), the study ensures a comprehensive examination that is both systematic and critical. These questions are interrelated and together provide a structured lens for examining the literature.

Ultimately, this theoretical framework underpins the study's aim to synthesize knowledge across engineering, design, and urban studies. The rationale for a systematic review is grounded in the need to connect these dots - to see the complete picture of how AI is shaping sustainable city practice and how scholars are (or are not yet) addressing the accompanying cultural and ethical questions. By answering the research questions, the study will identify current trends and gaps in the literature, thereby establishing a clearer understanding of our current position and the directions future research and practice might take. In doing so, it provides a scholarly foundation for guiding both the creative innovations and responsible implementations of AI in the pursuit of sustainable, smart, and humane cities.

2. Research Methodology

This section explains the systematic review methodology employed in the study, detailing the search strategy, inclusion criteria, and analytical procedures used to ensure transparency and replicability.

In this study, the systematic review method was employed. Systematic review aims to identify, evaluate, and synthesize all relevant publications on a topic by following a predetermined protocol, ensuring a repeatable and transparent process (Moher et al., 2009). The PRISMA framework was chosen to ensure a transparent and standardized approach to identifying, screening, and selecting studies for the review, making the methodological process both replicable and accountable.

The steps implemented below have been carried out in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards (Moher et al., 2009).

Two leading international databases (Web of Science and Scopus), which index high-impact journals in the fields of social sciences, engineering, and design domains, were selected in line with the scope of the study.

In the search conducted on April 20, 2025, the keyword set was shaped around prominent terms such as "artificial intelligence," "speculative design," "sustainable cities," "architecture," and "urban planning." The obtained results were later refined using Boolean operators.

The terms used in the search are as follows for WoS and Scopus.

Wos: (ALL=(TS=((("artificial intelligence" OR "machine learning" OR "deep learning") AND ("sustainable city*" OR "urban sustainability" OR "smart city*" OR "sustainable urban") AND (architect* OR "urban planning" OR "urban design" OR "spatial design") AND (speculative OR "critical design" OR ethic* OR participat*)))) AND ALL=(TS=((("artificial intelligence" OR "machine learning" OR "deep learning") AND ("sustainable city*" OR "urban sustainability" OR "smart city*" OR "sustainable urban") AND (architect* OR "urban planning" OR "urban design" OR "spatial design") AND (speculative OR "critical design" OR ethic* OR participat*))))

Scopus: TITLE-ABS-KEY (("artificial intelligence" OR "machine learning" OR "deep learning") AND ("sustainable city*" OR "urban sustainability" OR "smart city*" OR "sustainable urban") AND (architect* OR "urban planning" OR "urban design" OR "spatial design") AND (speculative OR "critical design" OR ethic* OR participat*)) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English"))

The literature screening process followed the standard PRISMA sequence of identification, screening, eligibility assessment, and inclusion. In the identification stage, all records retrieved from Web of Science (n = 41) and Scopus (n = 141) were combined. At the screening stage, duplicate records (n = 28) were removed, and the remaining publications were evaluated based on titles and abstracts. During the eligibility stage, full texts were reviewed in accordance with the predefined inclusion and

exclusion criteria. The final inclusion stage resulted in 11 studies that met all methodological and thematic requirements.

In the initial screening conducted in the databases, 41 results were retrieved from WoS and 141 from Scopus. The results were subsequently analyzed in accordance with the PRISMA guidelines.

Inclusion and exclusion criteria were defined prior to screening to ensure a consistent and transparent selection process. Only peer-reviewed journal articles published within the last ten years were included to ensure the recency and reliability of insights, given the rapidly evolving nature of artificial intelligence and urban technologies. The review focused on open-access publications to allow full access to methodological details, data, and visuals required for qualitative analysis. Non-article documents, such as book chapters, reports, and conference abstracts, were excluded because they lack the methodological depth and peer-reviewed rigor required for a systematic synthesis. Studies not written in English or published before 2015 were excluded to maintain comparability across methodological approaches and to reflect the significant increase in AI-related urban research in the last decade. A systematic search initially yielded more than one hundred records, but the application of strict inclusion criteria narrowed the final selection to 11 highly relevant studies. This focused corpus was deemed sufficient for the aims of this review, as it allows for in-depth analysis while maintaining thematic coherence.

Following the initial identification of 182 records from Web of Science ($n = 41$) and Scopus ($n = 141$), 28 duplicate entries were removed based on DOI matching. The remaining 154 records were screened for relevance. During this phase, 91 records were excluded because they were non-article publications, published before 2015, or not written in English. A total of 63 studies were assessed for eligibility. At this stage, 52 articles were excluded based on the following criteria: 27 were not directly related to the research topic, 21 were not open access, and 4 lacked sufficient data or fell outside the theoretical scope of the study. As a result, 11 articles met all inclusion criteria and were incorporated into the final systematic review (Figure 5). Each exclusion step was applied consistently to ensure methodological transparency: records were removed because they were non-article documents, outside the specified date range, not written in English, not open-access, or not sufficiently aligned with the thematic scope of AI, architecture, and sustainable cities.

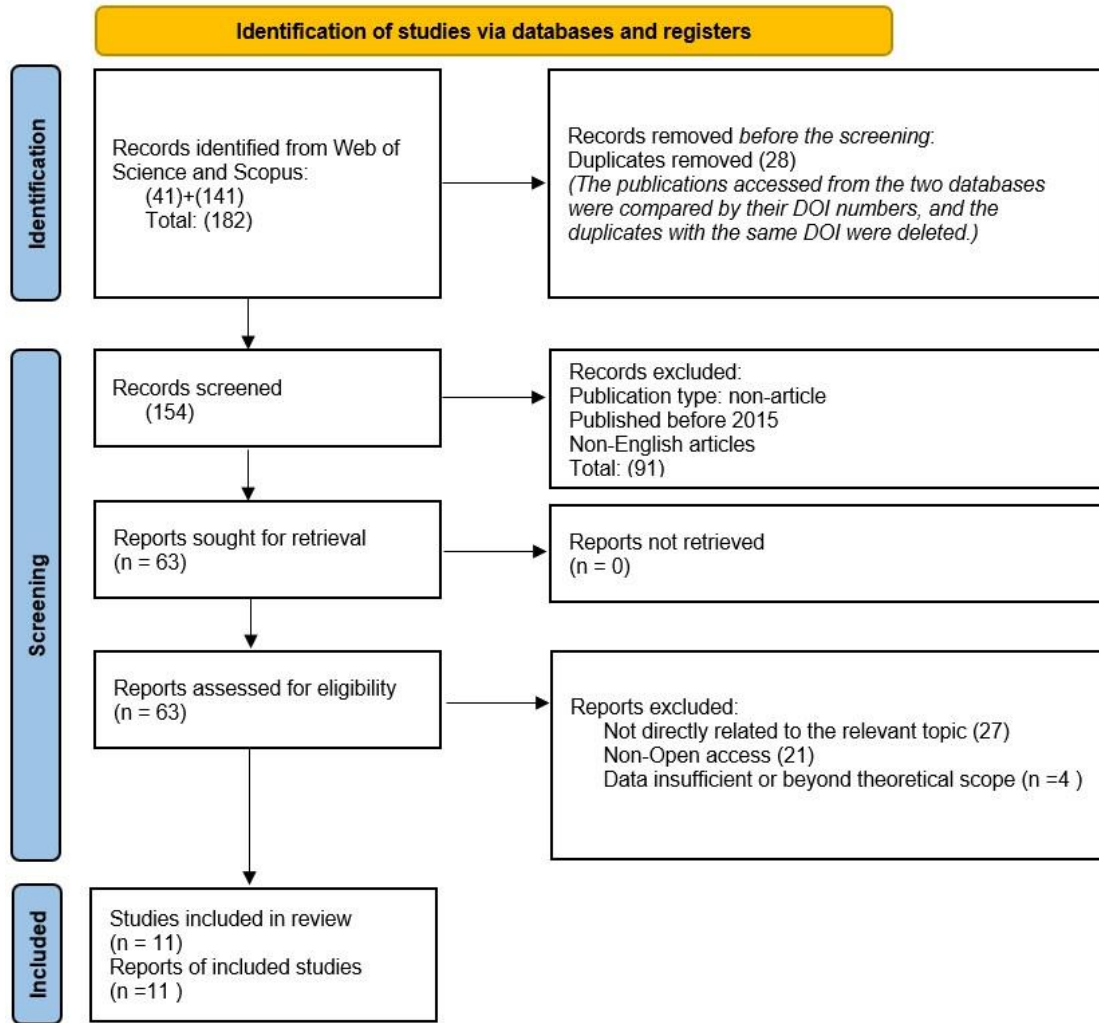


Figure 5. PRISMA Flow Diagram Illustrating the Identification, Screening, Eligibility, and Inclusion Steps of the Systematic Review.

Each of the 11 studies was analyzed by extracting key insights and then coding these insights into thematic categories (e.g., technical AI applications, participatory governance, speculative design). This thematic coding process enabled the identification of five overarching themes across the literature.

To ensure the reliability and validity of the synthesized findings, all included studies underwent a critical appraisal of their quality. Although no formal tool such as MMAT or CASP was applied, each publication was evaluated based on methodological clarity, transparency of data and analysis, and relevance to the core themes of AI, architecture, and sustainable cities. Only studies that demonstrated sufficient methodological rigor and conceptual consistency were retained in the final synthesis.

This review included only open-access publications to allow full data access and transparency of analysis. This practical choice, however, may introduce a selection bias by excluding potentially relevant studies that were not openly accessible. Therefore, the findings should be interpreted with this limitation in mind.

3. Findings

This section presents the synthesized findings of the systematic review, organizing the selected studies into five thematic categories that collectively address the research questions.

Based on the outcome of the screening and eligibility procedures, relevant studies have been identified and are presented in Table 1, organized by their thematic focus, methodology, and key insights.

Table 1. Most Related Papers as a Result of Systematic Literature Review.

No	Authors	Topic	Purpose	Method	Insights and Conclusions
1	(Marasinghe et al., 2023)	Computer vision applications for urban planning: A systematic review of opportunities and constraints	To consolidate how CV is applied across the urban planning process and identify the challenges planners face in its adoption.	Systematic literature review using the PRISMA protocol; 87 full-text articles analysed.	CV supports planning through data collection, issue identification, design, implementation, and evaluation, but challenges include data limitations, lack of training datasets, and underuse in post-design phases.
2	(Sherman, 2023)	The Polyopticon: a diagram for urban artificial intelligences	To propose the “Polyopticon” as a distributed, multi-perspectival framework for conceptualizing Urban AI, challenging the sufficiency of the Panopticon metaphor.	Conceptual/speculative analysis: historical review of Bentham’s Panopticon, Foucault’s critique, smart-city literatures, and diagrammatic formulation of the Polyopticon.	The Polyopticon reframes urban surveillance as a decentralized AI network of human and non-human observers, highlighting the complexity and ethics of distributed urban intelligences.
3	(Lombardi & Ferretti, 2015)	New spatial decision support systems for sustainable urban and regional development	To present MC-SDSS using the Analytic Network Process (ANP) to improve complex spatial decision-making in sustainable urban and regional planning.	Literature review + three Italian case studies using GIS-integrated ANP modeling; expert focus groups for value function building, weighting, and “what-if” scenario simulation.	MC-SDSS enhances transparency, stakeholder learning, and scenario testing in urban decision-making; although powerful, it requires significant expert input, careful facilitation, and data integration capacity to address multi-scalar, feedback-rich planning problems.
4	(Sepehri et al., 2024)	Artificial Intelligence’s Role in Promoting Saudi Arabia’s Smart Cities: Addressing SDGs for Socio-Cultural Challenges	To explore how AI can address key socio-cultural challenges in Saudi Arabia while supporting SDG implementation within smart city frameworks.	Structured narrative review of literature and case studies; four-step methodology identifying key challenges, linking SDGs, and AI tools; emphasis on cultural-context sensitivity.	AI can effectively support SDGs such as gender equality, climate action, and youth employment by using NLP, CV, Geospatial AI, and decision-support models; ethical, cultural, and infrastructural constraints must be addressed for successful implementation in the Saudi context.
5	(Othengrafen, Sievers, & Reinecke, 2025)	From Vision to Reality: The Use of Artificial Intelligence in Different Urban Planning Phases	To map and evaluate different types of AI systems across all urban planning phases.	A systematic literature review of 32 articles, case studies from European cities, and 8 expert interviews was structured using a conceptual matrix of AI types and planning phases.	AI enhances urban planning in diverse phases but is a supportive tool, not a substitute for planners; ethical concerns and responsible governance remain central.
6	(Cheng et al., 2023)	UrbanGenoGAN : pioneering urban spatial planning using the synergistic integration of GAN, GA, and GIS	To introduce UrbanGenoGAN, a novel algorithm integrating GANs, GOAs, and GIS to enhance scalable, efficient, and sustainable urban spatial planning.	Hybrid AI-GIS methodology combining GAN-generated designs, GOA optimization, and GIS visualization; tested through case simulations across Shanghai’s urban zones.	UrbanGenoGAN achieves superior performance in terms of scalability, computational efficiency, and planning outcomes, offering a flexible and stakeholder-engaging tool for sustainable cities.
7	(Quan et al., 2019)	Artificial Intelligence-Aided Design: Smart Design for Sustainable City	To develop the Smart Design framework, integrating AI-aided design with participatory planning.	Theoretical framework and a case study in Seoul using generative design, genetic algorithms, and energy simulations.	Smart Design supports co-evolving objectives through AI and human collaboration; however, further refinement is needed for multi-objective complexity.

		Development			
8	(Berigüete, Santos, & Cantalapiedra, 2024)	Digital Revolution: Emerging Technologies for Enhancing Citizen Engagement	To examine how digital technologies, such as VR/AR, BIM, and AI, enhance urban governance and citizen participation.	Qualitative literature review and comparative analysis of six city-level case studies using the SET framework.	These technologies enhance transparency and participation, but they also face challenges, including digital divides and regulatory gaps.
9	(Ferreira et al., 2023)	Predicting People's Concentration and Movements in a Smart City	To model crowd dynamics in Lisbon using mobile phone data and neural networks.	CRISP-DM framework using Bi-LSTM models on telecom data integrated into a live dashboard.	Accurate prediction supports mobility, planning, and safety using anonymized data; future work will include the development of spatial models.
10	(Haraguchi, Funahashi, & Biljecki, 2024)	Assessing governance implications of city digital twin technology	To develop CITYSTEPS Maturity Model to assess digital twins in smart city governance.	Conceptual modeling and governance-focused framework based on maturity models and case studies.	CDTs have potential in urban planning, but data privacy, inclusion, and standardization remain key barriers.
11	(Gilman et al., 2024)	Addressing Data Challenges to Drive the Transformation of Smart Cities	To review smart city data challenges and propose a multidimensional governance framework.	Comprehensive literature synthesis and comparative review of standardization efforts and smart city data systems.	Smart cities require integrative design approaches that address data openness, infrastructure, and the ethical use of data.

Building upon the findings of the systematic literature review, a curated body of academic work has been analyzed to explore how artificial intelligence (AI) technologies are employed across the domains of architecture, urban planning, and speculative design. The analysis is organized thematically under five key categories: (1) Applications of AI in Urban Planning Processes, (2) Decision Support Systems and Scenario Development, (3) Social Participation and Urban Governance, (4) Conceptual and Speculative Approaches, and (5) Sustainability Perspective.

1. AI Applications in Urban Planning Processes (Addresses RQ1)

This theme directly contributes to RQ1 by showing how AI is integrated into urban planning, particularly through data-driven analysis and early-stage design support. Marasinghe et al. (2023) demonstrate that computer vision assists in data collection, issue detection, and spatial evaluation, although its use remains limited in post-implementation phases. Othengrafen et al. (2025) map the distribution of AI tools across planning stages in European cities, emphasizing their role as supportive (not substitutive) mechanisms for planners. In addition, Cheng et al. (2023) demonstrate how generative models, such as UrbanGenoGAN, can produce alternative spatial scenarios, thereby expanding planners' ability to test sustainability-oriented land-use configurations. Together, these studies demonstrate that AI serves as a computational partner, capable of accelerating the assessment of complex spatial conditions while facilitating the exploration of multiple planning futures. This collective evidence strengthens the contribution of this theme to answering RQ1.

2. Decision Support Systems and Scenario Development (Addresses RQ1)

This theme expands the answer to RQ1 by demonstrating how AI-supported models enhance scenario development and evidence-based decision-making in urban planning. Lombardi and Ferretti (2015) demonstrated that GIS-integrated multi-criteria decision support systems enhance transparency, facilitate stakeholder learning, and enable planners to simulate "what-if" alternatives in complex spatial problems; this illustrates how AI-enabled evaluation frameworks systematically inform value-based planning decisions. Complementing this, Son et al. (2023) demonstrated that algorithmic urban planning models can integrate heterogeneous datasets to forecast long-term spatial outcomes, providing planners with a more structured approach to test multiple policy scenarios under varying environmental and demographic conditions. Together, these cases demonstrate how AI-driven decision systems enhance planners' ability to explore alternative urban

futures, mitigate uncertainty in policy evaluation, and align scenario analysis with sustainability-oriented objectives.

3. Social Participation and Urban Governance (Addresses RQ3)

This theme provides empirical insights for RQ3, particularly regarding how AI tools enable citizen participation, transparency, and ethical oversight. Numerous studies on the application of AI in urban governance demonstrate that technology is enhancing citizen involvement and institutional decision-making capabilities. Berigüete et al. (2024) stated that tools such as augmented reality, BIM, and AI-based interfaces enhance citizen participation and procedural transparency, despite these systems continuing to face barriers related to digital divides and uneven access to technology. Haraguchi et al. (2024) emphasized that digital twin technologies improve data-driven decision-making and support more accountable governance practices, while simultaneously raising concerns about data privacy and inclusivity. Complementing these findings, Willems et al. (2017) demonstrated that AI-supported platforms can enhance participatory processes when cities actively integrate citizen feedback loops into their smart governance models. Taken together, these examples reveal that AI not only mediates participatory mechanisms but also reconfigures governance infrastructures by creating more transparent, traceable, and ethically accountable decision-making environments that are essential for socially sustainable cities.

4. Conceptual and Speculative Approaches (Addresses RQ2)

This theme contributes to answering RQ2 by revealing how AI-driven speculative imaginaries shape future-oriented architectural and urban visions. Conceptual and speculative studies exploring the transformative potential of AI introduce new intellectual frameworks for understanding future cities. Sherman (2023) proposes the “Polyopticon” as a decentralized model of urban intelligence, reframing surveillance and perception as distributed across human and non-human agents. Quan et al. (2019) demonstrate how AI can support multi-objective design processes by linking generative design with participatory planning, illustrating the coexistence of human-centered and performance-driven logics. These speculative and conceptual works collectively show that AI enables the construction of alternative futures by expanding representational capacities, multiplying design scenarios, and exposing societal, ethical, and spatial implications that conventional design tools cannot surface.

5. Sustainability Perspective (Addresses RQ1 & RQ3)

This theme supports the interpretation of RQ1 and RQ3 by linking technological, environmental, and socio-ethical dimensions of AI-driven urban transformation. The relationship between AI applications and the goals of sustainable urbanism and architecture is widely addressed in the literature. Cheng et al. (2023) emphasize that the UrbanGenoGAN algorithm generates sustainable spatial planning outputs with improved energy efficiency and design adaptability. Quan et al. (2019) similarly contribute to sustainability-oriented multi-objective decision-making through AI-assisted design processes that integrate energy simulations and genetic algorithms. Ferreira et al. (2023) advance sustainable transportation planning by forecasting urban mobility patterns with high predictive accuracy. In addition, Sepehri et al. (2024) directly link AI to broader SDG-related themes such as climate action, equality, and youth employment. Taken together, these cases demonstrate that AI enhances sustainability not only by optimizing technical performance but also by enabling long-term resilience, improving environmental foresight, and informing more equitable policy-making, revealing its dual role as both a computational and socio-environmental actor.

The evaluations conducted under these five thematic headings demonstrate that artificial intelligence can be a holistic transformation tool that supports not only technical but also social and

environmental sustainability. The realization of the vision for sustainable cities and built environments depends on the integration of technology into design and planning processes in an ethical, participatory, and context-sensitive manner.

Overall, the literature reveals a clear pattern: AI applications in urban contexts are predominantly oriented toward technical efficiency and data-driven decision-making. At the same time, speculative and socially oriented approaches remain comparatively limited. The thematic synthesis indicates that RQ1 is primarily addressed through studies focusing on technical AI integrations in planning and design processes, RQ2 is informed by conceptual and speculative works that explore future-oriented design imaginaries, and RQ3 is supported by research emphasizing governance, participation, and ethical concerns. Together, these findings demonstrate that while AI offers substantial technical capacity for sustainable urban development, its social, ethical, and speculative dimensions remain unevenly covered in the current literature.

CONCLUSION AND RECOMMENDATIONS

This study has explored, through a speculative approach, the potential transformative role of artificial intelligence technologies in the fields of architecture and urban planning, aligning with sustainability goals. Based on a systematic review of eleven studies, the findings indicate a clear pattern: AI applications in urban contexts are predominantly oriented toward technical efficiency and data-driven optimization, while socially oriented, participatory, and speculative approaches remain comparatively limited. In this sense, the review confirms that AI already has a tangible impact on how cities are planned, designed, and governed, but also reveals significant gaps in relation to social justice, ethical responsibility, and future-oriented design imaginaries.

Regarding RQ1, the literature indicates that AI is being integrated into architecture and urban planning primarily through data-intensive analysis, scenario modeling, and performance-based decision support. In urban planning, computer vision, multi-criteria decision systems, and generative models such as UrbanGenoGAN expand planners' capacity to test multiple spatial configurations and evaluate long-term impacts on mobility, land use, and energy performance. In architecture, AI-assisted generative and optimization tools allow designers to rapidly produce and assess numerous alternatives in terms of energy consumption, material efficiency, and environmental comfort. Studies such as Quan et al. (2019), Cheng et al. (2023), and Qian et al. (2023) collectively suggest that AI operates as a "computational partner" that can process complex urban data, mediate stakeholder dynamics, and support the design of more sustainable built environments. However, the review also indicates that these tools are still largely framed as technical instruments, with limited explicit attention to the cultural and experiential dimensions of architecture and urban space.

Regarding RQ2, the intersection of AI and speculative design remains relatively underdeveloped yet conceptually rich. Conceptual works such as Sherman's "Polyopticon" and practice-oriented studies on AI-enabled design imaginaries demonstrate that AI can generate new narrative and visual frameworks for thinking about future cities. In these accounts, AI is not only a tool for optimization but also a medium that enables the construction of alternative futures, challenges surveillance regimes, and explores new forms of human-machine collaboration. At the same time, the literature review by Østfold et al. (2024) reveals that many AI-supported speculative projects risk becoming visually impressive yet context-poor, producing "futuristic" images that fail to engage with social, ecological, or political implications adequately. This tension suggests that speculative design has significant potential to connect AI with sustainability and justice-oriented visions, but that this potential remains unrealized mainly in current research. The findings, therefore, highlight an opportunity for future work to more systematically connect speculative design experiments with concrete questions of policy, governance, and everyday urban life.

In relation to RQ3, the studies reviewed emphasize that AI applications have significant implications for social participation, ethical responsibility, and multi-stakeholder governance; however, these dimensions remain unevenly addressed. Research on digital twins, citizen engagement platforms, and smart city data infrastructures shows that AI can enhance transparency, accountability, and opportunities for participation when citizens are actively involved in decision-making loops. At the same time, critical works emphasize that data privacy, algorithmic bias, and the digital divide pose significant risks to inclusive and equitable urban development. Contributions from Willems et al. (2016), Gilman et al. (2024), and Haraguchi et al. (2024) suggest that ethical AI governance frameworks are still in development and often lack concrete mechanisms for operationalizing principles such as fairness, explainability, and accountability. Overall, the review suggests that while the importance of ethical and participatory governance is widely acknowledged, a notable gap exists between discursive recognition and practical implementation in AI-driven urban projects.

When the findings are considered in a broader geographical and policy context, further limitations become visible. Several of the reviewed studies focus on cases in Europe and other highly resourced urban contexts, where institutional capacity and digital infrastructures are relatively advanced. By contrast, contributions such as Sepehri et al. (2024) and Nyaaba and Ayamga (2021) illustrate how AI-enabled solutions must be interpreted differently in regions facing infrastructural deficits, socio-cultural constraints, or uneven access to technology. In such settings, AI applications can directly address fundamental service gaps while also introducing new dependencies, vulnerabilities, and governance challenges. This uneven geography of AI applications highlights the need for more comparative and context-sensitive research that considers how local conditions shape both the risks and opportunities of AI for sustainable urban development.

From a speculative design perspective, the pattern observed in the literature can be interpreted as an indication that AI in cities is still predominantly framed within an efficiency-oriented paradigm. The dominance of technical optimization suggests that many AI projects continue to reproduce existing planning logics, rather than opening up radically new imaginaries of sustainable and just urban futures. Speculative design offers a way to respond to this limitation by deliberately exploring “what if” scenarios that foreground social values, ecological limits, and questions of power. By linking AI-based modeling and visualization tools with speculative narratives, designers and planners can use AI not only to optimize given objectives but also to question those objectives and co-create alternative futures with diverse communities. The findings of this review therefore support the argument that AI-supported speculative design has the potential to expand sustainability agendas beyond incremental improvements, toward more transformative and inclusive visions of urban life.

In practical terms, the results of this study have several implications for future research and practice. For researchers, the review highlights the need for more integrative frameworks that combine technical performance analysis, speculative design methods, and critical studies of governance and ethics. Future work could, for example, systematically test how AI tools can be embedded in participatory design processes, or how speculative scenarios about AI-driven cities might inform concrete planning guidelines and regulatory frameworks. For practitioners, the findings underscore that AI should not be treated as a neutral or purely technical solution. Architects and planners are encouraged to utilize AI as a means to expand the design space, engage stakeholders more effectively, and make the social and environmental implications of design choices more transparent, while maintaining critical oversight and ethical accountability.

In conclusion, the impact of artificial intelligence technologies on sustainable cities and architectural practices extends beyond enhancing the efficiency of existing tools. These technologies also reopen fundamental questions about how cities are lived in, for whom they are designed, and according to which values they are shaped. Truly sustainable cities are not only technically “smart” but also

socially just, culturally sensitive, and environmentally resilient. Therefore, the disciplines of architecture and urban planning should critically evaluate the possibilities offered by AI and combine them with creative, ethical, and participatory design approaches. In doing so, they will not only construct buildings and infrastructures for future cities but also contribute to the formation of more inclusive and reflective urban futures.

Future research should build on these findings by examining AI applications across more diverse geographical, socio-economic, and cultural contexts, as the existing literature remains heavily concentrated in technologically advanced regions. Further studies could also develop operational frameworks that integrate ethical governance, participatory processes, and speculative design methods into AI-driven urban planning workflows. Additionally, there is a need for empirical research that tests how AI-supported speculative scenarios can inform real-world planning policies, regulatory mechanisms, and community-based decision-making. Such efforts would help ensure that AI contributes not only to technical optimization but also to socially inclusive, context-sensitive, and democratically grounded urban futures.

Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this article.

Ethical Approval

This study does not involve any human participants, animal testing, or sensitive data that would require ethical approval. Therefore, ethical committee approval was not required.

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