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Towards A Hybrid Urban Framework Integrating Eco-City, New Urbanism, and Greyfield Precinct Regeneration in Bahrain

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Abstract

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Sustainability today requires that cities become the central point for managing the climate and urbanization crises, serving as pivotal spaces for transitions. This paper examines how green strategies, New Urbanism, and the Eco-Digital City can be integrated into an urban development model. Hybrid framework is obtained by comparing the synthesis of spatial, ecological and digital spaces across the chosen urban models. It analyses possible ways in which eco-digital governance-based frameworks can regenerate compact, walkable, and participatory neighborhoods. The Eco-Digital City model is focused on a hybrid model that creates urban green infrastructure powered by Smart Technologies and is a co-design model created by citizens. The study presents a proposal for Bahrain's urban evolution, grounded in global case studies and the Greyfield Precinct Regeneration (GPR) framework. The integration of biophilic design, participatory planning, and adaptive governance is presented in strategic policy recommendations that can support their implementation within the national urban policy framework.

Keywords: Sustainable Urban Development; New Urbanism; Eco-Digital City; Greyfield Precinct Regeneration (GPR); Bahrain.

1. Introduction

Over 75 percent of global resource consumption and more than 70 percent of greenhouse gas emissions (UN-Habitat, 2020) occur in urban areas. Cities are important players in both contributing to and being exposed to climate change and, therefore, are pivotal players in sustainable development transitions (UNEP, 2022). Urbanization at a rapid pace, environmental degradation, and increasing social inequality require radically different ways of planning for the urban realm, including being inclusive, regenerative, and future-ready (UN-Habitat, 2020; Al Ghatam, 2019).

This paper critically examines how Sustainable Urban Development (SUD) joins with greening strategies and New Urbanism approaches the problem of thinking about and remaking cities. The emerging Eco-Digital City model is also introduced as an integrated paradigm of digital technology and green infrastructure along with participatory coordination (Wang et al., 2003; Bibri, 2021). Attention specifically focuses on Bahrain's urban context, and proposes pathways for digital, socially inclusive, as well as low-carbon transformation through the Greyfield Precinct Regeneration (GPR) model (Newton & Glackin, 2025; Government of Bahrain, 2021).

2. Literature Review: The Remaking and Future of Cities

In the 21st century, urban transformation increasingly seeks to reconfigure neglected or abandoned urban spaces to meet the demands of sustainability, inclusion, adaptation, and more (Eldardiry & Elghonaimy, 2022; Konbr, 2022). The willingness of cities to remake themselves is no longer limited to expansion; they now believe those new forms should align with ecological, technological, and participatory goals. Based on this framework, that of Greyfield Precinct Regeneration (GPR), a strategic model pertaining to reviving and restructuring low-density, aging urban areas into becoming vibrant and sustainable precincts is central (Newton & Glackin, 2025).

GPR is intended for so-called 'grey fields', i.e., previous residential suburbs developed after the 1950s, characterized by poor infrastructure, inefficient land use, and poor environmental performance. This is particularly relevant to Bahrain, where many districts have not kept up with zoning regulations, contribute to an automobile-dependent lifestyle, and are not climate-responsive (Ministry of Housing, 2016).

The GPR model presents an eclectic urbanism framework based on the transitional urbanism that incorporates the following:

- a. Spatial Re-zoning: To encourage medium density, mixed-use redevelopment in the place of underperforming land uses.
- b. Digital Visualization Tools: To test and communicate development outcomes through technologies such as scenario modelling, urban dashboards, and augmented reality with stakeholders (Akram, Elghonaimy, Eldardiry, 2024; Newton & Glackin, 2025; Aziz Amen & Ali, 2025).
- c. Participatory Co-Design: Involving communities at the local level who will bear the brunt of development to ensure socially responsive as well as context-sensitive outcomes (Eldardiry & Elghonaimy, 2016).

This aligns with the United Nations Sustainable Development Goals, which aim to achieve inclusive, safe, resilient, and sustainable cities (SDG 11, UN-Habitat, 2020). As such, the GPR model bridges the physical transformation of urban space with digital governance and community engagement, which are similar core inputs to the Eco-Digital City model described in the following section. GPR has a unique potential to reverse sprawl, address infrastructure inefficiencies, and enable the creation of walkable, inclusive urban corridors aligned with Bahrain's Vision 2030.

2.1. The New Urbanism Approach: Definition and Ideological Roots

New Urbanism is a twentieth-century movement in urban design and planning that arose in response to the degradation of sprawl and car dependency. Later, He actively encourages walkable, mixed-use neighborhoods with plenty of social interaction and human-scale urban design (Calthorpe 1993; Amen et al., 2023). Based on traditional town planning, SDG 11: Sustainable Cities and Communities is aligned by aiming to make cities inclusive, safe, resilient, and sustainable.

This model was formally launched by the Congress for the New Urbanism in the 1990s and has had a global impact, promoted compact form and revitalised public realms. It questions regular zoning and infrastructure-led planning in the city-making process, by highlighting place identity, public participation, and ecologically sensitive factors.

Among these principles, New Urbanism model defines an assembly of intertwined principles to create compact, human-scaled, and eco-sensitive urbanism (Duany, Plater-Zyberk & Speck, 2000). Some of the above-listed causes include a compact urban form, mixed land use, a variety of housing types, a walkable environment, the availability of public spaces, and an integrated PT system. The first of these is the reclaiming of streets as civic, used, public spaces, where car corridors are transformed into socially alive, walking/sitting/shopping urban spaces. New Urbanism is in tune with eradicating single-street zoning and the dominance of auto-oriented structures by advocating for small-grained, diffuse urban grids and mixed-use development (Eldardiry, 2023).

In new urbanism, there are many factors, including a fine-grained urban grid, street orientation, and green integration, that emphasize connectivity, environmental quality, and aesthetic compatibility, respectively. There is, therefore, a shift from viewing streets only as movement axes; instead, streets transform the identity of the community in which they are located into civic space rather than merely a civic space (Duany et al., 2000). The particular assessment aligns with global trends in urban development. For instance, compact and connected approaches towards sustainability are endorsed by UN-Habitat (2020).

2.2. Greyfield Precinct Regeneration (GPR): Framework and Operational Dimensions

Greyfield Precinct Regeneration (GPR) is an innovative urban renewal strategy for the redevelopment of national urban sprawls, exemplified by areas of Bahrain that can be developed using this concept, beginning in the 1950s with urban sprawl, infrastructural obsolescence, and environmental inefficiencies (Newton & Glackin, 2025). GPR works towards restructuring obsolete residential zones (i.e., the grey fields) into ecologically restorative, densified, and environmentally dynamic urban precincts.

In terms of a three-pronged strategic model, Newton and Glackin (2025) frame GPR as the following:

- a. Spatial and Regulatory Reform: Spurring rezoning to greater density, mixed-use development, and transit proximity was part of one departure from the car-based planning mainstream.
- b. Digital Scenario Modelling: Computerized modelling tools that both simulate the city (the digital twin, 3D zoning software) to predict social, environmental, and economic impacts of redevelopment. It makes the data-based decision-making more transparent (Bibri, 2021).
- c. Participatory Co-Design Mechanisms: The interaction with the citizen is done at every stage of the development process using interactive apps, a visualization dashboard, and feedback loops so as to ensure that the outcomes at plan development match the local priorities and lived realities (UN-Habitat, 2020).

These methodologies can serve as an extension of the eco-digital principles outlined later in the paper and are in keeping with both the New Urbanism orientation toward community-scale development and the biophilic city campaigns for human-nature connection (Beatley 2011).

2.3. Greening Strategies in Contemporary Cities

In cities, green strategies are integrated systems that combine natural and engineered green elements to achieve both environmental and social benefits (Roseland, 1997; UN-Habitat, 2020). Greening strategies integrate natural and engineered green infrastructure with urban design to support ecological, social, and economic goals. UN-Habitat (2020) describes green infrastructure as critical to sustainable urban planning, especially in dense, climate-vulnerable urban areas. All these include green roofs, urban forests, permeable pavements, bioswales, green corridors, stormwater management infrastructure that helps contribute to climate resilience, biodiversity conservation, and urban livability (Wang et al., 2003; Bibri, 2021). Benefits include climate adaptation, biodiversity conservation, improved air and water quality, and public health benefits (Wang et al., 2003; Bibri, 2021). In other words, such interventions are not merely aesthetic improvements but essential components of city development that can be built in an ecologically and socially sustainable manner.

Consequently, in their 2011 article, Beatley defines the term 'biophilic cities' as cities that embed nature into laws, design codes, public spaces, and day-to-day urban life. Urban planning in cities, urban heat island mitigation, community well-being, and integrating nature into long-term community planning support the SDGs (Beatley, 2011).

2.4. The Eco-Digital City: A Unique Integration

The Eco Digital City is a new approach to developing old urban sustainability frameworks, leveraging the Eco City Model and the technological capabilities of the smart city. These cities would be sustainable and, in addition, adaptive, regenerative, and inclusive: ecological urbanism was merged with real-time data systems and a participatory planning platform to formulate this hybrid urban model (Alfadhel, M., & Elghonaimy, I. H., 2025). Where Wang et al. (2003) have defined the Eco-Digital City framework based on four critical functional layers, the Eco-Digital City framework in this paper is based on the work of other authors, but unlike previous work, the Eco-Digital City work in this paper is structured around four critical functional layers:

- a. Data Acquisition: Sensors, remote sensing technologies, and data acquired from the collection of environmental and infrastructural data, and behavioral data, respectively.
- b. Technological Infrastructure: IoT networks, renewable energy systems, and connectivity – but they do not make good energy storage systems.
- c. Application Systems: software layers for energy management, mobility optimization, and participatory governance.
- d. Decision-Making Interfaces: dashboards, digital twins, and augmented reality tools for planners, citizens, and decision-makers.

These layers enable real-time environmental monitoring, dynamic urban planning, and increased urban transparency, collectively constituting a cyber-physical ecosystem that enhances the city's ecological functionality (Wang et al., 2003). Although cities located in hot–arid climates face extreme temperatures and water scarcity, the parts of this model that remain critical include ecological elements of urban forests, green roofs, bioswales, urban wetlands, and solar energy systems, but with different approaches tailored to local regions. For example, these creations are supplemented with sensor networks to monitor plant health and soil moisture, which employ AI algorithms to forecast plant patterns of water demand and energy demand, and blockchain tools to record public participation as well as land use (Bibri, 2021; Eldardiry, 2022).

This approach is completed by “biophilic integration” (Beatley, 2011), which anchors the human-nature relationship in cities through design that prioritizes efficiency as well as psychological and social well-being. Based on these ecological interactions, this further builds on the Eco-Digital City, which embeds them in digital feedback loops where green infrastructure is monitored, optimized, and co-created with citizens.

In addition, this model also discusses why New Urbanist thinkers such as Calthorpe (1993) and Duany et al. (2000) are critical of urban sprawl and disconnection. New Urbanism is right to advocate for compact, walkable neighborhoods and mixed-use development, but they often lack environmental metrics and real-time public engagement tools. This is complemented by the Eco Digital City, which is dynamically responsive to form, function, climate, community, and computational insights.

Greyfield Precinct Regeneration (GPR) is emphasized as a role of digital modelling and scenario planning by Newton and Glackin (2025), a strategy which can cohere with the Eco-Digital City's layered framework of digital. The eco-digital infrastructure provides continuous feedback and adaptive management throughout the city's lifecycle and also serves as a base for scalable GPR interventions.

3. Research Context and Methodological Approach

3.1 The Research Context: Bahrain

The Kingdom of Bahrain is a fast-urbanizing island of the Arabian Gulf driven by post-oil economic diversification and limited land resources. The suburbanization has resulted in low-density patterns of development as well as environmental stresses, especially in areas near arid climates (Elghonaimy and Mohammed, 2019; Mouzughy, Bryde, and Al-Shaer, 2014). The national plans are guided by Bahrain Vision 2030, which focuses on sustainable, compact, and technologically integrated urban development (Government of Bahrain, 2021; Khan and Alkhalifa, 2023). Against this dynamic background, this study investigates hybrid planning strategies to facilitate resilient and adaptive urban change.

3.2 Research Problem

Despite their tremendous potential, cities have frequently developed in fragmented ways, focusing on either spatial form or technical function at the expense of ecological integration and citizen participation (Roseland, 1997; Beatley, 2011). The purpose of this paper is to make a forward-looking framework to bridge these divides. It explores how adapting this model to be guided by Greyfield Precinct Regeneration (GPR) principles can address Bahrain's critical urban challenges, such as low-density sprawl, car dependency, and outdated zoning regulations (Newton & Glackin, 2025; Government of Bahrain, 2021).

3.3 Study Aim and Objectives

The aim of this paper is to critically analyse how, New Urbanism greening strategy may be integrated into in the Greyfield Precinct Regeneration (GPR) framework (Newton & Glackin, 2025) to enhance its sustainable remaking. Attention is drawn particularly to the context in which these models are relevant and applicable to different contexts. The paper proposes applying the integrated model in Bahrain's urban context to address the challenges facing the kingdom.

The objectives of this paper are listed as follows:

- a. To evaluate the significance of New Urbanism in addressing contemporary urban problems, including sprawl, automobile dependency, and social disintegration of an American city in the 21st century.
- b. To analyze the Eco-Digital City model as a hybrid framework in which the ecological planning and digital technologies are merged to form real-time governance.
- c. to assess the viability of the Greyfield Precinct Regeneration (GPR) model in transforming redundant urban areas in Bahrain.
- d. To put forward policy recommendations for the implementation of green-smart retrofitting and participatory planning as part of Bahrain's emerging urban strategy.

3.4 Theoretical Framework: Sustainable Urbanism

Sustainable urbanism is being viewed as a multidisciplinary framework for meeting the global sustainability objectives. In the process, it promotes ecological regeneration, socio-spatial equity, and economic viability simultaneously, and aligns with international policy frameworks, including the United Nations Sustainable Development Goals (UN SDGs), specifically SDG11: Sustainable Cities and Communities. Compared to about 200 years ago, cities today are very different, and UN-Habitat (2020) clearly states that to overcome inequality, build resilience, and protect the environment for future generations, cities should plan on an integrated level, consolidating resources across sectors.

Urban systems for sustainable development support simultaneously the preservation of the environment, social inclusion, and economic productivity. However, according to UN-Habitat (2020), cities need to promote low-carbon growth, biodiversity, equitable access to infrastructure, livelihoods, and innovation in a climate-sensitive manner.

The three dimensions of sustainable urban development are listed as follows:

- a. Environmental Dimension: Examples of these are the Environmental Dimension, which protects ecosystems, lowers carbon footprints, as well as adapts to climate risks (UN-Habitat, 2020).
- b. Social Dimension: Inclusive access to housing, services, and being participatory governance is what the social dimension advocates (Beatley, 2011; UN-Habitat, 2020).
- c. Economic Dimension: It has an Economic Dimension supporting green economies, sustainable transport, and renewable energy (Wang et al., 2003; Bibri, 2021).

Kong (2022) points out the necessity of 'low entropy cities' derived from the repurposed infrastructure and community resilience. Sustainable urbanism is about fostering regeneration and people-centered cities that align with global climate targets and human development goals, rather than just smoothing over the damage. The Theoretical framework discussed in this paper is further made clear in (Figure. 1) below.

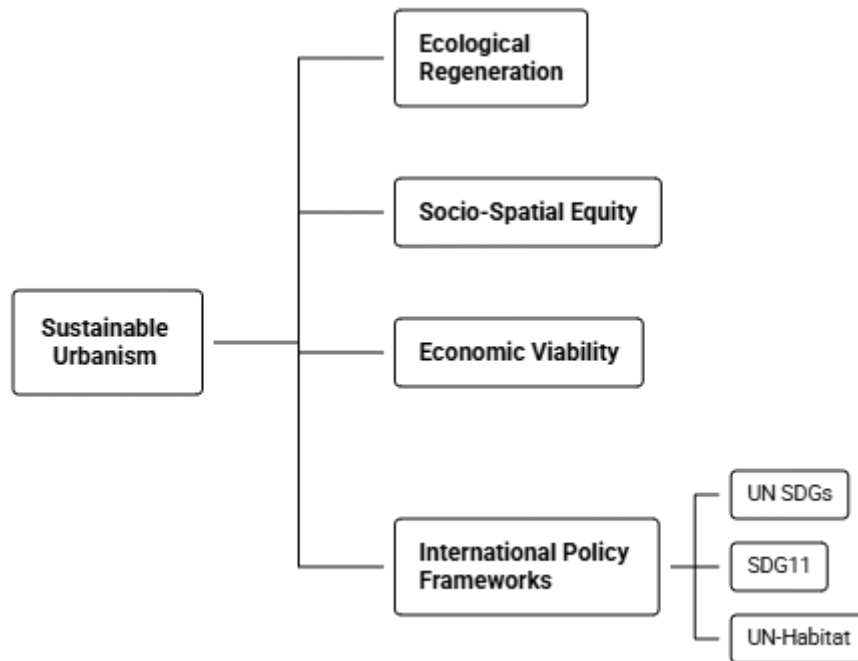


Figure 1. Theoretical framework of sustainable urbanism adopted in this study. Source: Developed by Authors.

3.5 Research Methodology

The research method used in this paper is a qualitative, comparative analysis and framework adaptation approach. The methodology focuses on integrating and synthesizing existing urban models (New urbanism, Eco-city, Eco-digital city, GPR) to create a hybrid framework specifically shaped to fit Kingdom of Bahrain's urban transition. The paper employs a 'Strategic Synthesis' approach to combine theoretical foundations and practical insights and proposes a progressive hybrid urban framework that integrates spatial, ecological, and digital dimensions. The research also reviews global case studies to draw conclusions on the adaptation of the discussed models. In short, the paper utilizes a multi-disciplinary framework to bridge physical urban transformation with digital governance and community engagement to address local and regional urban challenges in Bahrain. The overall methodological process adopted in this study is illustrated in (Figure 2) below.

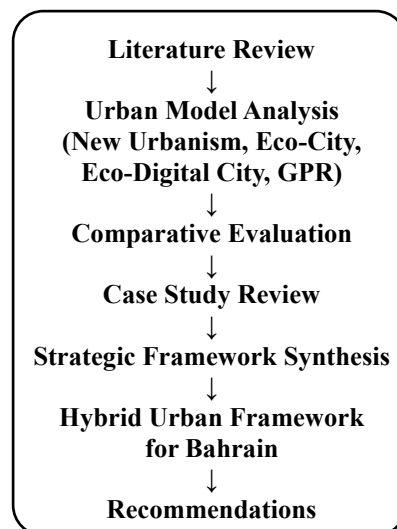


Figure 2. Research methodology and framework development process. Source: Developed by Authors.

3.6 Significance of the Study

Urban environments continue to grow, bringing both opportunities and challenges. Today, most of the world's cities are marked by outdated zoning dates, car dependency, low-density sprawl, and social fragmentation (Duany et al., 2000; Calthorpe, 1993). Worse still, rapid land consumption and little integration of green and digital strategies make these issues even more critical for Gulf countries, such as Bahrain (Al Ghatam, 2019). Today, over 70% of global carbon dioxide emissions come from urban areas that are expected to become more sustainable and inclusive systems, as they face pressure to do so, according to UN-Habitat (2020).

This places heavy emphasis on ultimately moving beyond conventional infrastructure-led planning and evolving toward models that are spatially intensive, socially engaged, and regeneratively ecological (Beatley, 2011; UN-Habitat, 2020). One particular relevant transitional model is Greyfield Precinct Regeneration (GPR). It meets the urgent need to address the underperformance in some inner urban areas by creating density, green infrastructure, and better embedding of citizen co-design and digital simulation technology (Newton & Glackin, 2025).

The paper also enriches global and regional discussions on urbanism by applying the Eco-Digital City and GPR frameworks within the context of Bahrain's planning approaches. Although these models exist elsewhere (e.g., Australia), this paper demonstrates how their framework can inform Bahrain's post-oil urban transition. By integrating ecological design, digital tools, and PPGIS into urban transformation, this paper connects with SDG 11 and Bahrain Vision 2030.

3.7 Structure of the Paper

The seven structured sections of this paper, as shown in (Figure 3) below, present a critical exploration of how greening strategies and integrated urban models can shape the future of the cities we live in.

- a. Introduction: Presents the background, significance, research problem, aim, and objectives.
- b. Literature Review: Studies existing urban models (New Urbanism, Eco-City, etc.) and points them against Bahrain's urban challenges.
- c. Theoretical Framework: Defines sustainable urbanism and outlines ecological, social, and economic theories relevant to city remaking and transformation.
- d. Comparative Analysis: Compares New Urbanism, Eco-City, Eco-Digital City, and GPR urban models.
- e. Discussion: Synthesizes insights from theory and practice to put forward urban futures in Bahrain.
- f. Recommendations: recommends integrated policy and design solutions for Bahrain's urban planning.
- g. Conclusion: Reflects on the research's contributions and identifies future pathways and room for more knowledge.

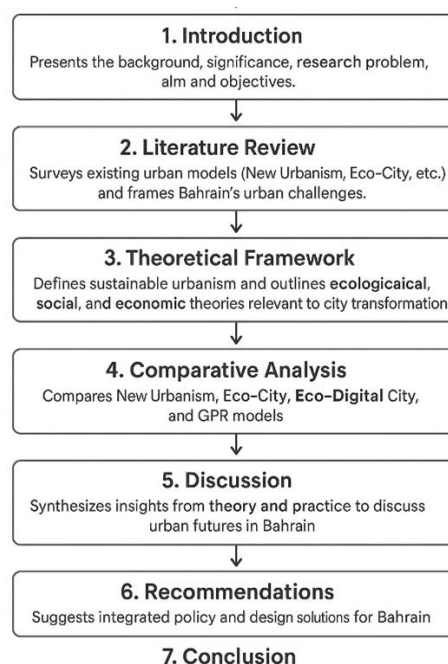


Figure 3. Research structure and analytical framework of the study. Source: Developed by Authors.

This research provides a contextual and theoretical contribution to the sustainable urbanism literature by developing an Eco-Digital urban model suitable for Bahrain. Besides, the novel integrates Ecological design, participatory governance, and digital technologies, which are the fundamental agenda of the Eco-Digital City (Wang et al., 2003; Bibri, 2021), to improve how cities transform into data-supported and eco-wise (Ehab, O. & Elghonaimy, I. H. (2023).

4. Analysis and Key Findings: Relevance of New Urbanism, GPR and Eco digital city models to Kingdom of Bahrain

This section discusses the relevance and applicability of the different models discussed in this paper to Kingdom of Bahrain and how those established models could benefit Bahrain's urbanism.

4.1 Relevance of Greyfield Precinct Regeneration (GPR) to Kingdom of Bahrain

New Urbanism principles are relevant and can guide the realisation of Bahrain's National Strategic Master Plan 2030, which seeks to transition from dispersed, low-density to high-density urbanisation and mixed-use regeneration (Ministry of Housing, 2016).

One such real-life example of New Urbanism is Seaside, Florida, a master planned urban area. It has a pedestrian-oriented approach and houses both residential, commercial, and civic facilities, so people spend more time engaging in social interactions rather than driving. In Seaside, the elements of design and planning encourage clients to embrace superior architectural design and effective planning to create sustainable, affluent communities. Designically in Bahrain, these design principles apply primarily in the city's districts currently experiencing fragmentation due to car-dominated planning. These design principles could be more relevant to Bahrain in its current effort to retrofit such districts with car-oriented planning.

While applying New Urbanism in Bahrain disciplines fragmented zoning and excessive dependence on the automobility by encouraging the development of compact mixed-use neighborhoods that are friendly to the environment as well as well to social objectives. This also supports the Greyfield Precinct Regeneration (GPR) model, learning about New Urbanist design through stakeholder engagement and co-creation, as well as the application of technology in planning the now-defunct urban area (Newton & Glackin, 2025).

4.2 Relevance of Greyfield Precinct Regeneration (GPR) to Kingdom of Bahrain

One is the adaptation of the Greyfield Precinct Regeneration (GPR) framework, established for suburban regeneration in Australia, to Bahrain's largely car-oriented, sprawling urban centers, which are proposed for densification and regeneration per the study (Newton & Glackin, 2025). Some planning frameworks in Bahrain, such as the National Strategic Master Plan 2030, support compact development, mixed-use neighborhoods, and retrofitting initiatives (Ministry of Housing, 2016), which may support the implementation of GPRs.

Thus, this integrated model contributes to the discursive formation of future cities by identifying how digital governance (IoT, AR, and blockchain) and green infrastructure (green roofs, bioswales, and solar microgrids) could breathe new life into urban areas. As such, the study aligns with Sustainable Development Goal 11, which focuses on making cities and communities safe, inclusive, resilient, and sustainable through strategic zoning, citizen participation in planning, and real-time feedback (UN-Habitat, 2020).

In the end, the study provides a roadmap for Bahrain and a model for other GCC nations struggling with the challenges of future sustainable urban development. It provides guidance on planning, policies, and the implementation of technology in climate-exposed, resource-scarce urban areas.

In Bahrain, GPR provides a context-sensitive strategy for addressing fragmented zoning, high car dependence, and an uneven distribution of green space. This model could be particularly applied to Greyfield areas to revitalize them and produce walkable, socially inclusive, and environmentally adaptable neighborhoods, particularly in Manama and Muharraq. This approach aligns with the objectives outlined in the National Strategic Master Plan (Structure Plan 2030), which advocates compact urban development, mixed land use, and sustainable transportation (Urban Planning and Development Authority, 2016). Simply put, GPR is not just a strategy for redevelopment; it is a transition framework that enables cities to metamorphose from outmoded land-use models into a regenerative, wirelessly administered, and socially connected urban future.

Greyfield precinct regeneration (GPR) in Bahrain offers a timely, contextually relevant approach that enables the legacy of car-dependent planning, spatial inefficiency, and stagnant zoning ordinances to characterize many districts in Manama and Muharraq (Newton & Glackin, 2025). These low-density housing, aged infrastructure, and single-use zoning Greyfield zones underperform, yet there is great development potential.

GPR for Bahrain is a direct implementation of the Kingdom's National Strategic Master Plan (Structure Plan 2030), which prioritizes compact urban development, mixed-use zones, sustainable mobility, and smart city solutions (Structural Network, 2016). GPR can operationalize these goals through a locally developed model grounded in the themes of spatial transformation, digital innovation, and participatory design.

Key pathways for adaptation include:

- a. **Spatial Reconfiguration:** Overcoming the region's limited urban plan by rezoning grey field areas for medium-density, mixed-use developments, combining residential, commercial, and public services to reduce the dependency on private vehicles.
- b. **Smart Infrastructure Deployment:** Planning and monitoring redevelopment of urban areas by using the sensor network, data dashboards of urban areas, and simulation tools. This fits into Bahrain's smart governance agenda as well as positioning of developing a climate resilient and behaving positively, whereby predictive analytics and real-time responsiveness ((Bibri, 2021)).
- c. **Citizen Engagement:** Co-design with urban futures via AR-enabled planning applications, co-design workshops, and digital avenues of feedback to ensure community involvement in shaping urban futures. In this way, the participatory model reinforces UN-Habitat (2020) guidelines, as well as New Urbanism's focus on place-based design, form, and social interaction (Duany et al. 2000).
- d. **Climate and Energy Resilience:** Green infrastructure retrofit, such as green roof, permeable surface, and solar microgrid, is introduced to improve environmental performance. They serve to fulfil the sustainability aspirations expressed in SDG 11 ("Sustainable Cities and Communities").

Bahrain can utilize GPR to drive its urban Greyfield revolution, turning them into future-ready precincts that are walkable, inclusive, and digitally enabled. Doing so can serve as a model for other GGC urban cities experiencing similar urban and environmental pressures.

4.3 Relevance of Eco-Digital City model to Bahrain's Future Urbanism

The overall conceptualization of the Eco-Digital City model is relevant to Bahrain, particularly in the context of the Vision 2030 policy plan and the country's ongoing process of urbanization. The urban context in Bahrain is a fragmented, automobile-centered, and climatically exposed city that requires the coordination between ecological processes and digital government (Government of Bahrain, 2021; Al Ghatam, 2019; UN-Habitat, 2020).

This paper proposes a framework by showing how existing districts, , can be retrofitted with installations such as vertical gardens, smart HVAC systems, micro solar grids, etc. Such elements call for promoting ecological cool, emissions cuts, and energy security, which help tackle climate change at the neighborhood scale (Beatley, 2011; Newton and Glackin, 2025). At the same time, real-time flood sensors and behavioral climate condition analysis in digital city measurement panels can help address the flood-prone coastal areas, an emerging need following sea level rise and climate volatility existing in the Gulf countries today (UN-Habitat, 2020; Bibri, 2021)).

Integrating applicable Augmented Reality (AR) planning applications can create an open contribution environment for people while facilitating the planning of the development of new infrastructure, the creation of new zoning boundaries, as well as the process of urban regeneration (Wang et al., 2003; Beatley, 2011). Whereas in urban Gulf countries such as Bahrain, these factors, including speculative gentrification and the sheer indefiniteness of land markets, have exacerbated housing poverty disparities and diminished institutional trust in planning systems (Elgendy, 2021). In this regard, blockchain-based land registries can ensure property data security, accurate land transactions, and minimized planning-related corruptions (UN-Habitat, 2020; Smart Nation Singapore, 2023).

In applying both the New Urbanism to the nation's corridors and the Eco-Digital City to its technological possibilities, Bahrain has a chance at molding and developing its corridors into efficient, pedestrian, low-carbon, and digitally integrated environment in contrast with the existing situation of inefficiency and fragmented zoning of Bahrain (Duany et al., 2000; Calthorpe, 1993; Roseland, 1997). As Roseland pointed out, cities have to grow into low-entropy systems, characterized by efficient use and stability of the natural environment. This could be achieved using the concepts within the Eco-Digital paradigm, which helps align economic dynamics with ecological systems' dynamics (Bibri, 2021); Newton & Glackin, 2025).

Global examples support the feasibility of this model. Singapore advances the concept of the 'Eco-Digital City', where a city leverages digital twins, IoT, and blockchain governance to facilitate decision-making, planning, and an accountable environment (Wang et al., 2003; Smart Nation Singapore, 2023). Singapore demonstrates, through this, green design and its approach, digital governance, and the intelligent, progressive integration with smart inclusiveness in coordination with its national strategic framework. Bahrain is following the same approach through Vision 2030 (Government of Bahrain, 2021).

At the same time, Freiburg, Germany, provides an example of the effective implementation of an eco-city, an innovative solar energy source, green mobility, and eco-zoning as a basis for a regenerative metabolism of cities (Bibri, 2021)). This is evident in the case of Freiburg, which underscores the need for policy coherence and environmental management as key indicators for decarbonizing Gulf states' cities and restoring degraded ecosystems (Elgendy, 2021).

Altogether, it is possible to state that the Eco-Digital City model can be viewed as a concept of a sustainable city of the future, which combines the principles of an ecological approach to urban planning (Eco-City), spatial rationality of New Urbanism, as well as the organizational and implementational aspects of the Greater Productivity Revolution (GPR). Being thus in line with the United Nations Sustainable Development Goal 11 on sustainable cities and communities, it furnishes a comprehensive and contextually appropriate blueprint for Bahrain to transition to a digitally integrated, and socially healthy city of the future (UN-Habitat, 2020).

5. Comparative Analysis and Critical Reflections

5.1. Comparative Insights and Theoretical Alignment

All of these, new urbanism, Eco City planning, the Eco Digital City Model, and Greyfield Precinct Regeneration (GPR) share the aim of producing sustainable, resilient, and inclusive cities. However, they differ in their approaches and the emphasis of their methodologies.

The physical form of New Urbanism takes a physical form perspective; it supports the idea of human-scale, mixed-use, walkable areas as an alternative to sprawling, car-dependent urbanism (Calthorpe, 1993; Duany et al., 2000). Moreover, it typically has little integration with digital systems or ecological metrics, and it is civic-oriented and focused on public space.

Eco-City models are characterized by the use of metrics to rate environmental performance and by the redesign of urban metabolism through the integration of renewable energy, circular water, and biodiversity corridors. However, they may not provide implementation tools at the neighborhood level while not putting emphasis on participatory governance (Bibri, 2021)).

Combining the spatial principles of New Urbanism with the ecological depth of Eco-City, the Eco Digital City embodies real-time technologies such as AI, IoT, and AR within its urban design. Cities are shaped into participatory, data-informed, responsive cyber-physical systems that transform cities (Wang et al., 2003; Beatley, 2011).

In low-density areas, such as Greyfield zones, Greyfield Precinct Regeneration (GPR) offers a spatial regeneration strategy particularly well matched to the character of 'black land'. So that rezoning, scenario modelling, and citizen co-design can be aligned into an adaptive planning knitting as a toolkit. In contrast to other models, this model is grounded in local retrofitting and inclusion.

These models are presented as a paradigm shift in urban thought from silo-based design traditions to an integrated, large-scale, systemic approach. Now planners are viewed as change facilitators, orchestrating ecological regeneration, spatial redistribution, and civic participation via digital and physical devices.

5.2. Strengths and Limitations of Urban Models

No planning model has an explicit focus on sustainable development; yet each presentation makes a unique contribution to it, and each also has its own limitations. In this section, Table 1 below compares their key strengths and limitations, and what they have in common is the greater need for integrative solutions that address local context, such as Bahrain.

Table 1. Comparative Evaluation of Urban Planning Models – Strengths and Limitations.

Model	Strengths	Limitations	Key References
New Urbanism	Promotes walkable, compact, mixed-use neighbourhoods; revives civic spaces	Limited ecological integration; lacks digital responsiveness	Calthorpe (1993); Duany et al. (2000)
Eco-City	Prioritizes green infrastructure, low-carbon systems, and biodiversity	Weak in participatory design; limited in real-time and neighbourhood-level implementation	Bibri (2021); Roseland (1997)
Eco-Digital City	Merges real-time digital tools with green design; offers adaptive and participatory urban systems	High technical and financial demands; requires institutional capacity and policy reforms	Wang et al. (2003); Beatley (2011)
GPR (Greyfield Precinct Regeneration)	Practical redevelopment model; emphasizes participatory co-design, zoning reform, and digital modelling	Barriers include outdated zoning laws, institutional inertia, and fragmented land ownership patterns	Newton & Glackin (2025); UN-Habitat (2020)

5.3. Strategic Synthesis: Implications for Bahrain

A hybrid strategy could therefore have a rather positive impact on Bahrain's car-dominated urban layout and disjointed spatial organization, while aiding a changed zoning. The proposed spatial transformation of the inner districts is a grounded mechanism, the retrofit of which is co-designed and is of medium density.

Emerging technological tools such as digital twins, smart sensors, and the AR Planning app fall under Eco-Digital City, which can take GPR to the next level by enabling adaptability and citizenship on an urban platform. Therefore, this perception, in the form of connective arrangements, eliminates these dichotomies simultaneously in relation to the infrastructural, ecological, and participatory in Bahrain.

This was due to New Urbanism's human-oriented design, Eco-City's environmental management, GPR's redevelopment strategies, and, last but not least, Eco-Digital City's readiness for future technology. Such a model aligns with Bahrain's National Planning and Development Strategy, as noted by the Government of Bahrain (2021), and is aligned with the global standard of UN SDG 11, as covered in UN-Habitat (2020).

Currently, Bahrain has policies on compact urban development, sustainable transport, and smart infrastructure in its National Strategic Master Plan 2030 (Government of Bahrain, 2021). Manama and Muharra's Greyfield zones are comparable in complexity to GPR model suburban subdivisions in Australia. Digital co-design, zoning reform, and the successful implementation of medium-density retrofits are key strategies that can help localize the GPR model in Bahrain (Newton & Glackin, 2025).

In the GCC, Abu Dhabi and Riyadh are also modifying zoning policies, introducing climate-friendly transport, and adopting climate-responsive urban design as environmental risks grow (Elgendy, 2021; UN-Habitat, 2020). These strategies offer more general, easily measurable ideas on how Bahrain can evolve toward eco-digital, human-centered urbanism.

The case studies were selected according to their adoption of the New Urbanism models, Eco-City, Eco-Digital City, and Greyfield Precinct Regeneration techniques. It includes precedents from global and regional benchmarks that may be applied to Bahrain's planning environment. Selection focused on examples that best integrate compact spaces, ecological

infrastructure, intelligent governance, and participatory planning—the main pillars of Bahrain's National Strategy (UN-Habitat, 2020; Bibri, 2021; Newton & Glackin, 2025). Relevance, transferability, and evidenced outcomes were used as inclusion criteria, following case study best practices for comparative urbanism (Flyvbjerg, 2006; Yin, 2018).

With that said, Table 2 below summarizes the global and regional case studies chosen for analysis that align with the urban models discussed in the theoretical framework and literature review (Olena Oliynyk, Dina Amandykova, Usama Konbr, Eldardiry, Galina Iskhonova & Tolegen Zhaina, 2023), highlighting our key lessons and possible applications for Bahrain.

Table 2. International and Regional Case Study Insights for Urban Models Application in Bahrain.

Case Study	Key Insight	What is Learnt	Application in Bahrain	Reference
Seaside, Florida	Compact, pedestrian-oriented community design with mixed-use zoning	Urban form can foster sustainability through walkability and civic spaces	Retrofit suburban zones (e.g., Muharraq) to walkable, socially cohesive urban forms	Calthorpe (1993); Duany et al. (2000)
Freiburg, Germany	Eco-zoning, solar policy, and green infrastructure integration	Environmental systems can be embedded in urban planning to support climate resilience and zero emissions	Embed eco-zoning, solar incentives, and green corridors into Bahrain's strategic retrofit planning	Bibri (2021)
Singapore – Smart Nation	Real-time planning via IoT, AR, digital twins, and blockchain governance	Smart infrastructure and participatory tools enhance adaptive planning and transparency	Adopt digital planning tools and blockchain for zoning and public engagement in Bahrain's smart city initiatives	Wang et al. (2003); Bibri (2021)
GCC Cities	Climate-adaptive mobility, zoning reform, and smart governance	Gulf cities are aligning urban policies to sustainability and resilience benchmarks	Bahrain can scale similar green infrastructure and reform outdated zoning codes using regional best practices	Elgendy (2021); UN-Habitat (2020)
Manama & Muharraq	Greyfield zones with outdated infrastructure and car-dependence	GPR's participatory and medium-density strategies can localize global models	Pilot GPR model in targeted greyfields using co-design, digital simulation, and eco-smart infrastructure	Newton & Glackin (2025); Government of Bahrain (2021)

6. Discussion: Towards Integrated Urban Futures

6.1. Integrating Urban Models for Bahrain's Sustainable Future

A comparison of urban planning paradigms, including New Urbanism, Eco-city, Eco-Digital city, and Greyfield Precinct Regeneration, reveals the increasingly complex and disjointed nature of evolving urban development in Bahrain. Each of these paradigms, while solid in theory, targets only one side of the bigger picture. Therefore, there is still poor integration, low density, a car-dependent system, and outdated zoning in Bahrain's urban planning (Al Ghatam, 2019; Government of Bahrain, 2021). It therefore becomes apparent that instead of one model being able to deliver all of the above solution, there is a need to develop an integrated urban framework that combines New Urbanist planning strategies (Calthorpe, 1993; Duany et al. 2000), the ecological recovery of Eco-City planning (Roseland 1997; Bibri, 2021), the technological innovations of Eco-Digital City planning models (Wang et al., 2003; Beatley, 2011) and the contextualized regeneration of GPR (Newton & Glackin, 2025; UN-Habitat The case of Seaside (Florida), Freiburg (Germany), and Singapore's Smart Nation provides an understanding of how such models could be applicable to Bahrain.

6.2. Model-Specific Contributions and Limitations

There exists an interesting New Urbanism design proposition that can offset Bahrain 's suburban disintegration. It includes developing places capable of accommodating people in terms of both numbers and needs, as well as promoting social interaction and the optimal use of space (Duany et al., 2000; Calthorpe, 1993). There is a clear example in Seaside, Florida, where the observations made and the action plan proposed by Duany and Plater-Zyberk have shown that the urban form otherwise required for sustainability can be achieved by encouraging pedestrian-oriented design and mixed-use (Congress for the New Urbanism, 2023). But the impact on ecological indicators is poor, and no adaptive digital tools are used in this model (Roseland, 1997).

Eco-City planning, on the other hand, has ecological depth, with ecological infrastructure, renewable energy, and low-carbon transportation integrated into the city design (Yamagata 2018, UN-Habitat 2020). The principles of FREIBURG. An example of an Eco-City is Freiburg, Germany, with its eco-Zoning, promotion of solar energy, and designs for Biodiversity Corridors that enhance the regenerative Urban metabolism (Bibri, 2021). This provides Bahrain with a model for incorporating sustainability into outdated areas, especially those with high emissions, such as central Manama.

The Eco-Digital City extends the thinking about urbanism into the smart governance paradigm by incorporating IoT, augmented-reality planning instruments, digital models, and blockchain technologies to secure land management systems (Wang et al., 2003; Beatley, 2011). In Singapore, the Smart Nation exemplified this model, in which citizens and residents are involved in planning through real-time urban indicators and mobile planning interfaces (Smart Nation Singapore, 2023; Bibri, 2021). However, this model is premised on a certain level of digital enablers and institutional environments, which are considered nascent in Bahrain at this stage (UNEP, 2022).

These frameworks are supported and supplemented by GPR, which provides a physical, neighborhood-level mechanism. Based on the Australian suburb, the GPR's main objectives include the reclassification of underutilized Greyfield through reform of zoning regulations, community engagement, and the use of digital strategies and future vision or scenario planning (Newton & Glackin, 2025). Bahrain manifests feature inherent in GPR contexts, particularly in the old urban centers of Muharraq Island and inner Manama. The use of planning tools within the models, along with their participatory nature, makes them useful in settings seeking to achieve both conservation and the regeneration of heritage (Government of Bahrain, 2021).

6.3. A Hybrid Urban Model For Bahrain

Bahrain's development and planning vision, as enshrined in Bahrain Vision 2030 and the National Strategic Master Plan, aims to intensify urban development, promote sustainability, and enhance people's participation (Government of Bahrain, 2021). A model of an ideal urban city, developed based on identified best practices from the global and/or regional context, can be considered a practical solution to address this requirement. As for the suburban context of Bahrain, specific planning retrofitting ideas might be borrowed from analyzing the spatial form of Seaside; Freiburg is useful here since eco-zoning and their solar innovation can help to integrate the resilience into infrastructure; lastly, Singapore's Eco-Digital model can help with the governance structures necessary for allowing for the data-driven planning and public access to all involved (Bibri, 2021; Wang et al., 2003).

Another advantage of the participatory regeneration strategy proposed by GPR is the fact that it will benefit Bahrain's Greyfield zones. Thus, proposed that by involving the community in co-design workshops, introducing real-life zoning exercises, and employing digital scenario modelling, Bahrain is set to plan and execute redevelopment that is both evidence-based and contextual (Newton & Glackin, 2025; UN-Habitat, 2020). Moreover, the application of blockchain in managing land records and mobile zonal interfaces would enhance the integrity of the process and reduce the likelihood of misappropriation planning issues as the nation's smart governance principles are being designed and implemented through the eGovernment Authority of Bahrain (UNEP, 2022). This plan suggests how to move Bahrain from a collage of disintegrated, pre-modern planning methodologies into a strategically digital, ecologically sensitive, and socially sustainable system of urban planning.

6.4. Global Alignment and Regional Relevance

The proposed integrated framework aligns with the advanced notion of the United Nations' Sustainable Development Goal 11, which promotes sustainable, safe, inclusive, and resilient communities (UN-Habitat, 2020). The same may be seen in the context of urban reforms across the GCC, especially in cities such as Abu Dhabi, where climate-resilient planning and green mobility have been integrated into urban planning frameworks (Elgendy, 2021). Likewise, Riyadh has undertaken significant zoning changes to support low-carbon development and digital urban infrastructure (UN-Habitat, 2020).

These regional lessons imply a great value for Bahrain. It should be noted that Bahrain's local policies focus on walkability, smart infrastructure, and sustainability improvements (Government of Bahrain, 2021). Therefore, it is possible to suggest that Bahrain's experience in planning integral urban development, integrating New Urbanism, Eco-City, Eco-Digital City, and GPR, can serve as guidance for other countries in the region in creating modern, sustainable cities for the future. It poses itself not just as a solution to Bahrain's socio-spatial dilemmas but as a model for GCC cities facing similar issues of urbanization, diversification after the oil era, and climate change.

Table 3. Overall Discussion Summary.

Urban Model	Key Contribution	Global Case Study	Application in Bahrain
New Urbanism	Promotes compact, walkable, mixed-use communities with civic spaces	Seaside, Florida (Duany et al., 2000)	Retrofit suburban areas like Muharraq using human-scaled design and spatial cohesion
Eco-City	Embeds ecological systems, green infrastructure, and renewable energy in planning	Freiburg, Germany (Bibri, 2021)	Incorporate eco-zoning, solar energy, and biodiversity corridors in high-emission districts
Eco-Digital City	Enables real-time, participatory planning using IoT, digital twins, and AR tools	Singapore Smart Nation (Wang et al., 2003)	Leverage AR, blockchain, and mobile planning apps to enhance governance and public trust
GPR (Greyfield Precinct Regeneration)	Provides neighbourhood-scale retrofitting with digital co-design and zoning reform	Melbourne Suburbs (Newton & Glackin, 2025)	Apply to Greyfield areas in Manama and Muharraq to regenerate outdated zones
Proposed Urban Model			

Integrated Hybrid Model	Synthesizes spatial, ecological, digital, and participatory strategies	Regional Cities (Elgendy, 2021)	GCC (Elgendy, 2021)	Aligns with Bahrain Vision 2030 and SDG 11 for holistic, resilient urban transformation
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7. Recommendations

Based on the comparative analysis of the integrated urban models and the discussions that followed, the following recommendations provide a strategic framework for Bahrain to attain the goals of a sustainable, inclusive, digitally adaptive urban endowment. They synthesize key elements from New Urbanism, Eco-City planning, Eco-Digital systems, and Greyfield Precinct Regeneration (GPR), and align with Bahrain's Vision 2030 and Sustainable Development Goal 11 (Government of Bahrain, 2021; UN-Habitat, 2020).

- Bahrain should encourage the piloting of regeneration projects in idle or sparsely populated areas of Manama and Muharraq, utilizing the GPR principles to transform these areas into motor-optional, mixed-use, medium-density precincts. These pilots must utilize, on the one hand, the more traditional tools of scenario modelling and geographic information system mapping, and on the other, the participatory planning workshops assisted by information and communication technologies for equitable redevelopment. Institutionalizing this strategy within the National Planning and Development Strategy will provide scalable insight into future redevelopment initiatives (Newton & Glackin, 2025; Government of Bahrain, 2021).
- Current urban planning laws should be changed to include form-based codes that promote compact mixed-use construction and do away with single-zoning. These reforms should also make green mobility infrastructure, bioswales, and solar energy systems compulsory in the new and existing neighborhoods. Such changes align with the principles of New Urbanism and Eco-City design, promoting spatial coherence and environmental resilience (Duany et al., 2000; Beatley, 2011).
- The Eco-Digital City model should be adopted as part of official planning policies as the primary guideline for all future urban developments. This involves using twin structures, real-time city scorecards, and smart sensor networks to monitor environmental performance, infrastructure, and urban growth. These digital systems are essential for building adaptive and resilient urban systems in the face of climate risks (Wang et al., 2003; Bibri, 2021).
- Greater digitally enabled participation is required for the reform of participatory urban governance through the official and innovative app relevant to planning, mobile consultations on zoning, as well as abbreviated and digital tools that enhance public involvement in the delivery of budgeting and design. Additionally, blockchain technology should be used to secure land-use records and validate community feedback, addressing the challenges of speculative development and planning opacity in Gulf cities (Bibri, 2021; Elgendy, 2021).
- The features that are inherent to biophilic design need to be made mandatory in the national planning policy, where practical strategies that include green roofs, green walls, and connecting corridors for biodiversity need to be implemented, and integrated into central business districts, etc. All large-scale developments must undergo ecological impact assessments to ensure integration with climate-responsive planning and enhance mental and environmental well-being in urban communities (Beatley, 2011; UN-Habitat, 2020).
- The creation of a National Urban Data Platform to gather data on existing buildings and infrastructures, environmental and climate conditions, population density, and demographic information, together with public feedback, is proposed to fall under the Ministry of Municipalities and Urban Planning. This platform shall assist in cognitive planning based on evidence, as well as assist in smart city advancements, while also providing a means for SDG 11 monitoring and reporting in real time (UN-Habitat, 2020).

Altogether, these six strategies present a clear plan of action for Bahrain to rethink its cities as safe, accessible, sustainable, and smart. They not only deliver sectoral solutions but also an integrated change model grounded in global theory, with practical relevance to the local context.

8. Conclusion

This paper emphasized analyzing sustainable urban transformation through the adoption of New Urbanism, Eco-City, Eco-Digital City, and Greyfield Precinct Regeneration (GPR) within the planning context of the Kingdom of Bahrain. The study began by focusing on cities as drivers of climate change, social justice, and infrastructure (UN-Habitat, 2020). Bahrain faces unique constraints of outdated zoning, spatial fragmentation, and automobile dependence (Al Ghatam, 2019; Government of Bahrain, 2021).

The theoretical framework established that sustainable urbanism is a multidimensional paradigm that engages ecological, social, and economic imperatives (Roseland, 1997; Beatley, 2011). This was built upon by the literature review, which integrated previously defined and emerging planning models to demonstrate how each can address one aspect of the sustainability problem, yet, when implemented on their own, might fail to adequately address the task.

In the comparative analysis, the paper revealed that none of the four models – the form, the ecology, the digital, and the participation – can in itself bring the change Bahrain needs. It is in this synthesis, specifically in the implementation of the GPR model applied to Bahrain's Greyfield zones, that the greatest potential lies (Newton & Glackin, 2025). The proposed hybrid model provides a clear vision for how Bahrain can integrate its aging, ineffective urban areas into compact, pedestrian-friendly, and digitally integrated precincts.

Benjamin's Position Paper discussion and recommendations put forward a reform vision based on the intertwining of zoning reform, infrastructural intelligence, green upgrade, and community engagement. This is a clear and sustainable vision as it adopted vertical gardens, blockchain-secured land ownership records, real-time planning web platforms, and co-designing with citizens.

As such, the Eco-Digital-GPR hybrid model offers a locally grounded yet globally applicable approach to achieving sustainable and resilient urbanism in Bahrain. It provides ideas and recommendations for policymakers, planners, and technologists involved in implementing Vision 2030 and the United Nations Sustainable Development Agenda. Therefore, it emerges that a response to these challenges requires certain conceptions and ingenuities to be developed at the cutting edge of urban ecology: these include ecological design, spatial reform, and digital governance, as the processes that will shape the future of the fast-urbanising, climate-vulnerable Bahrain. This study contributes to sustainable urbanism literature by proposing a context-specific hybrid framework for Bahrain that integrates ecological regeneration, digital governance, participatory planning, and precinct-scale regeneration.

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The Authors declare that there is no conflict of interest.

Data Availability Statement

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Institutional Review Board Statement

Ethical review and approval were not required for this study because it is based solely on literature review, comparative analysis, and secondary-source research and did not involve human participants, animals, or personal data.

CRedit Author Statement

Ghaida Mohamed Jameel: conceptualization, investigation, literature review, methodology, formal analysis, visualization, writing of the original draft.

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