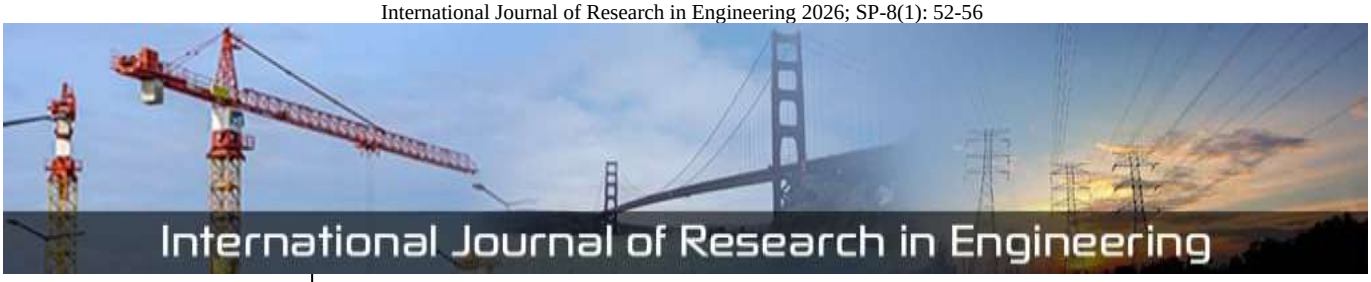

E-ISSN: 2664-8784
P-ISSN: 2664-8776
Impact Factor: RJIF 8.26
IJRE 2026; SP-8(1): 52-56

www.engineeringpaper.net
Received: 05-02-2026
Accepted: 08-03-2026

Sujata Sharma
Department of Pharmacy,
DPG College of Pharmacy,
Gurugram, Haryana, India

Arpita Kasliwal
Department of Pharmacy,
DPG College of Pharmacy,
Gurugram, Haryana, India

Corresponding Author:
Sujata Sharma
Department of Pharmacy,
DPG College of Pharmacy,
Gurugram, Haryana, India

Recent Advancement in Multidisciplinary innovation and research RAMIR-25

Green by design: The role of smart technologies in environmental protection and sustainability

Sujata Sharma and Arpita Kasliwal

DOI: https://www.doi.org/10.33545/26648776.2026.v8.i1a.180

Abstract
Urbanisation grows at an erroneous rate through decades projected to continue in future. Both opportunities and complex challenges go hand in hand for this sustainable development. Although only a 2% share of land throughout the globe is occupied by cities, they are responsible for 60–80% of global energy consumption. Therefore, innovative approaches to urban sustainability is the need of the hour. Rapid urban growth intensifies pressures on daily essentials like housing, transportation and infrastructure while aggravating environmental problems such as air and water pollution and climate-related impacts including heatwaves, floods, and storms. Moreover, the uneven distribution of urban benefits often deepens social and economic inequalities.
The present review highlights the fact that smart technologies and green urban design play a important role in progressing environmental protection and sustainability. Integrating technology with environmental principles improves resource efficiency and resilience, quality of life while fostering inclusivity and community engagement. Smart technology includes use of smart grids, solar panels and LEDs to manage energy consumption, smart traffic signalling and smart parking systems to reduce congestion and smart water conservation system for efficient waste water management. This paper explores the concept of "Green by Design," as an approach to create alternatives that have minimal impact on environment and create cities that are equitable, resilient, and ecologically sustainable.

Keywords: Generative AI, health, depression, anxiety

1. Introduction
Traditional urban development models have been largely linear—extracting resources, consuming energy, producing waste, and generating environmental degradation [1]. To counter these patterns, policymakers and planners are increasingly adopting integrated and technology-enabled solutions. Smart technologies provide real-time monitoring and adaptive management of resources, whereas green design focuses on passive strategies and eco-centred planning. Together, they form a dual pathway to address environmental challenges while improving quality of life.
The objective of this review is to synthesise existing research on how smart technologies and green urban design interact to promote sustainability outcomes in cities. The Green by Design ideology, which emphasizes designing cities with ecological responsibility ingrained in their fundamental structure, is further examined. The issues of urbanization's effects on the environment and society, new smart technologies, green urban design principles, and integrated strategies for resilient and sustainable cities are covered in the following parts.

2. Urbanisation and Its Environmental Challenges
2.1 Resource Consumption and Energy Demand
Despite their modest spatial footprint, cities consume a majority of global energy and emit huge volumes of greenhouse gases. Fossil-fuel-based energy systems, inefficient building stock, aging infrastructure, and increasing transportation demand intensify this dilemma [2].
Key concerns:
- High power use in buildings for heating, cooling, and appliances.
- Inefficient transportation systems leading to carbon emissions and air pollution.

- Growing demand for water and poor wastewater treatment.
- Increasing solid waste creation owing to consumerism and population density.

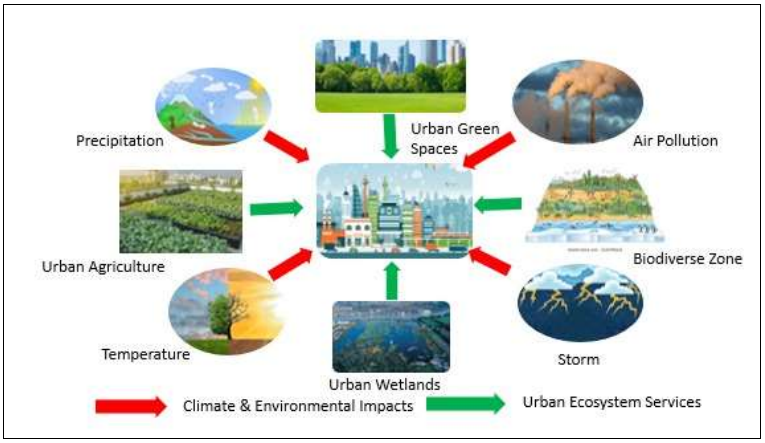

Fig 1: Impact of conventional urban development on climate and environment compared with ecosystem services offered by green-by-design urban planning.

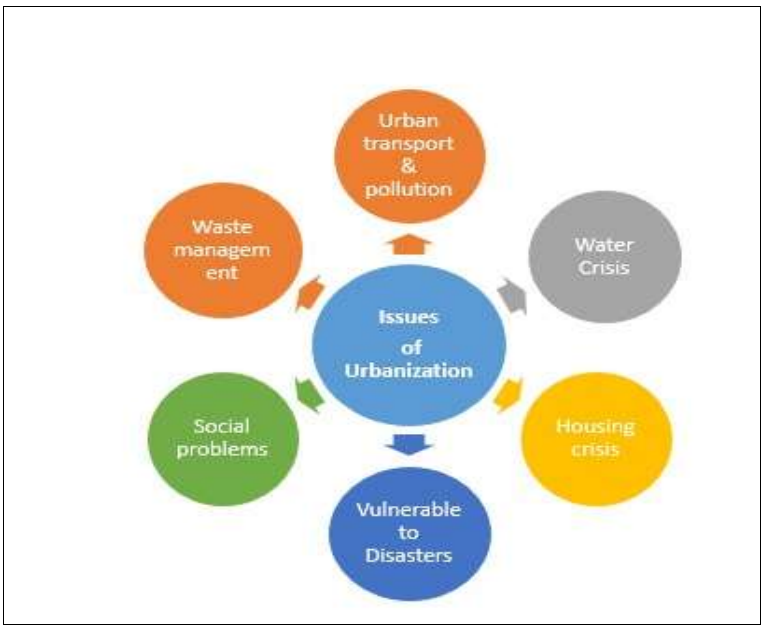

Fig 2: Issues of Urbanization

2.2 Climate-Related Effects

- Heatwaves and Urban Heat Islands (UHI), which are caused by dense built-up structures, less vegetation, and heat-absorbing materials, are among the climatic threats that urban regions confront [3].
- Stormwater overload and floods are caused by impermeable surfaces and inadequate drainage.
- Deterioration of air quality: High concentrations of ozone, nitrogen oxides, and particle matter.
- In coastal cities, rising sea levels are putting low-lying communities and infrastructure at risk.

2.3 Social and Economic Inequalities

2.3.1 Economic and Social Inequalities

Socioeconomic inequality is frequently made worse by urbanization. Green landscapes, safe housing, sanitary facilities, and clean water are all inaccessible in informal communities. Participation in smart urban systems is further restricted by digital divides [4]. Social justice must be incorporated into smart technology deployment and urban design in order to ensure inclusivity.

2.3.2 Intelligent Technologies for Sustainable Urban Growth

To improve urban systems, smart technologies make use of sensors, data analytics, automation, artificial intelligence, and the Internet of Things (IoT). These technologies enhance productivity, cut waste, and promote evidence-based policymaking when used properly.

3.1 Smart Energy Systems

3.1.1 Intelligent Networks

Real-time energy usage monitoring, dynamic load balancing, and the integration of renewable energy sources are all made possible by smart grids. They improve dependability, lower power losses, and facilitate decentralized generation like rooftop solar [5].

3.1.2 LED Technologies and Solar Panels

Adoption of high-efficiency LED lighting and photovoltaic (PV) systems lowers energy expenses and carbon emissions. LEDs have much longer lifespans and can use up to 75% less energy than conventional lights.

3.2 Systems for Intelligent Transportation (ITS)

Vehicle pollution and traffic congestion continue to be significant urban problems. These issues are lessened with the use of smart transportation systems.

Examples

- Adaptive signal control systems that react to current traffic patterns are known as smart traffic signals.
- Smart parking systems: These reduce needless driving by using sensors to direct cars to open parking spots.
- Integrated public transportation platforms: digital ticketing, multimodal trip planning, and real-time bus and train tracking.

According to studies, ITS can cut emissions by 10–20% and traffic by up to 30% [6]

3.3 Smart Water and Waste Management

Water usage is optimized by technologies including automatic irrigation systems, smart meters, and leak-detection sensors. IoT-based fill-level sensors in waste collection systems increase collection efficiency while lowering pollution and fuel consumption.

3.4 Platforms for Urban Data

Predictive analytics and improved governance are made possible by centralized systems that include data on energy, mobility, the environment, and public services. Digital twins, which are virtual representations of entire cities used for disaster relief and infrastructure development, are one example.

4. Green Urban Design

Concepts and Methods In order to improve human well-being and lessen environmental effects, green design incorporates ecological concepts into constructed spaces.

4.1 Solutions Based on Nature (NBS)

NBS provides ecological services by integrating natural systems with urban areas.

Examples include:

- Street trees and urban forests for carbon sequestration and cooling.
- Bioswales and wetlands to reduce flooding.
- Green walls and roofs to improve biodiversity and provide insulation.

  These methods improve public health and attractiveness while addressing climate adaption.

4.2 Eco-Friendly Building Design and Architecture:

To maximize natural ventilation, daylighting, and insulation, green buildings employ passive design techniques. Green building is encouraged by certifications like LEED, BREEAM, and GRIHA [7].

Benefits include:

- Lower operating costs;
- Less energy and water consumption.
- Improved indoor environmental quality.

4.3 Green Transportation and Urban Mobility

Sustainable mobility comprises of public transportation, cycling, walking, and electric vehicles. Transit-oriented development (TOD) generates compact, pedestrian-friendly neighbourhoods that lower dependence on private vehicles [8].

4.4 Resource-Efficient Urban Planning

Key strategies include:

- Mixed-use development to reduce travel distances.
- Compact city design to limit land consumption.
- Circular urban metabolism—recycling materials, reusing water, and recovering energy.

5. Combining Green Design with Smart Technologies

Although smart and green initiatives are sometimes seen in isolation, their combination produces better sustainability results. While green design can increase the efficacy of smart technologies by lowering baseline resource consumption, data-enabled systems can enhance the performance of nature-based and green infrastructure [9].

5.1 Sensible Green Collaborations

For example:

- Smart irrigation and green roofs increase cooling while consuming less water.
- In green spaces, IoT sensors monitor soil moisture, tree health, and microclimate variables.
- Smart building systems optimize lighting, heating, and cooling based on occupancy and the external temperature [10].
- Renewable energy-powered smart grids enable low-carbon regions.

5.1 Intelligent Green Partnerships

For instance:

- Green roofs and smart irrigation improve cooling while using less water.
- IoT sensors in green areas track microclimate conditions, tree health, and soil moisture.

5.2 Strengthening Resilience

Flood-monitoring sensors connected to green stormwater management are one way that integrated systems enhance readiness for disasters.

- Urban tree-cover planning in conjunction with heatwave forecasts.
- Climate-adaptive infrastructure combined with early warning systems.

5.3 Encouraging Inclusivity in Society

- Equity must be considered while designing technology:
- Access to digital services at a reasonable cost.
- Participation of the community in data-driven planning.
- Creating public areas that are accessible to all, inclusive, and safe.

6. "Green by Design" as a concept

Instead, then retrofitting solutions after issues develop, "Green by Design" emphasizes integrating sustainability at the outset of planning, engineering, and policymaking.

6.1 Fundamental Ideas

Preventive Design: Using building orientation, materials, and site selection to minimize environmental effect.

- Smart building systems optimise heating, cooling, and lighting based on occupancy and external climate.

- Renewable-energy-powered smart grids support low-carbon districts.
- **Systems Thinking:** Recognizing the connections between urban and natural ecosystems.
- **Regenerative Approaches:** Creating cities that do more than just lessen damage to the environment.
- **Scalability and Flexibility:** Enabling infrastructures and technology to adapt to changing demands.
- **Community-Centred Planning:** Making sure local perspectives influence development priorities.

6.2 Implementation Strategies

- **Policy integration:** requiring sustainability criteria in development approvals, urban regulations, and zoning.
- **Testing design scenarios** to attain the best possible environmental performance is known as digital-twin modelling.
- **Lifecycle assessment:** Analysing how development and deconstruction affect the environment.
- **Green financing:** Supporting sustainable projects using incentives, carbon credits, and green bonds [11].

7. Case Studies of Smart-Green Integration

7.1 Singapore: Smart Nation with Green Vision

- Smart water recycling and desalination systems are examples of how Singapore combines ecological design with digital systems.
- The "City in a Garden" approach, which promotes extensive urban vegetation.
- Congestion pricing and intelligent transportation management [12].

7.2 Copenhagen: Carbon-Neutral Urban Planning

Copenhagen uses digital platforms to manage energy and mobility while integrating green roofs, district heating, and bike infrastructure. With the goal of becoming the first carbon-neutral metropolis in the world by 2025, Copenhagen is well known for its aggressive carbon-neutral urban design. The city incorporates green infrastructure, renewable energy, and sustainable transportation into its urban development. Large bike lanes prioritize cycling, which lowers pollution and reliance on cars. Waste-to-energy, biomass, and wind-powered district heating systems effectively supply buildings with energy. Environmental performance is further improved by energy-efficient architecture, urban green spaces, and climate-resilient design [13]. Copenhagen's all-encompassing planning strategy shows how citizen involvement, policy integration, and sustainable design can greatly lower urban carbon footprints while enhancing quality of life.

7.3 Barcelona: Smart Urban Ecosystem

Barcelona's "superblocks" use sensor-based irrigation for urban green spaces, lessen traffic, and enhance walkability.
These illustrations show how clever and environmentally friendly tactics can improve livability, lower emissions, and increase resilience [14].

8. Future Prospects and Challenges

With the help of smart technologies, Green by Design has a bright future for sustainability and environmental preservation. Real-time monitoring and effective control of energy, water, and waste systems are made possible by technologies like artificial intelligence, the Internet of Things, and data analytics. Adaptive infrastructure and smart buildings can improve climate resilience, cut carbon emissions, and use less resources. But there are also issues, such as expensive implementation costs, complicated technology, and uneven access, especially in developing nations. Adoption is also hampered by concerns about data privacy, cybersecurity, and the requirement for qualified personnel. Long-term planning and robust policy frameworks are necessary for integrating smart technologies into current urban systems. Achieving sustainable and resilient urban development requires addressing these issues through inclusive policy, innovation, and capacity building.

8.1 Emerging Technologies

- AI-enhanced mobility and logistics.
- Urban robotics for maintenance and environmental monitoring.
- Blockchain for transparent energy trading.
- Distributed renewable microgrids.

8.2 Challenges

- High financial costs of implementation.
- Data privacy and cybersecurity risks.
- Technological inequalities across communities.
- Need for interdisciplinary planning and governance.

8.3 Opportunities

- Digitally empowered citizen engagement.
- Nature-positive urban regeneration.
- Climate-adaptive infrastructure investments.
- Potential for net-zero and circular cities.

9. Conclusion

Green urban planning and smart technologies offer complimentary approaches to the complex problems of fast urbanization. Smart systems enhance infrastructure efficiency, maximize resource utilization, and facilitate evidence-based decision-making. Ecological balance, resilience, and human well-being are prioritized in green design. Cities may move toward sustainable, fair, and climate-resilient futures by using the integrative lens of Green by Design.
The most promising route for creating cities that are inclusive, regenerative, and sensitive to new global issues is a holistic approach that combines technological innovation, environmental care, and community involvement.

Reference

1. Girardet H. Creating regenerative cities. London: Routledge; 2015.
2. Gungor VC, Sahin D, Kocak T, *et al*. Smart grid technologies: Communication technologies and standards. IEEE Transactions on Industrial Informatics. 2013;7(4):529–539.
3. International Energy Agency. World energy outlook 2021. Paris: International Energy Agency; 2021.
4. Wan G, Zhang X, Zhao M. Urbanization can help reduce income inequality. npj Urban Sustainability. 2022;2(1):1.
5. Luizelli MC, Canofre R, Lorenzon AF, Rossi FD, Cordeiro W, Caicedo OM. In-network neural networks: Challenges and opportunities for innovation. IEEE

Network. 2022;35(6):68–74.
6. Litman T. Transportation and environmental policy. Victoria: Victoria Transport Policy Institute; 2020.
7. Al Hassan HMK. Optimizing sustainable architecture: Machine learning approaches for eco-friendly building design. Civil Engineering and Architecture. 2025;13(1):625–636.
8. Mavlutova I, Atstaja D, Grasis J, Kuzmina J, Uvarova I, Roga D. Urban transportation concept and sustainable urban mobility in smart cities: A review. Energies. 2023;16(8):3585.
9. Chipriyanov M, Chipriyanova G, Veselinova N. The role of green technologies and smart city projects (synergy for a sustainable future). In: Environment. Technology. Resources. Proceedings of the International Scientific and Practical Conference. 2025;1:125–132.
10. Yang Q, Geng R, Feng T. Does the configuration of macro- and micro-institutional environments affect the effectiveness of green supply chain integration? Business Strategy and the Environment. 2020;29(4):1695–1713.
11. Ozili PK. Green finance research around the world: A review of literature. International Journal of Green Economics. 2022;16(1):56–75.
12. Sipahi EB, Saayi Z. The world's first "smart nation" vision: The case of Singapore. Smart Cities and Regional Development Journal. 2024;8(1):41–58.
13. Kohl U, Andersen J. Copenhagen's struggle to become the world's first carbon neutral capital: How corporatist power beats sustainability. Urban Planning. 2022;7(3):230–241.
14. De Luca C, Langemeyer J, Vaňo S, Baró F, Andersson E. Adaptive resilience of and through urban ecosystem services: A transdisciplinary approach to sustainability in Barcelona. Ecology and Society. 2021;26(4):1–25.