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Resource-Efficient Smart Cities: Recommending Green Artificial Intelligence Technologies in the Indian Context

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Abstract

The integration of green Artificial Intelligence (AI) in the sphere of urban planning in India is a significant step towards tackling challenges linked with urbanisation, sustainability, and environmental conservation. As India progresses, there is a growing need for innovative solutions to minimise the ecological impact, optimise resource management, and enhance the overall quality of life in urban areas. Green AI is an emerging field that focuses on utilising the power of AI not only to make cities smarter but also more environmentally friendly. It emphasises energy efficiency, conservation, and environmental sustainability. This article examines the literature on the areas of green AI in smart city planning and recognizes the key sectors where these technologies can be incorporated into the existing smart cities in India. The key sectors identified for integrating green AI technologies are water quality and resource management, air quality management, traffic management, waste management, and energy efficiency and management. The article endeavours to identify the sectors where AI can be utilised to create sustainable and environmentally conscious smart cities, ultimately contributing to establishing eco-friendly and resource-efficient urban environments in the Indian context.

Keywords: Smart City Planning, Urban Planning, Resource Efficiency, Environmental Sustainability, Green Artificial Intelligence

1. Introduction

India, currently the world's most populous nation, is undergoing a rapid urbanisation trend, with urbanisation expected to rise to 50% from its current level of 34% by 2030 (MoEF, 2019). This demographic shift causes many major challenges, especially concerning resource utilisation and environmental impacts. To achieve a GDP of 2.6 trillion USD in 2015, material consumption increased from 1.18 billion tons in 1970 to 7 billion tonnes which marks about 6-fold and is expected to be 14 billion tonnes in 2030 (MoEF, 2019).

The increased demand for products and services due to rapid urbanisation puts pressure on already stressed and limited resources. The indiscriminate exploitation of natural resources to meet this growing demand raises serious concerns about resource depletion and environmental degradation. The increased usage of resources also indicates the increased generation of waste, again causing environmental pollution. These ultimately affect the economy, livelihoods, and quality of life, which raises sustainability concerns.

The Smart Cities Mission launched by the Government of India in 2015 transforms urban areas into technologically advanced and sustainable hubs. Green artificial intelligence (AI) technologies play a

pivotal role in harnessing the power of data for environmental sustainability. Green AI refers to the use of artificial intelligence techniques to optimise energy efficiency, reduce environmental impact, and promote sustainability. In the context of smart cities, Green AI can be applied to analyse the collected data and derive actionable insights for better resource allocation and planning.

Integrating Green AI technologies into smart cities in India facilitates the collection and analysis of data, enabling informed decision-making for sustainable urban development. These technologies contribute to a more environmentally friendly and efficient urban landscape, addressing the challenges of rapid urbanisation and promoting a higher quality of life for residents.

2. Methods

This paper explores the potential of Green AI for resource-efficient and eco-friendly development in Indian smart cities through a literature review and analysis of relevant literature case studies. The method adopted for the study is an exploratory and non-empirical approach because of the nascent stage of Green AI implementation in India and the focus on exploring practical applications.

To find relevant literature, a comprehensive search using academic databases (e.g., Google Scholar) with keywords like "Green AI," "Smart Cities," "Sustainability," "Indian Smart City Mission," and relevant combinations. Inclusion criteria prioritised recent (2018-2023) peer-reviewed articles and reports in English discussing Green AI concepts and applications in urban contexts. Excluded materials included outdated publications, opinion pieces, and irrelevant content. The analysis of the literature was done based on themes such as key sectors of applications in smart city planning, methods of applications, benefits, and challenges. Five key sectors of applications were identified after the literature review.

The case studies were selected based on the applications of Green AI identified from the literature studies. Five case studies, one for each application, of international smart cities were selected. The data collection was done by reviewing the official websites of the implementing agencies, the websites of relevant NGOs, news articles etc. The issues that led them to integrate Green AI technologies in their smart cities, the method of integration, and their initial outcomes were analysed.

3. Results and Discussion

3.1. Key environmental issues concerning the resource efficiency of Smart Cities in India

The study identified that the key issues in various environmental-related sectors of smart city planning that focus on natural resources and the environment include;

3.1.1. Water quality and resource management

Water is one of the most important natural resources, and in the wake of global climate warming, its sustainability has become one of the biggest challenges of the 21st century. The environmental infrastructures of cities, including water pollution, were not designed to accommodate large population increases and waves of migration, leading to challenges in managing water resources efficiently (Meric Yilmaz Salman, 2023). The oversharing of water in the world has become an important component of international relations, and India is known to be depleting its surface water resources at a much faster rate than other countries. Approximately 70% of surface water is estimated to be unfit for consumption. India's waters were profoundly degraded by the illegal disposal of trash, silt, and raw sewage into rivers and lakes. An insufficient waste management system and the almost complete lack of pipe planning are making matters worse. Nearly 40 million Indians suffer from waterborne diseases like typhoid, cholera, and hepatitis and nearly 4,00,000 fatalities each year (Igini, 2023). Water fulfilment is one of the main

necessities of peri-urban and urban societies; scarcity of water can have catastrophic effects on a country's economic and living conditions.

3.1.2. Air quality management

Major cities are continuously facing the challenges of global greenhouse gas emissions, contributing to air pollution that blankets them from time to time. Lack of planning and policy in the areas of transportation, industry, energy use, and waste generation frequently results in air pollution. Millions of people worldwide are known to be impacted by contaminated air. Globally, millions of people are affected by polluted air.

According to the 2021 World Air Quality Report, India is home to 63 of the 100 most polluted cities, with New Delhi having the worst air quality in the world. The study also found that PM2.5 concentrations in 48% of the country's cities are more than 10 times higher than the 2021 WHO air quality guideline level (Igini, 2023).

The World Health Organisation (WHO) reports that air pollution causes over seven million premature deaths annually. India has one of the highest numbers of people affected by air pollution in the world. The rapid increase in population and its unsustainable policies have made cities in India among the most polluted in the world. Continuous monitoring, identification of sources, and finding solutions to air pollution are prerequisites for creating sustainable smart cities. Smart cities must implement technology-based solutions to reduce emissions and improve air quality (Meric Yilmaz Salman, 2023).

3.1.3. Traffic management

Transportation, a vital industry and a pillar of smart city development requires careful consideration to maximise mobility by controlling traffic, achieve safety by minimising accidents, mitigate air pollution by lowering vehicle exhaust emissions, and advance socioeconomic goals. As one of the most built-in challenging factors to transportation, traffic congestion will keep rising proportionally with cities' development, which directly affects their socio-economic activities (Meric Yilmaz Salman, 2023). Since most social and economic activities depend on integrated, sustainable transportation, transportation networks should be extended to cover and accommodate anticipated development as cities grow because of other activities. The integration of advanced technology with transportation management will also significantly aid in achieving the goals of smart cities.

3.1.4. Waste management

Waste Management is considered one of the key components of urban environmental systems planning. Growing populations, demographic shifts, rising living standards, and rising consumption rates are the main causes of the rise in urban waste volumes. Planning and executing a comprehensive waste management programme, connecting the various sectors like residential buildings, commercial & industrial establishments, hotels, health care institutes, the transport sector, public places, tourism spots and many others, is one of the challenges in Smart City projects (Meric Yilmaz Salman, 2023). Infrastructure development and systems planning will be greatly impacted by increasing waste quantity trends. The ecological footprint of garbage is greatly impacted by unscientific handling and management.

3.1.5. Energy efficiency and management

The influx of a huge urban population will generate a huge energy demand for housing, lighting, transport, and water management. India must fulfil the demands of this urban population, where energy management could prove to be a crucial point. Per capita energy consumption is known to be strongly correlated with the human development index (HDI). Reliance on green energy for most of the demand fulfilment, as well as efforts at trying to minimise the carbon footprint, could be an arduous task if not carefully planned

(NitiAayog, 2017). Another important role of smart cities could be to decrease the energy demand. The green building concept should be promoted to reduce energy consumption. Growing trends in waste amount will have a significant impact on system planning and infrastructure construction. Improper treatment and disposal of waste have a significant negative influence on the environment.

3.2. Case studies of incorporating AI into smart cities

Water Quality and Resource Management: Singapore, a world leader in water sustainability, shows how Green AI can transform the management of water. The NEWater plan uses cutting-edge membrane technologies and AI-based monitoring to convert used wastewater into safe drinking water. Aside from cutting on the dependence on natural resources, it reduces wastewater that is discharged hence reducing threats to marine waters.

Traffic Management: Amsterdam's Smart Mobility initiative demonstrates the transformative power of Green AI in traffic optimization. Real-time data analyses carried out through sensors and cameras enable dynamic adjustment of traffic signals and public transport schedules, thereby reducing congestion and emissions. Improving efficiency in travel by this smart system also contributes to cleaner air and a sustainable urban environment.

Air Quality Management: Calliope Urban is an example from Barcelona showing how Green AI can help us improve air quality. This networked system relies on sensors which are implemented together with AI algorithms for monitoring real-time air pollutants. In using a data-oriented approach it identifies and mitigates pollution sources towards a cleaner atmosphere and better health of the public.

Waste Management: Green AI and waste optimization in Barcelona via smart bins and data analytics are demonstrated. Smart bins with sensors that monitor fill levels optimize collection routes, while waste composition identification is done through data analytics for efficient recycling and resource recovery. Moreover, this smart system reduces waste collection costs, as well as the reliance on landfills and promotes a circular economy.

Energy Efficiency and Management: Suwon's IoT & AI Smart Buildings and Energy City Initiative under the Korean Government is an example of Green AI-powered energy management. Building energy consumption is monitored by smart sensors and controlled using AI algorithms allowing real-time adjustments of heating, cooling, and lighting systems among others. Furthermore, the approach minimizes energy loss resulting in reduced carbon dioxide outputs leading to a more sustainable built environment.

These case studies depict the varied applications of Green AI across different environmental sectors as well as their potential for transformation. By leveraging data analytics and intelligent automation for instance; Green AI can empower smart cities to pursue environmental sustainability whilst enhancing public health thereby increasing present and future generation's quality of life

3.3. Sectors for incorporating green AI in smart cities of India

Therefore, the key sectors in which green AI technologies should be incorporated to address the issues in resource efficiency in Indian smart cities as;

1. Water quality and resource management
2. Air quality management
3. Traffic management
4. Waste management
5. Energy efficiency and management

4. Conclusion

Green AI, an evolving field at the intersection of artificial intelligence and environmental sustainability, holds immense significance in driving resource efficiency improvements within cities. The rapid urbanisation rate witnessed by India today and issues such as climate change, global warming, etc., necessitate the need to find technological solutions for the cities. The introduction of smart cities in 2015 to create replicative models for other cities laid the foundation for adopting technological solutions for the issues of urban centres in India.

This paper identified the environmental-related sectors and key issues in smart city planning, where green AI can be incorporated, encompassing water quality & resource management, traffic management, air quality management, waste management, and energy efficiency & management. Also, case examples of using AI in these sectors provide evidence for obtaining benefits from integrating green AI into the smart city planning paradigm that enhances resource efficiency.

To sum up, combining Green AI with smart city planning is not only a futuristic approach but also an emergency response to the critical challenges that our cities are facing. The incorporation of green artificial intelligence (AI) appears to be a promising development for the future of urbanization, leading to resource-efficient, eco-friendly, and technologically advanced smart cities

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