

# Sustainable Development of Smart City Renewable Energy Source, Development and Sustainable of Automation System

Moditha S<sup>1</sup>, Usha J<sup>2</sup>, Varsha K<sup>3</sup>, Varsha B J<sup>4</sup>, Varshitha N<sup>5</sup>, Varshini A<sup>6</sup>, Vandana Raj S<sup>7</sup>, Vaishnavi S<sup>8</sup>

<sup>1</sup>Assistant Professor, Sapthagiri NPS University, Bengaluru, India

<sup>2,3,4,5,6,7,8</sup>U.G Student, Sapthagiri NPS University, Bengaluru, India

**Abstract**— The emergence of new technologies, such as information and communication technologies and the Internet of Things, is making cities more digital and intelligent as we move into the fourth industrial revolution. The smart sustainable cities concept is human-centered, involving the multidimensional integration of people and digitization, predicting the future development of global cities. However, the concept might not apply to all cities around the world. In this paper, a quantitative bibliometric analysis of 4643 published articles on smart cities and other related research is conducted, and aims to develop a framework with multiple dimensions to help improve the understanding of the concept applicability. The main finding reveals that four pillars, namely environment, society, governance, and economy, are integrated into the framework to improve the understanding of the concept capability. This framework can allow urban planners and policymakers to assess the effectiveness of the concept in their practice projects.

**Index Terms**— Bibliometric analysis , Sustainable development , Smart sustainable cities framework

## I. INTRODUCTION

Since the middle of the 20th century, the world has experienced a wave of urbanization unprecedented in the history of mankind. As economic opportunities become increasingly centered in urban areas and mobility increases between cities and the countryside, billions of people now make their homes within vast agglomerations whose size could scarcely have been imagined as recently as a century ago. Since 1950 alone, the global urban population has risen from 751 million to 4.5 billion, and will likely reach 5.2 billion by 2030. This constitutes a near doubling of the global urbanization rate since 1950, from 30% to 57% today

and an estimated 60% by 2030. The number of people living in cities today already exceeds the global population in 1980, and the urban population in 2030 will surpass the global population in 1990.

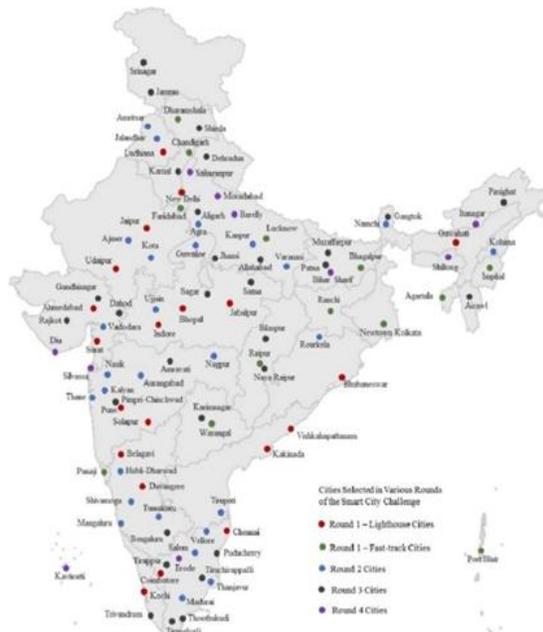
Urbanization has accelerated in every part of the world, but nowhere has it unfolded faster than in Asia, where the urban share of the population has tripled from 17.5% to 51.1% since 1950. Within Asia, India is likely to make the greatest contribution to this growing urban population over the coming decades. Since 1950, the number of Indians living in cities has grown nearly eightfold, from 62 million to 482 million, while the overall urbanization rate has doubled from 17.3% to 35%. Population growth is expected to continue until just before 2050, and an ongoing evolution away from the agriculture sector and towards manufacturing and services will coincide with this growth, pulling a larger share of the population into cities in a fashion similar to what China witnessed from 1980 onwards. In the coming decades, Sub-Saharan Africa will likely be the only region to add a greater number of urban residents to global totals than India, largely due to that region's higher population growth rates. As soon as 2030, urban areas are expected to house 40% of the Indian population and be responsible for 75% of national GDP. The GOI estimates that handling India's urban expansion efficiently could add as much as 1.5% annually to the country's GDP.

## II. BACKGROUND AND MOTIVATION

India's Smart Cities Mission

Faced with a future of continuing urban growth, challenges across the spectrum of sustainable

development, and increasing pressure on existing cities to deliver opportunity and quality of life to their residents, the Government of India under PM Narendra Modi launched the National Smart Cities Mission on June 25, 2015. With an initial funding level of 48,000 crore INR (6.4 Billion USD) over five years, a total of 100 cities were selected to take part in the NSCM. Cities which complete their projects are intended to serve as demonstrative examples for their peers of the power of incorporating smart city innovations. Ultimately, the success of these pilot projects is intended to spark a wave of public-private investment in further development of smart cities without the need for direct intervention from the central government. To this point, the NSCM has sparked a total of 1.84 lakh crore INR (24.6 billion USD) in tendered investment from both public and private circles for its projects across the country. 174 cities by “smartness,” which incorporated indicators for human capital, social cohesion, economic prosperity, governance, environment, mobility, urban planning, international outreach, and technology. Indian cities ranked between 153 for Bengaluru and 169 for Kolkata, with Mumbai and Delhi falling in between. Only Douala, Lagos, Caracas, Lahore, and Karachi ranked lower in the index, demonstrating the continuing challenges Indian cities face not just in becoming the hubs of technological governance envisioned by the SCM, but even in delivering basic services to all their residents.



### III.METHODOLOGY

1. Vision and Objective Setting Define Goals: Align the smart city vision with the United Nations' Sustainable Development Goals (SDGs), focusing on energy efficiency, waste reduction, inclusive growth, and environmental conservation. Stakeholder Engagement: Include government agencies, private sector partners, academia, and citizens to create a shared vision
2. Baseline Assessment Conduct Surveys and Studies: Assess the city's current infrastructure, technology usage, resource consumption, and population needs. Gap Analysis: Identify areas lacking in sustainability, such as energy inefficiency, inadequate public transport, or pollution hotspots.
3. Planning and Policy Framework Integrated Urban Planning: Incorporate land use, mobility, housing, and green spaces into urban planning. Policy Formulation: Develop policies for renewable energy, green building standards, waste management, and water conservation. Legal Framework: Create regulations to support sustainable initiatives (e.g., carbon credits, building codes).
4. Technology and Innovation Deployment IoT and Smart Infrastructure: Deploy Internet of Things (IoT) devices for real-time monitoring of energy, water, and traffic systems. Data-Driven Solutions: Use Big Data and AI for predictive maintenance, energy optimization, and urban planning. Renewable Energy Integration: Implement solar, wind, and other renewable energy sources within city infrastructure.
5. Resource Management Smart Water Management: Use sensors to monitor water quality, detect leaks, and optimize distribution. Waste Management: Employ smart bins, recycling programs, and waste-to-energy systems. Energy Efficiency: Promote smart grids, LED street lighting, and energy-efficient buildings.
6. Mobility and Connectivity Smart Transportation: Develop electric vehicle (EV) infrastructure, integrated public transport systems, and shared mobility options. Traffic Management: Use real-time data to manage congestion and improve road safety. Digital Connectivity: Ensure high-speed internet access to all areas, reducing the digital divide.
7. Environmental Sustainability Green Urban Design: Promote vertical gardens, rooftop solar panels, and sustainable architecture.

Carbon Neutrality: Set targets for reducing greenhouse gas emissions through technology and behavioral changes. Biodiversity Conservation: Create urban forests, parks, and conservation areas.

8. Social Inclusivity Affordable Housing: Ensure accessible housing for low-income groups. Digital Literacy Programs: Empower citizens to engage with smart city technologies. Healthcare and Education: Enhance access through telemedicine and e-learning platforms.

9. Monitoring and Evaluation Performance Metrics: Develop key performance indicators (KPIs) to track progress (e.g., reduction in energy consumption, increase in green cover). Feedback Loops: Use citizen feedback to refine and improve initiatives. Transparency: Publish regular reports on progress and sustainability impact.

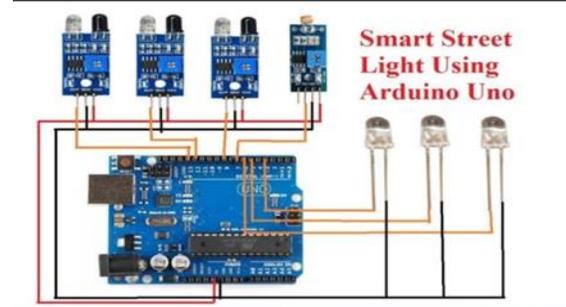
#### IV. SYSTEM OPERATION

In the sustainable development of smart cities, advanced systems like solar trackers, automatic street lights, smart dustbins, passive electricity generation, and carbon purifiers are integrated with control software for real-time monitoring, optimization, and visualization of performance data. Here's a simplified breakdown with the inclusion of control software and plotting processes:

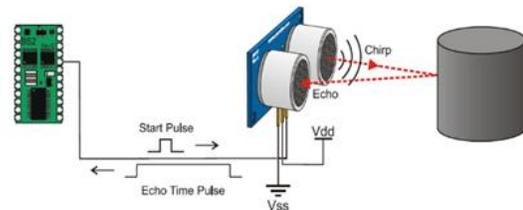
1. Solar Tracker System Control Software: Uses microcontroller-based systems (e.g., Arduino or Raspberry Pi) to adjust the solar panels' position based on sun position data from sensors (e.g., LDRs or GPS). Plotting Process: Tracks solar energy generation over time. Plots sun angle vs. power output to optimize positioning. Outcome: Maximizes renewable energy output and efficiency.



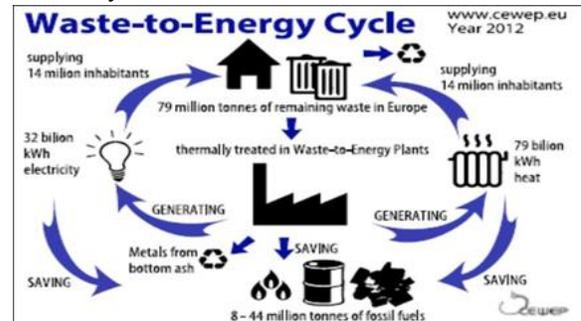
2. Automatic Street Light System Control Software: Embedded systems linked with motion and light sensors to automatically switch lights on/off. IoT integration allows remote monitoring and control via mobile apps or dashboards. Plotting Process: Energy usage vs. time (to identify peak hours). Motion activity vs. light activation. Outcome: Reduces energy consumption while ensuring safety.



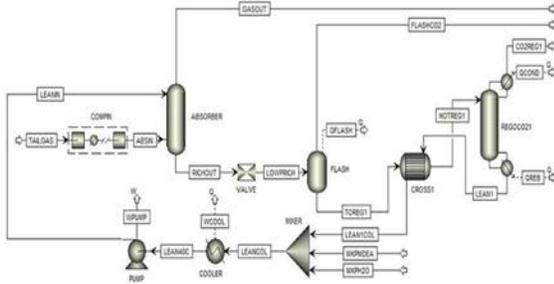
3. Smart Dustbin Control Software: IoT-based systems monitor bin fill levels using ultrasonic sensors. Data is sent to a central platform for waste collection route optimization. Plotting Process: Waste levels vs. time for each bin. Collection efficiency vs. waste overflow instances. Outcome: Optimizes waste collection and prevents overflow



4. Passive Electricity Systems Control Software: Microcontroller-based systems manage energy harvesting from piezoelectric devices, kinetic generators, or heat recovery systems. Plotting Process: Power generated vs. input activity (e.g., footsteps). Energy stored vs. energy consumed over time. Outcome: Supports supplementary energy needs efficiently.



5. Carbon Purifier System Control Software: Air quality sensors (e.g., PM2.5, CO2 monitors) feed data to software that adjusts purification intensity. IoT-enabled dashboards allow monitoring of air quality. Plotting Process: Air pollutant levels vs. purification activity. Filter efficiency vs. time (for maintenance planning). Outcome: Enhances air quality and reduces emissions.



Integrated Control Software Centralized Management: A cloud-based IoT platform integrates all systems for real-time monitoring. AI and machine learning predict maintenance needs and optimize processes. Visualization: Dashboards display system performance metrics. Graphs and plots show trends, such as energy use, air quality, and waste management efficiency. Example Tools: MATLAB, Python (Matplotlib/Seaborn), SCADA systems, or custom IoT platforms.

Plotting Examples

Solar Tracker: Sun angle vs. energy output. Street Lights: Energy consumption vs. activation hours. Smart Dustbin: Waste levels vs. collection frequency. Carbon Purifier: Pollutant concentration vs. purification time. These integrated systems ensure the smart city functions sustainably, with real-time data and visualizations guiding decisions for optimization and resource conservation.

V. RESULT AND OBSERVATION

These are innovative and essential technologies that can significantly contribute to the development of a smart city. Here's an overview of each:

1. Solar Tracker A solar tracker ensures solar panels follow the sun's path throughout the day to maximize energy absorption. Result in a Smart Enhanced energy efficiency by increasing solar panel output by up to 30-40%. Reduced dependency on non-renewable energy sources. Lower carbon footprint and energy costs.

2. Automatic Dustbin Automatic dustbins use sensors to detect motion and open/close without human contact. Result in a Smart City: Promotes hygienic waste disposal. Reduces manual handling of waste, lowering health risks. Can be integrated with IoT for efficient waste management (e.g., alerts for bin collection).

3. Automatic Streetlight Automatic streetlights operate based on ambient light levels or motion detection, turning on/off automatically. Result in a Smart City: Significant energy savings by reducing unnecessary usage. Increased safety in poorly lit areas. Reduced operational costs and environmental impact.

4. Trash-to-Electricity This technology converts waste into usable energy, such as electricity, through processes like incineration, pyrolysis, or gasification. Result in a Smart City: Sustainable waste management and reduced landfill dependency. Generates renewable energy to power homes, industries, or public infrastructure. Cuts greenhouse gas emissions from waste decomposition.

5. Carbon Purifier A carbon purifier captures and filters harmful pollutants and carbon emissions from the air. Result in a Smart City: Improves air quality, promoting better public health. Reduces urban heat and combats climate change. Creates a cleaner and more livable urban environment.

VI. CHALLENGES AND FUTURE WORK

Challenges of a sustainable smart city: Data Privacy and Security: Extensive data collection through sensors raises concerns about individual privacy and potential misuse of personal information. Need for robust data protection measures and transparent data governance practices.

Social Equity and Inclusion: Ensuring access to smart technologies for all demographics, including marginalized communities. Addressing digital divide and providing necessary training to bridge the gap.

Technological Integration: Challenges in seamlessly integrating diverse smart technologies across different city systems. Compatibility issues and potential for system redundancy.

Environmental Impact: Potential for increased energy consumption from smart devices and infrastructure.

Need for sustainable energy sources and efficient energy management strategies.

**Financial Sustainability:** High initial investment costs for smart city projects. Finding long-term funding mechanisms and securing public-private partnerships.

**Governance and Policy:** Developing clear regulations and standards for smart city technologies. Ensuring effective collaboration between government agencies, private sector, and citizens.

**Citizen Engagement and Acceptance:** Educating citizens about the benefits of smart city initiatives. Incorporating community feedback and addressing concerns throughout the development process.

**Cybersecurity Threats:** Vulnerability to cyberattacks on critical infrastructure and data systems. Implementing robust cybersecurity measures to protect sensitive information.

#### Future work

Future work for a sustainable Smart City focuses on leveraging advanced technologies like AI, IoT, and big data to optimize resource management, improve energy efficiency, promote sustainable transportation, enhance citizen engagement, and prioritize environmental sustainability across all aspects of urban planning and infrastructure, aiming to create resilient and eco-friendly urban environments.

Key areas for future development in sustainable Smart Cities:

**Smart Grids and Renewable Energy:** Integrating smart grids with distributed renewable energy sources like solar, wind, and geothermal to optimize power generation and consumption. Utilizing AI to predict energy demand and adjust power supply accordingly. Implementing smart home technologies to monitor and manage energy usage at the individual level.

**Sustainable Transportation:** Advanced traffic management systems using real-time data to optimize traffic flow and reduce congestion. Promoting electric vehicles (EVs) with charging infrastructure and smart charging algorithms. Developing autonomous vehicle systems for efficient public transportation networks.

**Smart Water Management:** Implementing intelligent water meters to monitor and manage water usage in real-time. Utilizing rainwater harvesting systems and advanced wastewater treatment technologies. Leak detection and repair systems using sensors and data analytics.

## VII. CONCLUSION

A smart city aims to utilize technology and innovation to address urban challenges and improve the quality of life for its citizens. Here's a detailed explanation of how the mentioned components contribute to a smart city:

1. **Automatic Street Lights:** These systems use motion sensors, timers, or light sensors to automatically adjust the lighting based on the surrounding environment. They help reduce energy consumption by ensuring lights are only active when needed, minimizing wastage, and lowering electricity bills.

2. **Solar Trackers:** Solar trackers optimize the efficiency of solar panels by adjusting their orientation to follow the sun's movement throughout the day. This increases energy generation by up to 30-40% compared to fixed solar panels, making renewable energy more viable and reducing dependency on non-renewable energy sources.

3. **Waste-to-Electricity Systems:** These systems convert organic and non-recyclable waste into electricity using technologies like incineration, anaerobic digestion, or gasification. They tackle waste management issues while generating clean energy, helping reduce landfill use and greenhouse gas emissions.

4. **Carbon Purifiers:** Carbon purifiers work to reduce air pollution by capturing and filtering harmful pollutants such as carbon dioxide, particulate matter, and volatile organic compounds. These devices improve air quality, contributing to better public health and environmental sustainability.

5. **Smart Dustbins:** Equipped with sensors and connectivity, smart dustbins detect when they are full and notify waste management authorities for timely collection. They help keep cities cleaner, reduce manual effort, and optimize waste collection routes, lowering operational costs and fuel consumption.

**Combined Benefits:**

**Environmental Impact:** By using renewable energy, efficient lighting, and better waste management, smart cities reduce their carbon footprint.

Economic Efficiency: Lower energy costs, reduced waste management expenses, and revenue from waste-to-electricity projects support economic sustainability.

Improved Public Health: Cleaner air, reduced waste accumulation, and better urban hygiene contribute to healthier living conditions.

Technological Advancement: These systems encourage innovation and create opportunities for further advancements in urban planning.

#### REFERENCE

- [1] You Tube. (2024). Energy efficient Smart City <https://youtu.be/PM5MiBjwmT8?si=y5q1EqLhk7BM8ULE> (Accessed: January 2025)
- [2] Arduino.(2018).using the LDR Sensor <https://projecthub.arduino.cc/SURYATEJA/automatic-street-light-controller-5e5cbf> (Accessed : January 2025 )
- [3] Reasearch.(2022).[https://www.researchgate.net/publication/361162204\\_Sustainable\\_Urban\\_Development\\_of\\_Smart\\_Cities\\_in\\_India-A\\_Systemetic\\_Lit\\_review\\_april2022](https://www.researchgate.net/publication/361162204_Sustainable_Urban_Development_of_Smart_Cities_in_India-A_Systemetic_Lit_review_april2022) (Accessed :January 2025)