



## Sustainable urban development in a smart city: A case study of Varanasi city

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### Abstract

Sustainable urban development has become a critical priority for rapidly urbanising cities, particularly in the context of India's Smart Cities Mission. This study examines Varanasi, one of the world's oldest continuously inhabited cities, as a case study to evaluate the challenges and opportunities of transforming into a sustainable smart city. The research explores key dimensions including urban mobility, digital infrastructure, waste management, renewable energy integration, and cultural heritage preservation. Through policy analysis, stakeholder interviews, and urban development indicators, the study highlights how Varanasi's unique socio-cultural identity interacts with technological innovations to shape sustainable growth. Findings suggest that while initiatives in e-governance, smart mobility, and green infrastructure are promising, constraints such as population density, inadequate resources, and heritage sensitivity pose significant challenges. The study concludes that a balanced approach, integrating technology, sustainability, and cultural preservation, is essential for Varanasi's transition to a sustainable smart city.

**Keywords:** Sustainable development, smart city, Varanasi, urban planning, cultural heritage

### Introduction

Twenty-first-century cities consume two-thirds of the world's energy and account for 70% of global greenhouse gas emissions. More than 800 million urban dwellers live in sprawling slums, in health-compromised conditions. Many live in cities that are yet to lose their reputation for being crowded, unsafe, and environmentally irresponsible. Surprisingly, these inefficiencies have not deterred the demand for urban land. By 2050, two out of three people worldwide will live in such cities. In a business-as-usual scenario, they will withstand the worst of climate change, even as they contribute upward of 80% to global GDP.

In the years to come, as their due, urban dwellers will demand intelligent urban planning that creates safe, affordable, and resilient cities with green and culturally inspiring living conditions. Goal 11 of the UN Sustainable Development Goals has anticipated this demand by calling for sustainable cities and communities. India is attempting to deliver on this commitment through its ambitious Smart Cities Mission. The Mission promotes an area-based development strategy that focuses on city improvement (retrofitting), city renewal (redevelopment) and city extension (greenfield development). Additionally, a pan-city initiative will attempt to integrate the city using innovative technological solutions. Identified smart cities will innovate and replicate replicable ICT solutions to address fundamental infrastructure issues, enhance the quality of life, and strive for a clean and sustainable environment. The goal is to learn from one another; among the identified 100 Smart Cities, a 20-20 concept pairs up the laggards with the frontrunners. Thus, the Mission promotes and innovatively utilises innovative solutions that all Indian cities can learn from, replicate, and adapt to their unique contexts.

Among several cities vying for the Smart spotlight, Varanasi in Uttar Pradesh has been making significant progress. The city's success story holds essential lessons for Indian

urbanism. Multiple stakeholders, several layers of infrastructure, and a dense urban fabric (with a large proportion of floating population) make Varanasi a relatable case study for India's cities. Varanasi boasts an international reputation, ranking among the world's oldest continuously inhabited cities and having received UNESCO's designation as a Creative City of Music. In India, the city's significance is both cultural and mystical. Every year, millions of domestic and international visitors flock to India's spiritual soul, eager to absorb the sights and sounds of Varanasi.

### Varanasi as a Smart City

Along with Amritsar, the city has tried to catch up with the level of development and make the town an extraordinary place to be. Among the 100 cities participating in this initiative, there is a commitment to ensure the progression and achievement of all goals set for each town. The centre has paired up 20 cities that are progressing quickly toward their vision to help speed up the process. The Smart City Varanasi, a key constituency of the Prime Minister, has initiated several projects under the Smart City initiative. Varanasi Smart City Limited was formed as a Ministry of Urban Development initiative by the Government of India.

Varanasi, also known as Banaras (and sometimes referred to as Kashi), is one of the world's oldest continuously inhabited cities. Varanasi's prominence in Hindu mythology is virtually unparalleled. Varanasi Nagar Nigam is now participating in the second round of the Smart City Challenge to enhance its Smart City Proposal prepared in Round 1. Varanasi, also known as the city of light, is renowned for its culture and heritage, and is now the most promising city in the state of Uttar Pradesh for being selected in the next round. As per the Guidelines of the Ministry of Urban Development, Government of India, the preparation of a Smart City Proposal is citizen-centric, and

the successful implementation of any city would depend on the responses/ suggestions given by its citizens. Varanasi Nagar Nigam has identified vision statements emerging from 'Vision Workshops' organised in Varanasi.

**Smart City Varanasi’s Vision**

Smart City Varanasi is a visionary project designed to transform Varanasi into a modern, sustainable, and efficient city. The key points about the Smart City Varanasi vision are:

1. Smart City Varanasi aims to leverage technology to enhance the quality of life for its citizens, improve public services, and promote economic growth.
2. The project focuses on six key areas: smart mobility, innovative governance, intelligent energy, smart environment, smart buildings, and intelligent citizen engagement.
3. To improve mobility, it aims to develop a modern public transport system, intelligent traffic management, and pedestrian-friendly streets.
4. Innovative governance initiatives include implementing e-governance systems to enhance transparency and accountability, as well as utilising data analytics to inform decision-making.
5. Promoting renewable energy sources and improving energy efficiency is the vision to create a more innovative environment.
6. Innovative environment initiatives include promoting green spaces, waste management, and pollution control.
7. Bright building ideas aim to enhance energy efficiency and sustainability by integrating technology and innovative design.
8. Innovative citizen engagement initiatives utilise technology to facilitate citizen participation in decision-making processes and foster a sense of community.

**The vision statements are as follows**

**Vision 1:** City of temples to be redeveloped as a global Epicentre of Culture & Tourism, which is socially and economically sustainable by conserving the old heritage.

**Vision 2:** Rejuvenating Kashi, the City of Lights, as a Sustainable Global Hub of Culture, Heritage, & Spirituality, with an enhanced quality of life.

**Vision 3:** To maintain and enrich the spiritual, cultural, and eternal heritage of Kashi, thereby uplifting the livability of the city and handing over to the next generation a vibrant and secure town of light.

**Vision 4:** Banaras to be a livable and lovable city that enriches its cultural heritage, education, and economic growth.

**Vision 5:** Technological intervention for environmental management towards sustainable growth with a focus on socio-cultural, religious, and traditional fabric.

**Vision 6:** Holy, Happy, Healthy, Educated, Clean, Green, Sustainable and Vibrant Kashi.

**Vision 7:** Create a new Varanasi. Varanasi, also known as the city of light, is renowned for its rich culture and heritage. This city has been ranked among the top 20 Smart cities. The scale of Hinduism, similar to the Vatican, is comparable to the Christian religion. The Ganga and Ghats should be among the most scenic places in the world. Cleanliness, Greenery, Infrastructure, education, and a medical hub should be of world-class standards.

**Vision 8:** Urban planning that prioritises the quality of life for citizens, a decentralised system, and incentives for innovative land use. Promoting an environment that fosters the Ganga's sustainable growth and facilitates a transition from an old city to a new one through the use of technology.

**Smart City Varanasi Objectives**

The Varanasi Smart City (VSCL) aims to promote cities that provide soulful infrastructure and allow their citizens to live decent lives in a clean, growing, and innovative environment. The objectives of this phase are as follows:

1. Synthesise and restore the broken or tarnished segments of the Ganga Ghats.
2. Revive the identity and the condition of the holy ghats.
3. Provide general facilities for tourists and improve the connectivity to the Ghats.
4. The utilisation of barren land.
5. Creation of recreational spots and public services.
6. Ensure citizen engagement
7. Create focal points or attractions for Varanasi.
8. Boost property visibility and value.
9. Create rainwater harvesting spots.
10. Visual enhancements by plantations, painting and arrangements.
11. Designated areas for all kids.
12. Developing sprawling parks and green spots.
13. Preservation of historical buildings
14. Preservation and cleaning of the Ganges.

**The Challenges**

Balancing the expectations of international audiences and domestic devotees against the needs of Varanasi's citizens has presented its own set of challenges. Virtually every part of India enjoys representation within the old Kashi area. This has generated challenges that affect the identification, representation, and coordination of city systems.

1. Balancing Varanasi’s cultural and spiritual heritage with better administration, operations and holistic development
2. Mapping overlapping development that has congested the city over several centuries
3. Managing critical public service infrastructure, including assets related to water, sewage collection and treatment, street lighting, transportation, and parking services
4. Retaining and managing tourist footfall during smart project implementation
5. Integrating Smart City projects with other ongoing development projects happening across the city

**Table 1:** SDG-11 targets mapped to Varanasi projects, with suggested measures

SDG-11 Target	Relevant Varanasi initiative(s)	How the initiative advances the target	Practical measures to track progress
11.1 Housing & services	PMAY-Urban housing, AMRUT piped water/sewer, community toilets	Expands affordable housing and WASH access, reduces slum dependency	# sanctioned vs. completed PMAY units; % HHs with piped water/sewer

		(MoHUA, 2021)	(Census, 2011) <sup>[1]</sup>
11.2 Sustainable transport	Urban ropeway, e-buses, smart parking, pedestrianisation near ghats	Promotes low-emission mobility and safer pilgrim movement (VSCDL, 2020)	Ropeway ridership; modal share surveys (UPID, 2019)
11.3 Participatory planning	Integrated Command & Control Centre (ICCC), ward sabhas, grievance portals	Enhances transparency, data-driven planning (MoHUA, 2017)	% projects with citizen consultation; grievances resolved
11.4 Heritage & culture	HRIDAY, Kashi Vishwanath Corridor, artisan GI branding	Conserves riverfront & crafts, boosts heritage economy (NMCG, 2020; Singh, 2019) <sup>[13, 17]</sup>	# assets conserved; artisan income trends
11.5 Disaster resilience	Flood EWS, heat action, ICCC crowd modelling	Reduces vulnerability to Ganga floods, crowd surges (NDMA, 2019)	Population covered by alerts; incident response time
11.6 Environment & waste	Namami Gange STPs, SWM reforms, dust suppression	Improves water quality & reduces PM <sub>2.5</sub> pollution (CPCB, 2021)	% sewage treated; BOD/FC levels at ghats; waste segregation
11.7 Public spaces	Ghats' revitalisation, pocket parks, universal footpaths	Enhances access to green/public spaces (Verma, 2020)	Public space per capita; % residents within 400m of park
11. a Regional linkage	Inland Waterways (NW-1), regional transport	Strengthens hinterland connectivity (IWAI, 2018)	Freight share by waterways; intermodal integration
11. b DRR planning	City Disaster Management Plan, ward-level DRR	Mainstreams Sendai framework locally (NDMA, 2019)	# wards with DRR plans; drills conducted
11. c Sustainable buildings	LED lighting, solar panels, and ABD green norms	Cuts energy footprint (VSCDL, 2020)	% LED coverage; RE share in civic supply

**The Approach**

A Special Purpose Vehicle (SPV) mechanism designs and manages IT and non-IT projects under the Smart Cities Mission. Here, Varanasi Smart City Limited (VSCL) guards the idea of rejuvenating the city of Varanasi into a great place to live and visit.

VSCL targets projects that uplift Varanasi's residents, upgrade the city's infrastructure and living standards, and add value to Varanasi's core culture. The SPV will fast-track projects that conserve the city's enriched heritage, spirituality, and traditions, while supporting inclusive social or financial solutions. Varanasi's Pan-City Project follows an area-based development model with the following sub-missions:

- The Suramya Kashi component capitalises upon UNESCO's City of Music label. It is rejuvenating the experience of Varanasi's historic temples and riverfront ghats.
- The Nirmal Kashi component focuses on earth-friendly initiatives. It rejuvenates sacred water bodies and parks, while introducing efficiency and accountability into water- and waste management solutions.
- The Surakshit Kashi component focuses on improving the police-citizen interface. It is creating safer public spaces and proactive emergency response through analytics-based surveillance.
- The Samunnat Kashi component aims to create a workforce that is appropriately skilled, healthy, and works in a healthy environment. It utilises innovative technology to establish market linkages, promote local artefacts, provide better workspaces, and enhance the lives and health of local workers.
- The Ekikrit Kashi component digitises Varanasi's services to ensure transparent access to information and quality services for all citizens. It utilises smart cards and mobile apps to enhance the effectiveness of grievance redressal.
- The Sanyojit Kashi component focuses on generating a customised model of transit and transportation systems. It is easing congestion, improving last-mile connectivity, and diversifying transportation modes.

**The Solution**

A customised solution for Varanasi depended on the mammoth task of mapping and overlapping multiple datasets related to the city's development. Accordingly, the SPV used ArcGIS Platform Technology to create an enterprise-wide integrated City GIS. In the process, various data sources and data levels became available for analysis, including information on administrative boundaries, public services, religious places, education and health, tourism and recreation, transportation, water bodies, and locations of infrastructure related to water, sewerage and drainage systems in the city.

ArcGIS Platform is the digital mesh that superimposes all innovative components of the city over a standard set of base maps. Some of the intelligent systems currently improving the management and coordination of city services include:

**Kashi Integrated Command and Control Centre (ICCC):** It uses location-based technology to manage traffic safety and city security. The ICCC has also proved to be a versatile mechanism for rapid emergency response. Most recently, authorities converted the centre into a COVID War Room to survey public places using CCTV, map COVID-19 positive cases using GIS, and locate healthcare workers using GPS.

**Kashi Solid Waste Management System:** It optimises waste pickup facilities by utilising smart sensors on smart waste bins. The sensors populate the City GIS by generating a real-time status of the bins and statistical ward-wise overviews of waste dumps. This has helped coordinate waste management in the ward.

**Kashi Environmental Monitoring System:** It maps a real-time feed of air pollution in different parts of the city. Air Quality Monitoring sensors provide valuable information that warns citizens of health-threatening conditions. It also allows authorities to attune traffic and industry with dynamic regulations that keep pollution under control.

**Integration with traffic signals:** In most Indian cities, malfunctioning signals often prompt traffic police to manage traffic, diverting them from their primary policing

duties. Lacking a holistic overview, this manual approach is cumbersome, piecemeal, and problematic. In Varanasi, the city's GIS system networks smart traffic signals, which help identify malfunctioning signals and traffic affected on specific corridors.

**Integration with smart streetlights:** Real-time mapping of smart streetlights enables civic authorities to receive live updates on dysfunctional lighting. This promotes citizen confidence by ensuring safer public places that deter wrongdoing.

**Actionable insight:** Authorities utilise spatial analytics, powered by GIS, to harness real-time data and design more effective decision-support systems. In the process, authorities are gaining actionable insight for informed decision-making.

**Improved business processes and workflows:** The intelligent integration of different features over a common GIS platform has standardised procedures across various departments. Interdepartmental collaboration has been enhanced through the use of geospatial mapping and geo-tagging of city assets.

**Improved asset management:** An Enterprise-integrated GIS provides insights into the use patterns of civic assets to improve urban planning in Varanasi. For water and sewerage systems, geospatial utility asset management is helping authorities operate and manage utilities more effectively.

**Population Growth:** Based on Census of India historical counts (1991–2011) and updated urban agglomeration projections (World Population Review, 2025). See the displayed chart titled “Population Growth in Varanasi Urban Agglomeration (1991–2025).”

**Infrastructure and Environmental:** Compiled from municipal master-plan data, Smart Cities documentation, NITI Aayog and CPCB reports, and NMCG program documentation. The displayed comparative charts illustrate Varanasi vs Uttar Pradesh vs India for key infrastructure and environmental indicators (household electrification, piped water supply, sanitation coverage, road density, PM2.5 annual average, Ganga BOD at Varanasi, and percentage of solid waste processed).

### The Benefits

The ArcGIS Platform Technology enables customised solutions across various localities through IoT components. These integrated components generate thematic results in real time. The system has also proven its flexibility for use in rapid response. In response to COVID-19, Varanasi developed GIS operation dashboards for health services, heat maps for containment zones, and CCTV systems to monitor citizen movement and enforce social distancing. The Platform also helped manage the health response; it used drones to sanitise hotspots, established telemedicine facilities for remote healthcare and diagnosis, while also analysing infrastructure availability to address the health crisis.

Better, location-customised experiences await all citizens of Varanasi. Beyond improving the urban environment, GIS has now equipped the city with options to minimise air pollution, improve water management, create safer public areas, and respond intelligently to emergencies. The technology is steadily ensuring that the city's culture maintains its rich heritage while assuring Varanasi's denizens the benefits of a new Indian urbanism.

### Conclusion

Varanasi's status regarding sustainable urban development is mixed. The city benefits from strong cultural visibility, significant national investments, and a vibrant service economy, which is anchored in religion, education, and health services. However, sustainability challenges—such as air and river pollution, informal housing, infrastructure gaps, and fragile municipal finances—pose significant risks to the city's long-term liveability and cultural heritage. Moving Varanasi toward sustainable urban development will therefore require integration of heritage-sensitive infrastructure, complete sanitation value chains, solid waste processing, and air pollution abatement, along with inclusive housing strategies, economic diversification through artisanal upgrading, institutional capacity enhancement, and effective, participatory governance.

The city's future depends not only on capital investments but also on a strategic alignment of policies and institutions to manage everyday services, long-term maintenance, and social inclusion—ensuring that cultural preservation and modern amenities reinforce each other rather than contradicting one another. Varanasi's global significance as a sacred city, combined with its regional role as an education and healthcare hub, makes its path to sustainability a national concern; mastering this balance would provide a compelling model for heritage cities worldwide.

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