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Digital innovations in urban management: Lessons from Chandigarh's experience

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Abstract
Cities worldwide are evolving towards greater connectivity and integration, leveraging digital innovation to enhance accessibility and inclusivity of infrastructure and amenities. This digital transformation is crucial for fostering economic, social, and environmental progress in an increasingly urbanized world. Chandigarh, a Union Territory in India, has been at the forefront of leveraging technology to enhance various aspects of urban governance and service delivery. The study examines the lessons learned from Chandigarh's experience with digital innovations in urban management, identifies best practices, and evaluates the effectiveness and efficiency of digital solutions in addressing urban challenges such as infrastructure management, public services delivery, and citizen engagement. The study primarily employs an exploratory research method. It relies on secondary data sources. Through the adoption of technology-driven solutions, Chandigarh has demonstrated the potential to transform various aspects of urban governance, including power generation, waste management, transportation, and public service delivery etc. Chandigarh is actively pursuing initiatives to achieve its zero-carbon emission target for combating climate change.

Keywords: Digital innovation, smart cities, urban administration, urban planning, urban local bodies

Introduction
Urbanization is vital for economic growth, innovation, and the concentration of resources, fostering cultural exchange and enabling efficient infrastructure development to meet the needs of growing populations. India is expected to experience a significant increase in urbanization over the next few decades. From 2011 to 2036, urban expansion is projected to account for 73% of the overall population growth (MoHFW, 2019) [24]. Urban resilience has emerged as a critical component of sustainable urban development, ensuring cities' ability to resist, adapt to, and recover from crises and challenges, as well as prevent the formation of new risks in the face of increased urbanization and the growing impact of climate change (UNDP, 2023) [33]. The challenges of urban management are multifaceted and complex. Urban centers, hailed as engines of economic growth, have become magnets for migration from rural and semi-urban areas, drawn by the promise of better socio-economic opportunities, infrastructure, and services. The rapid influx of people into urban areas has caused chaotic development, making it difficult for local governments to manage cities effectively. These governments are finding it hard to provide basic services and infrastructure to meet the growing needs of urban residents. Thus, the mismatch between the rapid urbanization rate and the capacity of urban management systems poses significant challenges to the sustainable development and liveability of urban centers (UPATI, 2024) [32]. With cities struggling to keep up with rapid growth, digital tools and innovations are stepping up as a promising answer. These innovations can help bridge the gap between the needs of growing populations and the resources available to city governments.
The significance of digital innovations in urban management has been extensively explored in academic literature, highlighting their transformative potential in enhancing efficiency, sustainability, and resilience in cities. By leveraging technologies such as data analytics, artificial intelligence, and the Internet of Things (IoT), cities can streamline administrative processes, optimize resource allocation, and improve service delivery to citizens (Bollier, 2006) [4]. For example, smart city initiatives have enabled real-time monitoring of urban infrastructure, leading to proactive maintenance and reduced downtime (Hollands, 2008) [16].

By harnessing data-driven insights and predictive analytics, cities can develop evidence-based policies to address environmental challenges, mitigate climate risks, and optimize resource utilization (Batty *et al*., 2012) [3]. For instance, smart energy grids enable efficient management of electricity consumption, reducing carbon emissions and enhancing energy security (Komninos, 2013) [18]. Similarly, Alawadhi and Morris (2008) [1] emphasize the significance of digital innovations in addressing urban challenges such as traffic congestion, pollution, and resource depletion. Their research highlights how technologies like Intelligent Transportation Systems (ITS) and smart grids contribute to sustainable urban development by reducing environmental impact and enhancing resource efficiency. Digital innovation has the potential to stimulate economic growth and innovation in urban economies (Townsend, 2013) [31]. By fostering a conducive ecosystem for technology startups, promoting digital entrepreneurship, and attracting investment in high-tech industries, cities can drive job creation, attract talent, and boost competitiveness on a global scale (Giffinger *et al*., 2007) [11]. Digital innovations have been recognized for their potential to foster citizen engagement and participation in urban decision-making processes (Nam & Pardo, 2011) [23]. Through online platforms, mobile applications, and social media, residents can interact with government agencies, provide feedback on public services, and collaborate on community projects (Moon & Norris, 2005) [22]. This participatory approach not only strengthens democratic governance but also enhances the responsiveness of local authorities to the needs and preferences of their constituents (Foth *et al*., 2009) [9]. However, issues such as the digital divide, data privacy concerns, and cybersecurity threats need to be addressed to ensure equitable access to digital services and protect sensitive information (Giest and Zurawski, 2020) [10].

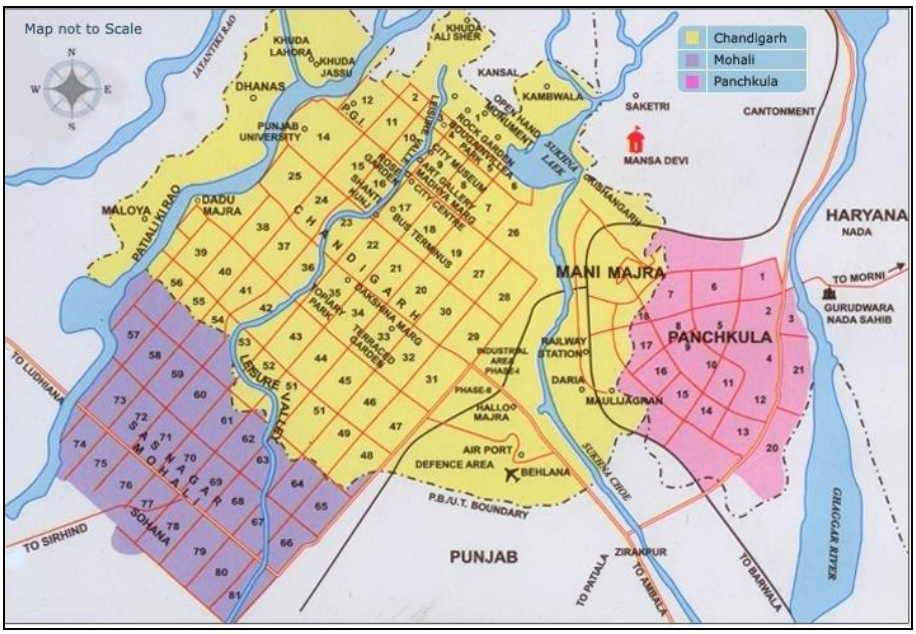
2. Objectives of the paper & methodology

The study examines the lessons learned from Chandigarh's experience with digital innovations in urban management identifies best practices and evaluates the effectiveness and efficiency of digital solutions in addressing urban challenges such as infrastructure management, public services delivery, and citizen engagement. The study primarily employs an exploratory research method. It relies on secondary data sources including academic journals, books, newspaper reports, government repositories, and reports from organizations such as the United Nations (UN) and the United Nations Development Programme (UNDP), Organisation for Economic Co-operation and Development (OECD), etc. The study aims to analyze and synthesize existing literature and reports to derive insights into the digital innovations implemented in urban management within the Chandigarh region.

The paper is structured into three distinct sections. The first part explains the urban development plan of Chandigarh. Following this, the second part explores Chandigarh as a smart city. The third section focuses on the role of digital innovations in urban development in Chandigarh, urban development challenges, best practices of Chandigarh for urban development, and a conclusion.

3. Urban development plan of Chandigarh

Nehru's dream city, Chandigarh, is beautifully planned in India. Designed by a famous French architect Le Corbusier**,** it is known for its modern architecture and is considered the best example of 20th-century urban planning. The combined urban regions of Chandigarh, Mohali, and Panchkula constitute a tri-city metropolitan area. As per the census of 2011, 10,25,682 (97.25%) of its population was urban and only 29,004 (2.75%) rural (GOI, 2024). Figure 1.1 shows the Chandigarh Tricity and its adjoining areas.



Source: https://www.mapsofindia.com/

Fig 1: Map of Tricity (Panchkula-Chandigarh-Mohali)

Urban management for Chandigarh has been structured based on a proper 'Master Plan' that includes:

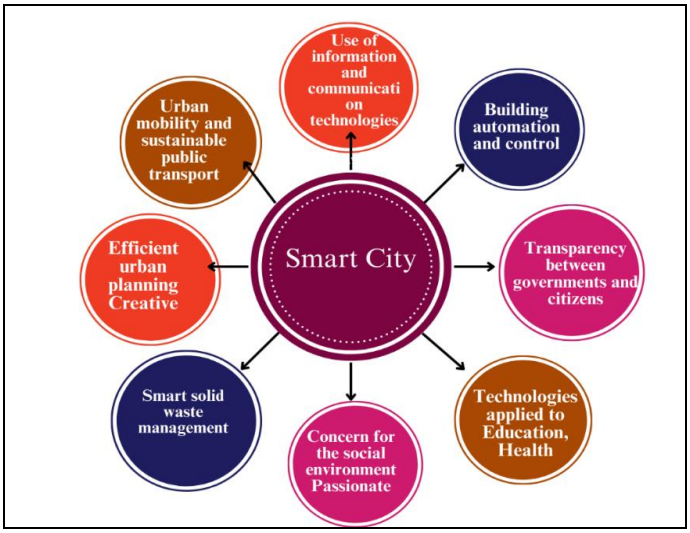
a. Neighborhood Concept: Organized into sectors, each serving as a self-contained unit with essential amenities within walking distance, fostering a serene living environment.

b. **Green City Concept:** Emphasizing abundant open spaces, ensuring every dwelling receives ample sunlight, space, and greenery.
c. **V7s Road System:** Following Le Corbusier's V7s road hierarchy, enabling diverse land uses while facilitating efficient circulation. The roads of the city are classified into seven categories known as systems of 7 Vs as below: V-1 Fast roads connecting Chandigarh to other towns, V-2 Arterial roads, V-3 Fast vehicular sector dividing roads, V-4 Meandering shopping streets, V-5 Sector circulation roads, V-6 Access roads to houses, V-7 Footpaths, and cycle tracks.
d. **Hierarchical Distribution of Population:** Population density gradually increases from northern to southern sectors, maintaining a balanced distribution.
e. **Low-Rise Development:** Designed as a low-rise city, adhering to principles that have been sustained for decades, though facing challenges such as population growth, traffic congestion, and infrastructure stress, prompting the need for adaptive management strategies.
f. **Preservation of the Lake:** Tranquillity is maintained by prohibiting noisy activities, ensuring its environment remains undisturbed.
g. **City Centre:** Sector-17's central plaza, known as "Pedestrians Paradise," prohibits vehicular traffic, emphasizing pedestrian-friendly design and fostering a vibrant public space.
h. **Industrial Area:** Chandigarh's industrial zones prioritize environmentally friendly practices, allowing only electricity-powered industries to operate. This approach aims to mitigate pollution and preserve the city's atmosphere (DUP, 2024) [8].

At present time, the Chandigarh Administration has embarked on a series of reforms following the principles outlined in the 74th Constitution Amendment Act (CAA), focusing on governance and pro-poor initiatives. These reforms are aimed at enhancing urban development and poverty reduction strategies. Governance reforms have been pivotal, with the establishment of the Strategy Performance and Innovation Unit (SPIU) to enhance administrative efficiency and effectiveness. Citizen charters have been introduced to ensure transparency and accountability, while e-governance initiatives such as *e-Sampark Kendra* have modernized service delivery channels. A framework for solid waste management has been developed, alongside action plans for poverty reduction by ULBs and the government, including initiatives like affordable water supply connections for Below Poverty Line (BPL) families and a citizen-friendly street vendor policy (DUP, 2024) [8]. At the local level, the Municipal Corporation of Chandigarh has implemented several reforms to enhance service delivery and municipal performance. Embracing information technology for better civic services and adopting an area-based property tax system are notable efforts. Utility mapping on GIS platforms is being pursued to enhance infrastructure planning and management. Fiscal responsibility has been emphasized, with efforts towards becoming a financially prudent organization. The introduction of user charges and road widening initiatives are part of this endeavor (DUP, 2024) [8].

4. Smart city integration

The term "smart city" was first coined in 1990 and is closely associated with globalization, technology, and creativity. It can be defined as a city that is instrumented, interconnected, and intelligent (Harrison *et al.*, 2010) [15]. OECD defines smart cities as “initiatives or approaches that effectively leverage digitalization to boost citizen well-being and deliver more efficient, sustainable and inclusive urban services and environments as part of a collaborative, multi-stakeholder process” (OECD, 2018) [25]. According to OECD 2019, technology is vital in creating smart cities, offering solutions for efficient urban development and management. Key technologies like 3D printing, IoT, big data analytics, AI, advanced energy storage, civic tech, drones, and Blockchain are being integrated to transform cities. Smart grids effectively manage energy consumption, while smart meters and pipes monitor water quality and detect leaks. Smart sensors optimize traffic flow, transportation, and waste collection routes. Mobile apps enable real-time reporting of issues and direct engagement with city services. As cities embrace these innovations, they move closer to becoming smarter, more sustainable, and more responsive to the needs of their citizens (OECD, 2019) [25]. Figure 1.2 indicates key aspects of a Smart City.



Source: IESE Cities in Motion Index (2022)

Fig 2: Smart City Module

Chandigarh's journey toward becoming a remarkable smart city is led by a multifaceted approach that integrates innovative technology, sustainable practices, community engagement, etc. Through strategic initiatives targeting key areas such as transportation, energy, waste management, and economic growth, Chandigarh is paving the way for urban centers worldwide. One of Chandigarh's major initiatives revolves around tackling greenhouse gas emissions, a critical aspect of urban sustainability. By setting ambitious targets to reduce emissions from residential buildings, urban transport, and waste systems, Chandigarh aims to contribute significantly to global efforts in mitigating climate change. The city's commitment to transitioning to electric vehicles and promoting renewable energy sources like solar power demonstrates its proactive stance in combating environmental challenges. By harnessing solar energy, the city not only reduces its carbon footprint but also sets an example for other regions to follow suit. The introduction of the Chandigarh Electric Vehicles Policy signifies the city's dedication to promoting sustainable transportation solutions. In Chandigarh, 1/4th of public buses are electric, and the rest are to be replaced in a phased manner. By incentivizing EV adoption and supporting local manufacturing, Chandigarh not only addresses air pollution and congestion but also stimulates economic growth in the clean energy sector. By prioritizing the creation of green jobs in sectors such as green building construction, and waste management the city fosters a robust economy.

Table 1 shows remarkable progress in managing urban problems by improving various sectors like road and transportation, water supply, waste management, electricity, housing, etc. At present, the Chandigarh Government has decided to integrate the 'Smart City project' with existing programs such as the Swachh Bharat Abhiyan, National Smart Grid Mission, and various other government initiatives.

Table 1: Chandigarh's performance across different Sectors outlined by the Government of India for smart cities

Parameter	Status
Transport	Integrated cycle tracks; efficient mass transportation within 800m; Mono Rail project underway ($700 million)
Water Supply	10-12 hours of daily supply; 100% direct water connections; 140 liters per capita per day; 85% metering; 72% cost recovery
Sewerage & Sanitation	95% population is connected to a sewerage network; the capacity to treat 45 mg out of 62.25 mg produced
Solid Waste Management	100% collection through daily doorstep collection by the Municipal Corporation
Storm Water Drainage	Natural slope facilitates easy disposal; occasional choking during heavy rains due to solid waste
Electricity	Nearly 99% of households connected; occasional power shortages during summers
Wi-Fi Connectivity	e-Sampark centers established; proposals for total e-governance with Wi-Fi zones
Health Care Facilities	3000 beds in different hospitals for a population of 10 lakh
Education	Several schools and higher education institutions, including 3 universities and 18 colleges
Fire Fighting	7 fire stations for a population of 10 lakh people

***Source*:** https://chandigarh.gov.in/sites/default/files/documents/physical-infra.pdf

5. Role of digital innovations in urban development in Chandigarh

Cities worldwide are evolving towards greater connectivity and integration, leveraging digital innovation to enhance accessibility and inclusivity of infrastructure and amenities. Digital innovation has the potential to enhance the sustainability and resilience of cities in various ways. For example, the adoption of smart meters and dynamic electric pricing can revolutionize energy consumption patterns. Electric vehicles offer a solution to reduce both noise and air pollution. Early warning systems for natural disasters like floods and cyclones can improve preparedness and response efforts. Access to big data and real-time monitoring of energy, water, waste, and transportation systems can significantly enhance urban services' productivity and integration (Harde, 2023) [14]. The cornerstone of the administration's ICT efforts in Chandigarh is e-governance, with its flagship initiative called 'Project e-Sampark'. This initiative, aligned with the Digital India campaign, aims to electronically connect with citizens. E-Sampark consolidates services from various departments into a single platform, offering residents a seamless "multi-service" - "single-window" experience. It addresses issues of transparency and citizen convenience while reducing bureaucratic hurdles. Through e-Sampark, citizens can access services such as obtaining certificates (Caste, Dependent, Character, Income, Residence), paying taxes, VAT/CST collection, passport applications and renewals, utility bill payments, scheduling doctor's appointments, and availing pension disbursements for senior citizens, widows, and disabled individuals.

One of the primary areas where digital innovations have made an impact in Chandigarh is in urban planning and management. Digital tools such as Geographic Information Systems (GIS) and remote sensing technologies have been utilized to gather spatial data, analyze urban patterns, and plan more efficient land use. The use of GIS in Chandigarh for spatial analysis, helps urban planners make informed decisions regarding infrastructure development and environmental conservation (Kumar and Prasad, 2018) [20]. According to a report by the Ministry of Housing and Urban Affairs, Government of India (2019) [21], Chandigarh has made significant progress in deploying smart city solutions such as intelligent traffic management systems and integrated command centers, leading to improved urban mobility and safety. The Integrated Traffic Management System (ITMS) and Adaptive Traffic Control System (ATCS), set global standards for efficient traffic management. The Integrated Command and Control Center (ICCC) acts as a centralized hub, leveraging real-time data and advanced analytics to enhance municipal services, emergency responses, and resource allocation, showcasing the city's commitment to smart urban governance. In terms of recognizing the cultural significance of its architectural heritage, Chandigarh has employed digital technologies for heritage preservation and conservation. Initiatives such as

3D laser scanning and virtual reality (VR) tours enable virtual exploration of heritage sites, offering immersive experiences to visitors and scholars.

However, urban development and digital innovation in Chandigarh, while marked by notable successes, also face a range of challenges. Chandigarh is facing several challenges in urban development has been discussed below:

a) **Inadequate Infrastructure:** Rapid population growth has outpaced infrastructure development in the city. The insufficient size and capacity of sewer systems in rehabilitated colonies fail to accommodate the population surge caused by migration, leading to sanitation issues and environmental concerns.
b) **Poor Drainage System:** The drainage system designed for minimal rainfall cannot handle heavy downpours, resulting in flooding and waterlogging, exacerbated by the disappearance of natural flood-absorbing channels due to urbanization.
c) **Inequitable Growth:** Despite Chandigarh's planned development, disparities in access to basic services and opportunities persist, leading to social exclusion and marginalization.
d) **Proliferation of Slums:** Shortage of affordable housing, particularly for low-income residents, leading to informal settlements and housing insecurity. The significant presence of urban poor, with a growing poverty profile, is evident in the proliferation of slum settlements lacking adequate basic services and infrastructure.
e) **Rapid Urban Expansion:** The rapid expansion of Chandigarh, fuelled by industrial growth and migration, strains resources and infrastructure, leading to unsustainable economic activities, increased vehicular transport, and air and noise pollution.
f) **Traffic congestion:** The reliance on personal vehicles and the lack of adequate alternative modes of transportation created congestion in Chandigarh. The coordination among different agencies responsible for road maintenance, traffic regulation, and public transport provision is essential to address congestion effectively.
g) **Chandigarh's public transportation issues:** People often experience long waiting times due to irregular bus arrivals and departures. The frequency of buses on many routes is insufficient to meet the demands of the growing population. Chandigarh's public transportation network suffers from poor connectivity, especially in suburban areas and satellite towns like Panchkula and Mohali.

Thus, all issues need to be addressed to achieve sustainable and efficient urban development.

6. Best practices of Chandigarh for urban management

Chandigarh is well known for its city management strategy. By leveraging innovative solutions, Chandigarh has set benchmarks in various aspects of urban management, from citizen engagement to infrastructure development. A few examples have been discussed below:

1. Chandigarh's Waste Management Strategy

Chandigarh, recognized for its innovative urban solutions, has established itself as a pioneer in waste management. Departing from traditional waste segregation practices, the city has adopted a holistic approach, categorizing waste into 10 to 12 distinct segments, each tied to specialized recycling facilities. One notable success story lies in the management of sanitary waste. From collecting a mere 15 kilograms daily in November 2021, Chandigarh has implemented effective measures, managing 500 kilograms daily with precision, guaranteeing proper disposal and recycling. Chandigarh has achieved a significant milestone by becoming the first Union Territory to completely process all its sanitary waste. The city boasts a 100% collection efficiency for municipal solid waste, the primary waste stream. Notably, strict measures have been implemented to ban single-use plastic items and thermocol products, with comprehensive amendments made to relevant notifications. Chandigarh efficiently manages its hazardous waste, generating minimal quantities and taking proactive steps to mitigate potential harm to both humans and the environment. Chandigarh's waste management initiatives extend beyond conventional practices. "Project Arpan," an ingenious endeavor, transforms temple floral waste into practical products, showcasing the city's innovative spirit and dedication to sustainability. The establishment of the Reduce, Reuse, recycle (RRR) center fosters community engagement by encouraging participation in repairing and repurposing used clothing, electronics, and footwear, thereby promoting a culture of sustainability at the grassroots level. In essence, Chandigarh's waste management strategies serve as an inspiration for other urban centers worldwide. By prioritizing innovation, community involvement, and sustainable practices, Chandigarh sets a high standard for waste management excellence, offering valuable insights and lessons for cities grappling with similar challenges globally (Kumar, 2024) [19].

2. Modernize CTU Buses Public Transit and Personal Mobility: In Chandigarh, the integration of smart technology in public transit, particularly in the city's bus system, exemplifies a best practice for urban development. By leveraging digital initiatives, Chandigarh's public buses have streamlined fare payment processes, transitioning from analog systems to e-payment solutions. This transition has not only made fare payment smoother but has also increased the carrying capacity of public transit by simplifying the boarding process and reducing time costs for passengers.

3. Citizen Engagement and Participation: Chandigarh's best practice of urban management is community participation through the Administrator's Advisory Council helps inclusive governance and collaborative decision-making. By involving members of the community, national and international experts, and eminent personalities, the city ensures diverse perspectives are considered in shaping its future. This approach extends to various facets such as community policing, Swachhta initiatives, cyber hygiene, and greening activities, fostering a sense of ownership and shared responsibility among residents.

3. Chandigarh's Model Jail: Chandigarh's Model Jail, Burail, stands as an example of best practices in prison and correctional administration. The initiative to transform it into the 'MOST LITERATE JAIL' in the country, coupled with providing convicts the opportunity to pursue higher education, reflects a commitment to rehabilitation and

reintegration into society. Initiatives like 'Shram Dan' by both jail staff and inmates foster a sense of community and responsibility. Telecasting programs like Mann ki Baat not only connect inmates with national discourse but also promote positive thinking and introspection. The installation of solar geysers and utilization of solar energy demonstrate a commitment to sustainability and environmental conservation. Leveraging the skills of inmates to produce jail products for retail sale not only generates revenue but also enhances vocational training and employability. Lastly, the production of biogas for the jail kitchen through a bio-gas plant showcases innovative solutions for sustainable resource management.

7. Conclusion

India is during a shift from predominantly rural to semi-urban living, which brings both challenges and opportunities for sustainable progress. This period underscores the importance of utilizing technology to facilitate organized growth, fostering economic and social advancement nationwide. Chandigarh's experience with digital innovations in urban management offers valuable lessons for cities trying to enhance efficiency, sustainability, and citizen engagement. Through the adoption of technology-driven solutions, Chandigarh has demonstrated the potential to transform various aspects of urban governance, including waste management, transportation, and public service delivery. Chandigarh is actively pursuing initiatives to achieve its zero-carbon emission target for combating climate change. The city is promoting renewable energy adoption, enhancing public transportation infrastructure, implementing energy-efficient measures in buildings, and fostering green spaces to mitigate environmental impact. To address the existing urban challenges of Chandigarh strengthening the capacity of urban governance institutions and personnel in digital skills and technologies is essential. Encouraging the sharing of open data among government agencies, private sector partners, academia, and citizens can foster collaboration and innovation in urban management. Digital platforms for citizen feedback to monitor the functioning of urban governance can empower residents to contribute to urban decision-making and hold authorities accountable.

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