Strategies For Advancing Bengaluru As Smart City: a Case Study

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Abstract The concept, origin, development, and history of Smart Cities were studied in conjunction with the backdrop, town, and economic characteristics of Bengaluru. The idea of Smart Cities is a "booming" global phenomenon, with Smart City initiatives being implemented worldwide. After the 2000s, the term "smart" gained popularity in urban policy making to describe the skillful use of information technologies (IT) to improve a city's infrastructure and service functionality and efficacy. With significant contributions from various technologies, including computer science, information technology, remote sensing, and enhanced multimedia, the idea of Smart Cities is a recent one in our country. This project explores the foundation of a Smart City by examining existing relevant parameters, such as electricity, solid waste management systems, water supply, and transportation, in Kondashettihalli and Chikkaballapur areas only due to the vastness of the city and the deciding parameters. Bengaluru's spatial expansion is examined, the shortcomings of the current situation are contrasted with those of a Smart City, and lastly, planning plans and recommendations are provided.

Keywords Information technology; Smart city; Spatial Growth; Transportation; Water supply

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Introduction

The notion of a "Smart City" is not new, but the phrase originated with the "Smart Growth" movement at the end of the 1990s, which advocated for new urban planning principles (Harrison and Donnelly, 2011). The idea of Smart Cities is a booming global phenomenon, with over 2000 Smart City initiatives started in Europe, Asia, Africa, and America. By 2013, there were more than 1500 projects underway, with a compound annual growth rate of 20%. After the 2000s, the term "smart" became widely used in urban policymaking to describe the clever application of information technologies (IT) to increase the effectiveness and productivity of a city's services and infrastructure (Robin Hodkinson 2011). Detailed explanations of the "smart city" phenomenon's elements are provided below. With substantial contributions from various technologies, including computer science, information technology, remote sensing, and enhanced multimedia, the idea of a Smart City is a recent one in our country. These new systems improve the efficiency, agility, flexibility, and sustainability of Smart City operations. India's first Smart City, GIFT (Gujarat International Finance Tec-City), was established in Gujarat in 2011 with the assistance of experts from CISCO and ABB. Other Indian cities with Smart City initiatives include Haldia (West Bengal), Amanora (Maharashtra), Pune, Lavasa (Maharashtra), and Electronic City (Bangalore).

Definition of Smart City

The concept of a "smart city" refers to a city that can achieve long-term economic growth, a high quality of life, and responsible resource management by investing in social and human capital, conventional (transportation), and modern (ICT) communication infrastructures. (Caragliu *et al.,* 2009). While the idea of applying information technology (ICT) to future cities has become popular in recent years, the focus of a smart city is not just on the role of ICT infrastructure but also on human capital/education, relational and social capital, and environmental challenges. These are considered significant drivers of urban growth. Smart cities are defined as "innovative, knowledge-intensive tactics designed to improve cities' competitiveness, logistical efficiency, and socioeconomic success. These 'smart cities' are supported by a promising combination of human capital (such as a skilled labor force), infrastructural capital (such as high-tech communication facilities), social capital (such as intense and open network links, and entrepreneurial capital) (Kourtit *et al.,* 2012). Smart computing technology can be applied to key municipal services and infrastructure, such as real estate, public safety, transit, and city administration, to make them more intelligent, networked, and effective. (Washburn *et al.,* 2010). There are various definitions of "smart cities" in use today, depending on the region and focus area. The UK Department of Business, Innovation, and Skills defines it as a process that improves a city's livability, resilience, and capacity to deal with challenges through increased hard infrastructure, citizen engagement, digital technologies, and social capital. The British Standards Institute defines it as "the effective integration of physical, digital, and human systems in the built environment to produce a sustainable, prosperous, and inclusive future for its residents," while IBM defines it as a city that makes the best use of interconnected information to better understand and govern its operations and optimize the use of limited resources. Cisco defines smart cities as those that implement scalable solutions that make use of information and communications technology (ICT), which boosts productivity, lowers costs, and improves the quality of life. Accenture defines it as a city that "delivers public and civic services to citizens and companies in an integrated and resource-efficient manner while enabling innovative collaborations to improve quality of life and expand the local and national economy." In summary, a city is considered "smart" when it successfully integrates information and communication technology (ICT) and the Internet of Things (IoT) into critical infrastructure components and services of the city, including education, public safety, city administration, transportation, healthcare, real estate, and utilities.

Need for Study

Globally, urbanization is rapidly accelerating. For the first time in human history, there were more urban residents than rural ones in 2008, and indications suggest that this trend will continue. By 2030, the majority of the world's population is expected to live in "megacities" (10+ million), major cities (5-10 million), medium-sized cities (1-5 million), and smaller cities and peri-urban villages, with a growing concentration in Asia, Africa, and Latin America. By 2050, this percentage could reach two-thirds. According to a recent report by the Intergovernmental Panel on Climate Change (IPCC) on Spatial Planning, Human Settlements, and Infrastructure, the expansion of urban areas (urban centers and suburbs) is, on average, twice as fast as the growth of the urban population, and the expected growth in the first three decades of the 21st Century will be greater than the total urban expansion throughout human history. As a result of this rapid urbanization, there is a greater need for resources like energy, water, and sanitation as well as for services like education and healthcare. This highlights the necessity of developing "smart" cities that can meet the needs of city dwellers while also utilizing resources effectively or "smartly."

Infrastructure development on all fronts - institutional, physical, economic, and social - is necessary for this. Improving the quality of life in cities, attracting tourists and investors, and igniting a cycle of growth and expansion all require these elements. The development of smart cities is a step in that direction. To meet the benchmarks, civil engineers must provide planning ideas and realistically implement them through infrastructure.

Smart City Evolution

"Smart Growth" emerged in 1992 as a concept aimed at providing an alternative model to detached homes, urban sprawl, and reliance on motor vehicles. Planners, architects, community organizers, and advocates for historic preservation were the primary drivers behind this movement. Innovative approaches to urban planning and design began to emerge, emphasizing that the expansion of a city should occur in compact, mixed land-use, and walkable urban centers, offering a range of transportation and housing options. In these areas, the community is involved in making decisions about development that are reasonable, anticipated, and economical. This idea gained widespread popularity in the 1990s before losing momentum as "Intelligent Cities" took its place. The concept of intelligent cities focused on how data and information technologies could impact the functioning of cities. The concept of a "Smart City" grew out of these discussions on intelligent cities and smart growth. Many of these conversations were led by "intelligent" and "smart" companies such as IBM, Siemens, and CISCO. Other digital giants, like Hitachi and Microsoft, have also developed "smart" technologies for cities. Contributions to this conversation have also come from MIT laboratories (Townsend, 2014; Harrison, 2011).

The discussion of smart cities became more prominent with the end of the global economic crisis in 2008. During this time, in order to offer public urban services, there were drastic cuts to urban finances and social welfare (Paroutis *et al.,* 2014). As a result, the concept of a "smart city" evolved, offering an interface that treats the city as a system of intricate information flows. The model assumes that there is an overarching objective for the city that can be amended to boost productivity in several industries, including transportation, healthcare, and others, for the benefit of the city as a whole (Steiner and Veel, 2014).

History of Smart City

The Smart City Mission (SCM) was launched by the Ministry of Urban Development (MoUD), Government of India on June 25, 2015, to be implemented in 100 cities dispersed throughout the country. The objective of the SCM is to create livable cities that provide employment opportunities, a sustainable and clean

environment, and "Smart" solutions. To achieve these objectives, the SCM has strategic elements of area-based development, such as place improvement (Retrofitting), city renewal (Redevelopment), and city extension (Greenfield Development), as well as a pan-city initiative in which smart solutions are implemented across larger areas of the city. To be considered for SCM, each city must pass a two-stage city challenge selection process. In the first round of the selection process, competition was held among the state's cities based on the prerequisites and scoring criteria specified in the SCM standards. Seven cities in Madhya Pradesh, including Bhopal, Indore, Gwalior, Jabalpur, Sagar, Ujjain, and Satna, were shortlisted in the first stage and are among the 100 cities identified by MOUD as potential smart cities. Each of the 100 shortlisted cities must prepare their ideas for the "City Challenge" in accordance with the Smart City Guidelines and submit them by the deadline specified by MOUD to participate in the second round of the selection process.

As part of the process of creating Indore's Smart City Plan, the Urban Development and Environment Department's Madhya Pradesh Urban Infrastructure Investment Programme (MPUIIP) team conducted a diagnostic study. The study examined a variety of smart solutions for different sectors of the plan based on secondary research, best practices from around the world, and the applicability of specific smart solutions. Based on the most important lessons learned from these studies, the MPUIIP team has created a manual of sector-specific "Smart Solutions." The handbook is intended to serve as a ready reference for local governments in creating smart solutions, ensuring that each city's smart city plan adheres to international standards and quality requirements and is developed in accordance with the Government of India's Smart City Guidelines.

History of Bengaluru City

Before Kempe Gowda, the feudal lord of the Vijayanagara Empire, constructed a fort made of mud, which is regarded as the precursor to modern-day Bangalore, in 1537 CE, the region that is now Bangalore was ruled by a sequence of South Indian kingdoms, including the Cholas, the Western Gangas, and the Hoysalas. The Marathas ruled Bangalore from 1638 until the Mughals retook the city and gave it to the Wadiyar dynasty of the Mysore Kingdom. The British gained control of the city after winning the Fourth Anglo-Mysore War (1799), and then gave authority back to the Sultan of Mysore. Mysore, which was a region of the British Raj that enjoyed some measure of autonomy, was given the old city as its official capital. Around the British cantonment, which was transferred from the old city to Bangalore in 1809, a town that was ruled as a part of British India rose. After India's independence in 1947, Bangalore was chosen to serve as the capital of Mysore State. This designation was retained even after Karnataka was added to the Indian state system in 1956. The city and the cantonment, which had grown as self-supporting urban communities, merged in 1949 to form a single urban center. The city's present Kannada name, Bengaluru, was chosen as its official name.

Physical Characteristics of The City

Bangalore is located in the southeast of Karnataka state, India. It is situated in the Mysore Plateau, which is a part of the larger Precambrian Deccan Plateau, at an average elevation of 900 meters (2,953 ft). With an area of 741 km^2, it is located at 12.97°N 77.56°E. The majority of Bangalore lies within the Bangalore Urban district of Karnataka, while the surrounding rural areas are included in the Bangalore Rural district. The former Bangalore Rural district was converted by the Karnataka government into a new district called Ramanagara. Bangalore's morphology is primarily flat, with some hilly areas in the western parts of the city. Vidyaranyapura Doddabettahalli, at a height of 962 meters (3,156 ft), is the highest peak located to the northwest of the city. There aren't any significant rivers that flow through the city, although the Arkavathi

and South Pennar rivers meet up to the north in the Nandi Hills, 60 kilometers away. Basavanagudi is the source of River Vrishabhavathi, a minor tributary of the Arkavathi, which runs through the city. Many of Bangalore's sewage flows jointly through the rivers Arkavathi and Vrishabhavathi. Five sewage treatment facilities are connected to Bangalore's sewerage system, which was built in 1922 and covers 215 km^2 of the city. The largest freshwater lakes and tanks in Bangalore are the Madivala tank, Hebbal lake, Ulsoor lake, Yediyur Lake, and Sankey Tank. Groundwater is found in layers of alluvial sediments ranging from silty to sandy. The most prevalent rock type in the region is the Peninsular Gneissic Complex (PGC), which is made up of granites, gneisses, and migmatites. Bangalore's soils consist of red laterite and red, fine loamy to clayey soils. Large deciduous canopies and a few coconut trees make up most of the city's vegetation. Despite being a member of seismic zone II (a stable zone), Bangalore has experienced earthquakes as powerful as 4.5.

Economic Profile of The City

The metropolitan region of Bangalore has been estimated to have the third- to fifth-most productive metro area in India, with a fluctuating GDP ranging from US$45 to US$83 billion. Bangalore is India's second-fastest-growing metropolitan city, with an economic growth rate of 10.3%, and the fourth-largest market for fast-moving consumer goods (FMCG) in the country. Forbes has identified Bangalore as one of "The Next Decade's Fastest-Growing Cities." It is also the third-largest hub for high-net-worth individuals and is home to around 10,000 millionaires who have made over $1 million, as well as over 60,000 super-rich people who have assets worth a combined total of $45 million (US$668,700) and $5 million (US$74,300). Bangalore has the corporate offices of several public sector organizations, including Hindustan Aeronautics Limited (HAL), Bharat Heavy Electricals Limited (BHEL), Bharat Earth Movers Limited (BEML), Bharat Electronics Limited (BEL), Central Manufacturing Technology Institute (CMTI), National Aerospace Laboratories (NAL), and HMT (previously Hindustan Machine Tools). The Indian Space Research Organisation (ISRO), which was founded under the Department of Space, has its headquarters in the city and was created in June 1972. Bangalore also houses numerous R&D facilities for various companies, including Airbus, ABB, Toyota, Bosch, GE, GM, Nokia, Google, Microsoft, Philips, Boeing, Mercedes-Benz, Oracle, Shell, and Tyco.

Bangalore is known as the Silicon Valley of India due to the high concentration of information technology firms in the city, which in 2006-07 accounted for 33% of India's 1,442 billion (US$21 billion) in IT exports. The three primary IT clusters in Bangalore are Electronics City, International Tech Park, Bangalore (ITPB), and Software Technology Parks of India (STPI). High-end commerce can be found in UB City, which is the headquarters of the United Breweries Group. Bangalore is home to many international SEI-CMM Level 5 Companies, including Infosys and Wipro, which are the third and fourth largest software companies in India, respectively. However, the city is facing specific challenges due to the growth of the IT sector. The city's IT tycoons often clash with the state government, whose voting base is mainly made up of residents of rural Karnataka, as they call for an upgrade to the city's infrastructure. The promotion of the high-tech sector in Bangalore did not help local employment growth; instead, it raised land values and drove away small businesses. Additionally, the state has not made significant investments to prevent the significant decline in urban transportation, which has already begun to push new and expanding companies to other hubs across India. Bangalore is also a center for biotechnology-related businesses in India, and in 2005 it was home to Biocon, the country's largest biotechnology company, as well as around 47% of the country's 265 biotechnology firms.

Steps involved in the Research work

(i) A survey of the key research articles that have influenced the area of sustainable smart cities.
(ii) Review of the Most Important Policy Literature, Including Initiatives, Experiences, and Recommendations from the World's Major Organizations and Experts in the Subject.
(iii) Building a repository of such efforts through the process of gathering documentation of Smart City ideas as well as the execution performance.
(iv) To assist in planning, implementation, and assessment of smart city ideas, create a framework based on contributions derived out of case study development, research, and policy literature review;
(v) Due to time restrictions, four parameters - transportation, water supply, solid waste management, and electricity, are taken into consideration.
(vi) Data collection and analysis:
(a) Revised Master Plan 2015
(b) BBMP Solid Waste management system data of the required areas
(c) Land use in 2004
(d) Existing land use 2015
(e) Final proposals: After analyzing all the data shortfall is calculated, issues and strategies are found, and the final proposal is prepared.

Limitations of the study

Limited to two intermediate areas (Kondashettihalli) and outer areas (Chikkaballapur) the study is limited to physical infrastructure viz., (a) Traffic and Transportation, (b) Water supply, (c) Solid waste management, and (d) Electricity.

Reviews of literature

The article reports on the findings of the EADIC research project on enterprise planning of smart cities (Kakarontzas *et al.,* 2014). The study reveals that interoperability, availability, usability, recoverability, security, and maintainability are the most crucial requirements for smart cities. The article presents a conceptual framework based on these criteria. Khan *et al.,* (2014) suggest a cloud-based architecture and service framework for context-aware services in smart cities. They argue that integrating various applications and enabling them to interact with intelligent information is necessary to produce intelligent information for efficient smart urban governance. Paroutis *et al.,* (2014) developed a novel method for developing and distributing technology to address urban challenges, particularly in the context of a recession. They constructed a conceptual framework based on recessionary literature to assess the case study of IBM on smart cities. Mulligan and Olsson (2013) discuss the two primary system architectures for smart cities: communications and ICT. They also explain how the system architecture must change to produce fresh and creative business models for smart cities.
Glebova *et al.,* (2014) studied the three largest cities in the Volga Federal Region with the idea of a "smart city" as a foundation (Karzan, Samara, and Nizhniy Novgorod) and offer suggestions for putting a smart city into practice. Vilajosana *et al.,* (2013) identified the reasons why smart cities are struggling to take off and presented a big data approach based on the concept of an API store to make smart cities a reality. Herschel (2013) introduces the smart city-regionalism concept to address the competing agendas and policy objectives of sustainability and competitiveness principles. Smart growth and modern regionalism combine to create smart city regionalism, serving as both an analytical framework and a process for formulating policy. Neirotti *et al.,* (2014) present a taxonomy for smart cities based on application domains, such as natural resources and energy, buildings, transportation and mobility, and the economy of people. The article also seeks to comprehend the potential effects that urbanity, economy, and demography may have

on the execution of a smart city. Lazaroiu and Roscia (2012) propose a smart city model that enables the calculation of a city's smartness index based on "smart" indicators. The authors argue that the suggested model could aid local management in formulating policies and making a final choice among the several possibilities that are on the table. Ojo *et al.,* (2014) develop a "Smart City Initiative Design Framework" based on an examination of ten cities with smart city initiatives, providing a tool for designing smart city projects. Piro *et al.,* (2014) focus on information for smart city services and develop a platform that falls back on common use cases, including business operations and water management. The article mainly emphasizes the technological aspects of smart cities that relate to ICT infrastructure and services.

Methodology

Case Study 1- International model

Seoul, South Korea is leading the way in e-governance by integrating IT with service delivery. In 2004, the government launched the u-City initiative, and in 2011, it unveiled Smart Seoul 2015 as its strategic plan to retain Seoul's competitiveness and solidify its position as a global technological leader. The plan aims to address several issues such as traffic, aging, and sustainability since people's expectations were rising.
The Smart Seoul 2015 strategic plan proposes using IT with service delivery as the solution, with most services funded by the city or the federal government. Most master plan-based services are contracted out to the private sector. For example, Seoul and three wireless service providers have signed a joint MOU to deploy public Wi-Fi, which will cover 13.5% of the Seoul region. Some of the initiatives under the plan include:

(i) Increasing ICT accessibility and closing the digital divide: The plan aims to provide IT training to low-income and senior groups, benefiting around 200,000 people every year. The city also donated smart devices, resulting in tax deductions of between $50 and $100 for each donated item. As of March 2012, all of Seoul's subway trains have Wi-Fi access, and the goal is to provide free, reliable Wi-Fi service to residents.

(ii) Enhancing public health and safety: Parents can monitor their children's travel patterns and alert the appropriate authorities in case of an emergency, thanks to U-Seoul Safety Services that use location-based services and CCTV. Another initiative is U-Health Care, intended to provide health examinations and priority medical care to the elderly and disabled with limited mobility.

(iii) Effective public service delivery through participatory governance: The plan aims to construct infrastructure such as data centers based on cloud computing that use less energy and smart work centers that allow government personnel to operate from ten offices. More than 60 services are available through the Mobile Seoul app, which also allows users to vote yes or no on proposals to enhance the city and locate nearby public bathrooms. Citizens can get information on all public services through a single platform on the Seoul Metropolitan Government's new website. The city's new Information Open Square online feature enables the proactive publication of official data and documents.

(iv) Improving commuting: Open 311 interfaces and the implementation of a touch card payment system based on GPS will help collect real-time traffic data for the 25,000 taxis in the city. This method is more affordable than adding sensors to the road infrastructure. To promote public transportation, TOPIS (Transport Operation and Information Service) integrates data from all forms of mass transit and connects with the traffic signal system. Additionally, when a starting point and destination are input, digital view terminals that have been installed in Seoul subway stations show thorough navigation and the best routes to travel. T-Money, an electronic payment system in the form of a card, can be used to pay for all types of public transit. Lastly, online shops are available for users to make purchases while waiting at bus stops, using a smartphone app that can read product barcodes.

(v) Increasing energy efficiency: The plan includes providing smart home electrical controllers and smart meters that show power usage and encourage energy-saving measures. Streetlights automatically adjust the lighting depending on the outdoor luminance. To cultivate organic food, hydroponic pavilions have been created.

Some of the benefits of these initiatives are:

(a) Service delivery and access to public information: Seoul reports that the percentage of public service reservations made online has increased from 26% to 85%. Additionally, Seoul has released more than 35% of the total 400 datasets, with 150 datasets available compared to only 40 in 2011.

(b) Economy: The availability of public information has enabled the private sector to create innovative solutions to meet public demands, such as the Seoul Bus app. The disclosure of public information has also contributed to the growth of the knowledge information and content market, which is expected to double in size by 2015, thanks to the estimated economic value of 1.2 trillion KRW. Seoul aims to increase the number of application developers from 2,000 in 2011 to 6,000 by 2015.

(c) Environment: In Seoul, energy-saving apps have been downloaded by 4 major banks, 22,000 buildings, and 479,000 homes. Seoul aims to reduce energy use by 10% and CO2 emissions by 2% by 2015. Smart sensors and informed electrical information are expected to help achieve these goals, resulting in a potential 10% reduction in power use and savings of 500 billion KRW.

Case study 2- National Model

Gujarat International Finance Tech-City or GIFT is a city that is currently under construction in Gujarat, India, located about 12 kilometers away from Ahmedabad International Airport. The construction is starting on a 2.0 km^2 block of land, and its main objective is to provide top-quality physical infrastructure such as gas, water, electricity, roads, broadband, and telecoms to financial and technology companies relocating from other locations like Bangalore, Mumbai, Gurgaon, etc., where the infrastructure is either insufficient or very expensive. The development will include a Special Economic Zone (SEZ), a Global Education Zone, Integrated Townships, Hotels, Convention Centers, Global Techno Parks, Stock Exchanges, Software Technology Parks of India (STPI) Units, an Entertainment Zone, Retail Stores, and Service Facilities. GIFT aims to develop a transportation system that ensures accessible, easy, and speedy mobility, with no traffic fatalities. This will be achieved by using a multimodal mix of transportation systems (MRTS/LRTS/BRT, etc.) for both intra-city travel and inter-regional transit (connecting Ahmedabad, the airport, Gandhinagar, and the city). Efficiency will be achieved by incorporating the "walk-to-work" idea into urban planning and adopting a 10:90 nodal divide for private and public transportation. GIFT will also use electric Personnel Rapid Transport systems within the city. Currently, it is connected to Ahmedabad BRTS, run by Ahmedabad Janmarg Ltd. The city will eventually be connected to other areas as well.

The first of its kind in India, GIFT is envisioned as an IT service and global financial center that will compete favorably with other financial hubs across the world like Tokyo, Shinjuku, London Dockyards, La Defense, Lujiazui, Shanghai, Paris, Shanghai, etc. Its Target Business Segments are KPO Services, IT services (Software Application development and maintenance), BPO Services, ITeS, Capital Markets and Trading, Financial Services Operations (Back-office of banking, Insurance, and Asset Management Companies). The land leveling work for GIFT city has completed its first phase, and construction is currently underway on two 29-floor commercial skyscrapers. They were finally finished in December 2016 following a three-year delay. The project's second phase involved creating roadways and building foundations from 2011 to 2013. The development and start dates for the third Phase were set for 2013 to 2017.

Guidelines and Features for Smart City

The Smart Communities Mission seeks to assist communities that provide a solid foundation for their citizens, a high standard of life, a healthy, sustainable environment, and the use of "Smart" Solutions. The goal is to analyze compact geographic areas and create a replicable model that would serve as a beacon for other aspirational communities. Sustainable and equitable development are the main priorities. A report, according to the Ministry of Urban Development, Government of India, 2015, some common characteristics of the extensive growth of smart cities are listed below:

(i) Encouraging mixed-use development in localized areas - planning for "unplanned regions" that have a variety of appropriate applications and activities close to one another to maximize the use of available land. The States will allow some wiggle room in their land use and building bylaws to accommodate change.

(ii) Inclusivity and housing- increase access to homes for everybody.

(iii) Creating walkable localities - increases the local economy, encourages interactions, and provides security while reducing traffic, air pollution, and resource depletion. All crucial administrative tasks are located nearby, and roads are constructed or refurbished not only for automobiles and public transportation but also for pedestrians and cyclists.

(iv) Preserving and developing open spaces - playgrounds, parks, and recreational areas to improve the standard of living for residents, lessen the effects of urban heat in some areas, and overall promote eco-balance.

(v) Encouraging a range of transportation choices - Public transportation, last-mile connectivity, and transit-oriented development (TOD) for paratransit.

(vi) Making government more cost and citizen-friendly - There is a growing reliance on online services to promote accountability and transparency, particularly when using mobile devices to lower service costs and deliver services without requiring residents to visit municipal offices; setting up online focus groups to hear from the public and gather feedback; and using online monitoring of programs and activities with the help of virtual site visits.

(vii) Giving the city an identity- based on its primary economic activity, such as its regional cuisine, education, sporting goods, arts and crafts, culture, health, furniture, hosiery, textiles, dairy products, etc.

(viii) Improving area-based development's infrastructure and services through the application of smart solutions. Using less energy, fewer resources, and offering less expensive services are a few examples.

Spatial Growth Analysis

Cities worldwide are undergoing various changes due to natural and human activities. The population growth of a city over time can result from socioeconomic changes, improved livelihoods, etc., which in turn leads to migration of the workforce into the city, drastically affecting land use patterns. To provide for the living needs of the workforce, land areas need to be developed, requiring proper planning and execution. Due to the already crowded nature of cities, intricate ideas are required to develop the necessary amenities within the limited space. The growth of urban population takes different forms, and to determine them, we must consider various land uses dedicated to the general public, such as residential, commercial, or industrial areas, parks and playgrounds, open spaces, and transportation and communication infrastructure. The challenges posed by the spatial growth of cities were first noticed in the 1980s (Kaya *et al.,* 2009).

In the context of urban planning, "Land Use" refers to the purpose for which a particular zone is designated, which may include residential, commercial, or industrial purposes, as well as parks, playgrounds, open spaces, and transportation and communication infrastructure. Over the past ten years, cities have seen development almost everywhere. Assuming all developments are relatively close to each other, the total built-up area of the city is taken into account. Spatial growth analysis provides accurate data for identifying and interpreting land use dynamics and urban growth tendencies. This involves analyzing and comparing

the total built-up area of a city at different stages, such as 2004 and 2015.

Analysis of Land Use Data in 2004

The analysis of land use data in the year of 2004 has been portrayed in Table 12.1. the relevant pie chart has been depicted in Figure 12.1.

Table 12.1. Land use data, 2004*

Land use type	Area (Hectare)
Industrial	1874778.836
Commercial	714721.9277
Residential	2493468.931
Park and Open space	225865.321
Civic Amenities	198254.9356
Transport	2346891.684
Total	**7853981.634**

*Land Use 2004 data is obtained from Revised Master Plan (RMP) 2004

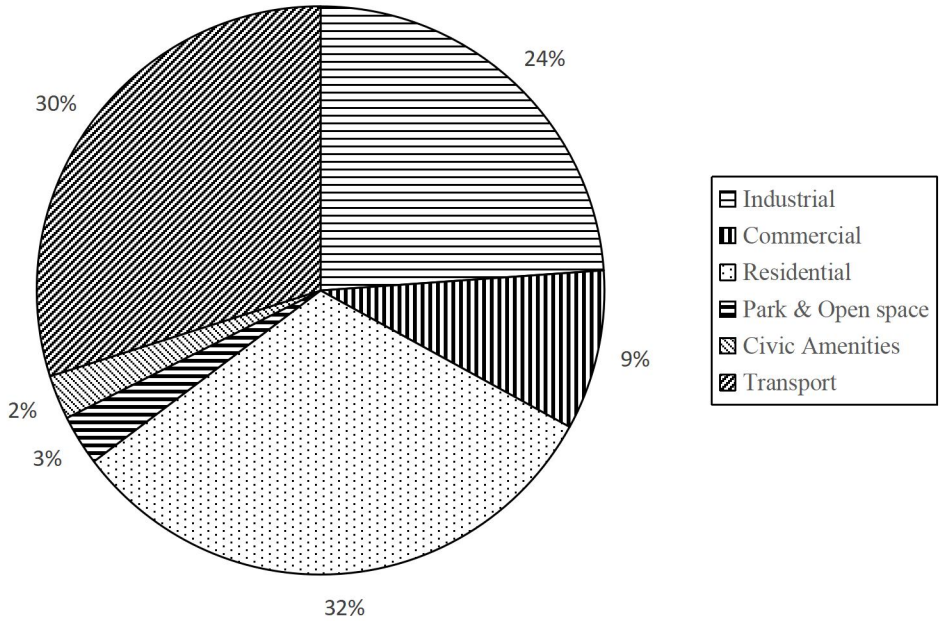

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Figure 12.1. Land use pattern 2004

Analysis of Existing Land Use Data, 2015

The analysis of land use data in the year of 2004 has been portrayed in Table 12.2. the relevant pie chart has been depicted in Figure 12.2.

Table 12.2. Existing land use data, 2015**

Land use type	Area (Hectare)
Industrial	1518940.631
Commercial	1098771.663
Residential	2193468.931
Park and Open space	208997.6717
Civic Amenities	346366.8219
Transport	2487435.916
Total	**7853981.634**

**Land Use 2015 data is obtained from Revised Master Plan (RMP) 2015

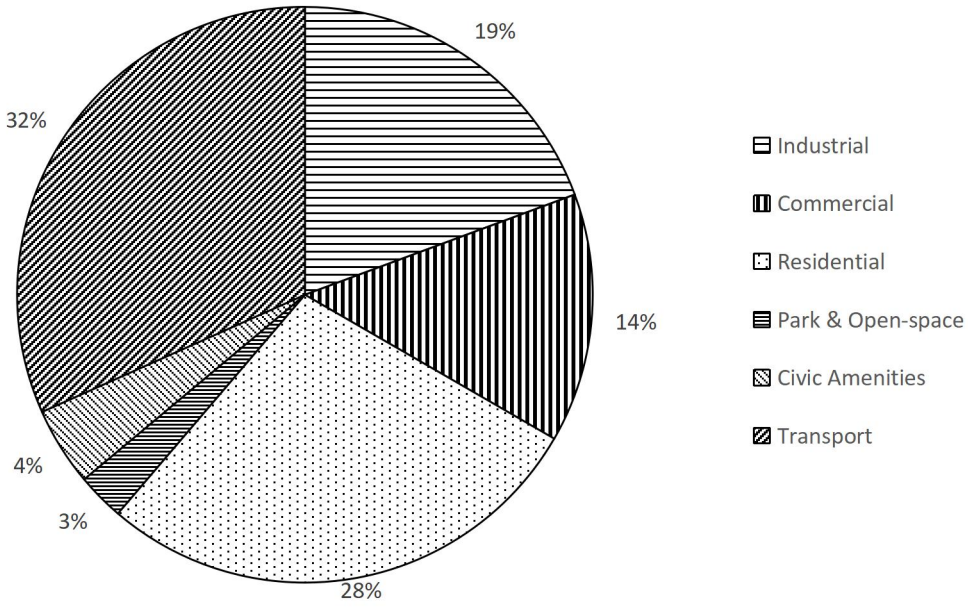

Figure 12.2. Land use pattern 2015

Comparison of Spatial Growth

The comparative study of the spatial growth has been made herein. The study analysis has been presented in Table 12.3 and Figure 12.3.

Table 12.3 Difference in 2004 and 2015 land use data

Land use	Land use data, 2004	Existing land	Difference

	(ha)	use data, 2015 (ha)	(%)
Industrial	1874778.836	1518940.631	-4.53
Commercial	714721.9277	1098771.663	4.89
Residential	2493468.931	2193468.931	-3.82
Park and Open space	225865.321	208997.6717	-0.21
Civic Amenities	198254.9356	346366.8219	1.89
Transport	2346891.684	2487435.916	1.79
Total	**7853981.634**	**7853981.634**	**-**

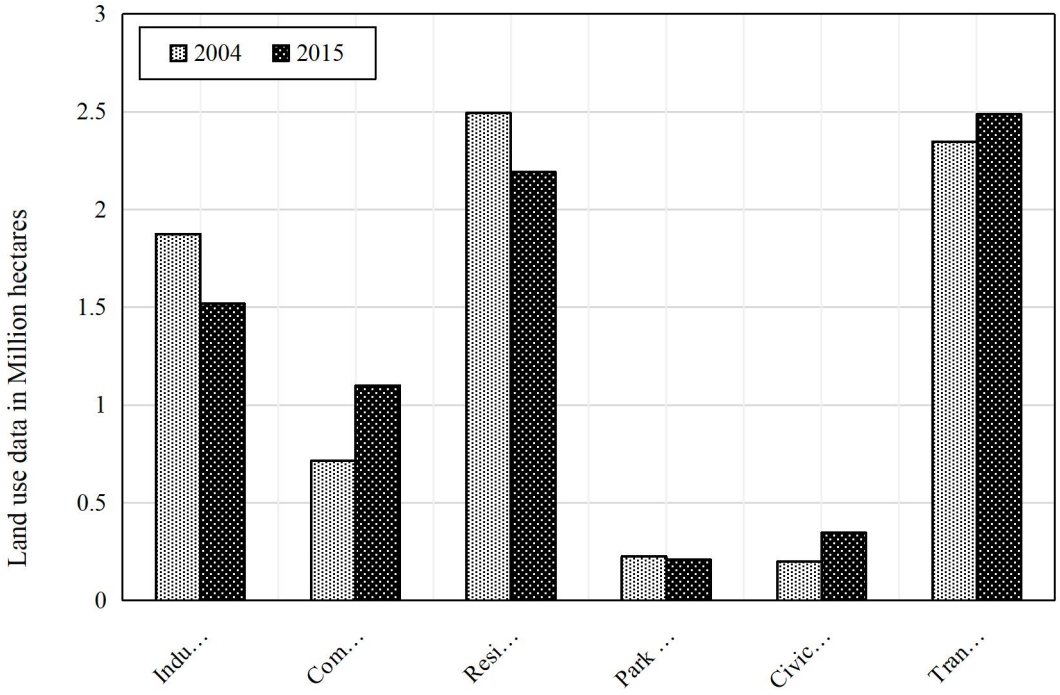

Figure 12.3. Comparison of land use data 2004 and 2015

Factors Affecting Growth of Bengaluru City

Future growth is greatly influenced by the growth figures in the Bangalore Metropolitan Region besides Bangalore's swift socioeconomic growth, which has had a substantial impact on the city's urbanization. The following are important initiatives promoting socioeconomic growth in the city and peri-urban area:

(i) Bangalore-Mysore Infrastructure Corridor (South-West Bangalore).
(ii) Information Technology (IT) Corridor (South-East Bangalore).
(iii) Bangalore Metro Rail (cross-cutting Bangalore City).
(iv) Bangalore International Airport (North Bangalore).
(v) Power supply and energy projects that are responsive.

(vi) Location of large-scale/manufacturing industries (East and North Bangalore).
(vii) Location of IT/ITES/Biotech Industries (East and South Bangalore).
(viii) Five Integrated Townships are being built in the BMR.
(ix) Power supply and energy projects that are responsive.
(x) Proposed Peripheral Ring Road (around Bangalore); and
(xi) Projects for delivering urban basic services presented by the city's local self-government organizations (funded through the Jawaharlal Nehru National Urban Renewal Mission)

Several local self-government organizations are in charge of handling the city's expansion, including Bangalore Metropolitan Transport Corporation (BMTC), Bruhat Bengaluru Mahanagara Palike (BBMP), Bangalore Development Authority (BDA), Bangalore Water Supply and Sewerage Board (BWSSB), Karnataka Slum Clearance Board (KSCB), ITBT, Karnataka State Road Transport Corporation (KSRTC), Bangalore Metropolitan Region Development Authority (BMRDA), Heritage Board, Karnataka Housing Board (KHB), Bangalore International Airport Area Planning Authority (BIAAPA), Bangalore Electricity Supply Company (BESCOM), Tourism Department, and the Karnataka Urban Infrastructure Development and Finance Corporation (KUIDFC). Numerous systemic problems related to the aforementioned institutions are brought on by the presence of multiple agencies, including problems with planning for service delivery, accountability, organizational development, and others. These problems have an impact on how services are provided in the city.

Identification of Indicators and Benchmarks

Indicators and benchmarks of core infrastructures viz. Solid waste management (SWM), Transport, Water supply, and Power are identified, and the shortfalls are calculated.

Transport

To improve the quality of life in smart cities, it is necessary to expand the public transportation system and implement smart parking integrated multimodal transportation. This is highlighted in Table 12.4.

Table 12.4. Service level benchmark on Transport #

Sl. No.	Indicators and Benchmark	Present Status	Shortfall
1	Maximum journey time is 45 minutes in metropolitan areas and 30 minutes in small and medium-sized cities.	Not efficient	100%
2	All streets with a row of 12 meters or more must have an uninterrupted, 2 m-wide walkways on each side.	Not efficient	100%
3	On all streets having a roadway wider than 10m, there shall be two dedicated bicycle lanes, one in each direction, that are at least 2 meters wide.	Not efficient	100%
4	All houses in places with a population density of more than 175 people per square meter of a constructed area must be within 800 meters (10–15 minutes walking distance) of high-quality, frequent mass transit.	Not efficient	100%

5	Para-transit Road is 300 meters away on foot.	Not efficient	100%

#The present status is obtained from the Revised Master Plan (RMP) 2015

Water Supply

To monitor adequate water supply, smart metering, leakage identification, and water quality monitoring are the smart solutions to 24/7 water supply with 135 litres per capita per day (lpcd). The scenario has been portrayed in Figure 12.5.

Table 12.5. Service level benchmarking on Water Supply [$]

Sl. No.	Indicators	Benchmark	Present Status	Shortfall
1	Households with direct water supply	100%	75.75%	24.25%
2	Per capita water supply	135lpcd	85 lpcd	50 lpcd
3	Metering of water connections	100%	0%	100%
4	Quality of water supply	100%	100%	-
5	Continue water supply	24 hrs	2 hrs	22hrs
6	Efficiency in the collection of water charges	100%	0%	100%

[$] The present status is obtained from the (RMP) 2015

Solid Waste Management

The practical approaches to managing solid waste include recycling and waste reduction, waste to electricity and fuel, waste to compost, and wastewater treatment. The details are shown in Figure 12.6.

Table 12.6. Service level benchmarking on SWM [#$]

Sl. No.	Solid Waste Management	Benchmark	Progress Achieved	Shortfall
1	Coverage at the family level	100%	0%	100%
2	The effectiveness of MSW collection	100%	0%	100%
3	Size of the segregation	100%	0%	100%
4	The extent of the recovery	100%	0%	100%
5	The scope of scientific disposal	100%	0%	100%

[#$] The present status from Burhat Bengaluru Mahanagara Palike (BBMP) Zone-wise Solid Waste Management process.

Electricity

Electricity and adequate electrification is the key for smart city development. So far as the electricity is concerned, the actual scenario is portrayed in Figure 12.7.

Table 12.7. Service level benchmarking on Power [$$]

Sl. No.	Description	Benchmark	Progress Achieved	Shortfall
1	Household electric connection	100%	98%	2%
2	Supply of electricity	24hrs	22hrs	2hrs
3	Metering of electricity supply	100%	90%	10%
4	Recovery Cost	100%	85%	15%

[$$] The present status is obtained from the RMP 2015

Issues, Strategies, and Proposals

Traffic and transportation

Issues:

(a) Rapid motorization, severe congestion, a growing number of traffic collisions.
(b) Inadequate public transportation and poor infrastructure.
(c) Poor infrastructure for other motor vehicles.
(d) Poor Infrastructure for Non-Motorized Transport (NMT).

Strategies:

(a) Improvements in public transport,
(b) Ring roads, by-passes, underpasses, elevated roads, improvements to the current roadways, and parking are all examples of additions to the infrastructure for other vehicles.
(c) Infrastructure upgrades for non-motorized transportation (walking, cycling).
(d) Information, communication, and technology (ICT) implementation in the transportation sector.

Proposals:

(a) Enhancements to public transportation, including BRT, Metro Rail, LRT, Trams, and Monorail.
(b) In the smart transportation system, using a personal automobile is strongly discouraged and public transportation is prioritized as the major mode of transportation.
(c) Access to public transport: All homes in the built-up region are within 800m (10–15 minutes' walk) of high-quality, frequent mass transit.
(d) Within a 300-meter walking distance should have a paratransit station.
(e) Discouraging personal motor vehicles, by introducing more tax on vehicles.
(f) Mandatory group pooling with a minimum of 1 person in cars.
(g) Minute parking charges.
(h) Infrastructure upgrades for various types of vehicles include parking, ring roads, underpasses, elevated highways, and bypasses.

(i) The bottlenecks in the road and rail networks must be examined as well, and underpasses, elevated roadways, and extra rail networks must be promptly installed where necessary.
(j) Improvement of circles at Shivkote, Hesaragatta, and Subbanahalli.
(k) Road widening: From Shivkote to Aivarakandapura and from NH44 to Subbanahalli road.
(l) Improvements in infrastructure for walking, and cycling.
(m) Introducing ICT in the transport system.
(n) Proposal to introduce a Smart card system in public transport.
(o) Proposal to introduce a Synchronous signaling system.

Water Supply System

Problems:

(a) Water supply covers 77 % while 23 % was not covered in the city.
(b) The piped water supply in the city covers only 75.75%.
(c) whereas the duration of drinking water 2 to 4 hrs is more i.e., 74%.
(d) While in slums water supply through public tapes amounts to only 73.3% and individuals 24.3%.
(e) Cost recovered only 20%.
(f) Per capita water supply 85 lpcd.
(g) A lot of distribution loss due to the old pipeline (18%).

Strategies:

(a) All inhabitants have access to a safe and sufficient water supply.
(b) A sufficient supply of piped water that is also widely available and satisfies standards for water quality, pressure, etc.
(c) Two separate water supply networks (that serve the needs of drinking water and other needs that would help in recycling water and conserving it.
(d) Covering 100% of the water supply to the entire city. Now it has been covered 75%, so the remaining 25% needs to be covered.
(e) Achieving 135 lpcd and 24/7 ware supply as per the smart city benchmark

Proposals:

(a) Use of modern techniques, particularly smart metering, to cut down on waste and energy use in water networks.
(b) Installing sensors in the supply system to continuously monitor water flow rates, water levels, and water use. These models will aid in not only finding and locating leaks but also in maximizing the network's energy usage. Smart water meters may also be installed to measure water usage more accurately and to give water consumers data to manage their water use and cut expenditures.
(c) Replacing deteriorated pipes which are installed long back.
(d) Collection of water charges, 100% efficiency.
(e) Training for staff who are involved in the water supply system by technical exports.
(f) Water tanks at Kurubarahalli, Shivakote, and Subbanahalli.

Solid Waste Management System

Issues/problems:

(a) Efficiency of collection of MSW is only 0%.

(b) Extent of segregation is only 0%.
(c) The extent of scientific disposal is only 0%.
(d) Household-level coverage is only 0%.
(e) Lack of technical knowledge and proper institutional setup.
(f) Dumping and burning in open spaces.

Strategies:

(a) The system of daily doorstep collecting reaches every family.
(b) 100% of municipal solid garbage is collected.
(c) Totally separating biodegradable and non-biodegradable trash at the source.
(d) Solid trash is recycled entirely.

Proposals:

(a) Separation of dry and wet trash, as well as recyclable and non-recyclable waste, at the source to enable complete recycling of solid waste.
(b) Decentralized areas should use the appropriate technology for waste treatment. Set up a method for collecting and disposal that works well.
(c) Promote the use of items made from recycled materials, particularly those for building materials, compost, and power (based on the cycling of debris and construction materials).
(d) Composting at home and product subsidies for compost.
(e) Development of sanitation with the involvement of the private sector and NGOs.
(f) community involvement, hygiene promotion, and awareness-raising .
(g) Building institutional strength and sanitation management capabilities in order to improve service standards.
(h) creating a recycling facility at Subbanahalli and the Mavallipura dump.

Electricity

Issues/problems:

(a) Up to 98 percent of households have power connections.
(b) Power losses in 2014 were 16%.
(c) There were 22 hours of electrical supply, and (d) there is a lack of knowledge about renewable energy sources.

Strategies:

(a) Making 100% of households have an electricity connection.
(b) All residents in smart cities must have constant access to electricity.

Proposals:

(a) Proposal to make 100% metering of electricity supply.
(b) Proposal to ensure full cost recovery.
(c) Tariff slabs designed to cut down on waste.
(d) Incentives for the adoption of the solar system, and mandatory issuing of building licenses.
(e) establishing a smart grid and integrating it with renewable energy sources like solar and wind energy to meet demand.

(f) It is necessary to improve the current distribution system.
(g) Systems for power banking must be built.
(h) To decrease the need for electricity, it is necessary to construct green structures and green transportation.
(i) Awareness of the use of the solar system in street lighting, use of LED, etc. Use of the solar system in public buildings like stadiums, theatres, etc.

(j) a shared customer service center and an integrated billing system for many services, such as water, electricity, gas, internet, and property taxes.
(k) Online payment system that is simple to use. (l) Encouraging Renewable sources such as solar and wind energy.

Limitations of Proposal

(i) The study was limited to two intermediate areas (Kondashettihalli) and outer areas (Chikkaballapur) in Bengaluru city.

(ii) The study is limited to physical infrastructure viz., a) Traffic and Transportation, b) Water supply, c) Solid waste management, and d) Electricity as the data were relatively available on the government websites and offices. Several other parameters such as availability of capital, ease of proposal for smart city, etc., were not taken due to time constraints and can be used as a future scope consideration.

(iii) The data used in the study is relatively old due to inaccessibility to the newer data from government machinery.

(iv) The Technology capital expenditures required must be substantial for a smart city assumed in this project.

(v) The per capita income of the population of the region could not be documented which would draw back the implementation of this sophisticated smart city as technology service providers are relied upon the most in a well-planned smart city which means that the everyday activities are mostly done in a relatively easy manner. And this increase in technology dependence can take a toll on the mental and physical well-being of the residents in the near future.

(vi) Real estate prices rise as construction and development become more challenging due to the technological inclusion in most of the buildings to provide for an easy and comfortable living which could lead to difficulty in implementation due to lack of the exact revenue data of the state to build a smart city.

Conclusions

The pillars of a smart city include transportation, social infrastructure, stormwater drain, sewerage, solid waste management, power, telecommunication, and water supply. Due to the vastness of the area of study, only four pillars have been studied and planning strategies proposed for them. Further research can be done on the remaining pillars to generate a more concise proposal for the development of a smart city. Based on the spatial growth analysis of 2004 and 2015, it is forecasted that the land use for industrial, residential, parks and open spaces will be reduced while commercial and civic amenities and transportation will increase. To achieve economic growth and a healthy environment, there should be an increase in industrial, parks, and open spaces, and a reduction in commercial land use. Transportation facilities should be conveniently planned with the proposed infrastructure. In the solid waste management system, the shortfalls should be checked by the proposed plans and timely monitoring. In the water supply segment, losses and usage of water should be regulated according to the proposed plans. Uninterrupted

power supply is a major factor in urban activities and can be achieved through the proposed harvesting method. The planning strategies and proposals aim to overcome the shortfalls of the selected smart city pillars. Thus, a general proposal for all smart city projects is established.

Conflict of Interest Statement

The author declares that there is no conflict of interest.

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