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The Impact of IoT on Smart City Infrastructure in India

Maya Mohan[1], Hemapriya Mani[2]

[1]Department of Architecture, Bharath Institute of Higher Education & Research, Chennai, India

[2]Department of Civil Engineering, Bharath Institute of Higher Education & Research, Chennai, India

E-mail: [1]mayamohan070@gmail.com, [2]hemapriya.civil@bharathuniv.ac.in

Abstract

Today, we live in a society where digital communication systems are so advanced that by the mid 2050's the world will be completely filled by smart buildings on the internet highway like those portrayed in science fiction movies. This is possible because of tech savvy tiny sensors or Internet of Things (IoT) devices embedded in the smart network in order to collect meaningful information about the citizens and their interaction with the ubiquitous environment. Smart sustainable cities are modelled on the Internet of Things blending ICT for better standard of living and citizen services. IoT will modify indoor temperatures and switch off unnecessary lights in homes, detect snags in equipment and fix machines remotely, and provide commuters with information on traffic jams on the go. IoT in smart cities can be implemented by the development authorities but the stake holders of this task are citizens, the municipal government and private organizations engaged in this partnership. Using sophisticated ICT systems makes the city smarter and improves community building and connectivity by interweaving all the components of a city. Privacy and security are the two watch words when it comes to capturing citizens' data. This data needs to be anonymised before it reaches the civic authorities. This study evaluates the advantages and disadvantages of using IoT in Indian smart cities after discussing an international case study of a smart sustainable city.

Keywords: Smart City, Internet of Things, Information and Communications Technology (ICT), Ubiquitous City, Connectivity, Smart Cities Mission (SCM)

1. Introduction to Smart Sustainable Cities

Smart cities use technology and citizen data to enhance the urban experience and improve quality of life. Both citizens and public authorities use IoT devices like sensors, cameras, and meters to collect and analyze large volumes of data.

Smart cities are urban centers using advanced technology to improve the standard of living and quality of life of the citizens in ubiquitous ways using IoT devices like meters, lights, sensors etc that are connected to networks that collate and analyze data for traffic regulation, better air quality and pollution regulation, safety through control centers in case of fires, COVID19 and other hazards, etc. Furthermore, this data is used by city administrators for e-governance i.e., payment of property tax, electricity bill etc.

The UNECE and ITU [1] together with 300 international experts gave the following definition for smart sustainable cities:

A smart sustainable city uses technology and innovation to enhance quality of life, make urban services more efficient, and stay competitive, while meeting the economic, social, environmental, and cultural needs of current and future generations. While ICT is a prerequisite for smart city, other aspects like Cloud Computing, Internet of Things (IoTs) and artificial intelligence (AI) are also a part of the smart city.

The major contributions of this study is to tabulate the use of smart IoTs in city planning and highlight the need to use IoTs more as is done abroad in advanced countries. For example, in India, IoTs are used in smart roads and smart trees in a small way when compared with developed countries like USA and Canada. In the smart road project, a stretch of road is identified and fitted with overhead cameras and sensors. Sometimes, these stretches can have driverless cars as in USA. In the smart tree project, a wi-fi provider is fixed to a tree typically in a university and the tree also has sensors and cameras to interact with students.

1.1 IoTs in Smart Cities

The Internet of things (IoTs) are small devices that capture information and send it through the internet to data processing computers. A good example is flood control devices mounted on street lights that detect the water level on the street below and trigger the necessary further action. Another example is a camera that takes count of the number of people going through a particular street. This camera is useful during temple festivals or even for counting

during the rush hours during peak traffic in a particular street. Climate can be monitored with sensors and the temperature and humidity of a space can be adjusted. Traffic jams can be sensed and alternate routes conveyed to the public. These are but a few applications of IoTs.

The concept of a smart city is deployment of entirely automated IoT devices like RFID (Radio Frequency Identification) tags, actuators and sensors with a computational capability wired to the internet using various networking protocols for comprehensive smart functionality. Internet protocols such as Internet Protocol version 6 (IPv6), Hypertext Transfer Protocol (HTTP), and UDP/TCP 25 (User Datagram Protocol/ Transmission Control Protocol) help interact with devices such as air-conditioner, heater, refrigerator, washing machine, and other equipment. These devices can be switched off or regulated remotely. For example, a switch on the dishwasher that can be controlled through the mobile phone. Other internet protocols like Z-wave, ZigBee and HART (Highway Addressable Remote Transducer) are used to communicate with furniture, food, clothing, etc. In a wired city or ubiquitous city where smart systems merge with citizen services, linking practically every device and service to a network of sensors and RFID tags. All parts of the city's data are intertwined and computers process this data based on user queries. Data is collected through smart devices like computers, mobiles, tablets, etc. through the Internet and processed by powerful computers. Citizens can control their spaces from anywhere through mobile interfaces and can use fingerprint or iris technology to unlock doors and gates. Video conferencing is used to deliver services like education, public health, etc. The internet also regulates electricity and illumination, and water use in all the buildings. The city is full of sensors, cameras and smart devices that track building fire and safety, monitor highway traffic, flood levels and more.

1.2 The IoT Policy of GoI

On June 25th, 2015, the Government of India selected 100 smart cities and aimed for a budget of Rs 7,060 crores investment , triggering a large-scale use of IoT throughout the country. In addition to this, the Digital India Program supported the beginning of IoT industry in India to include digitally powerful communities.

Smart interventions are sought out in:

1. Smart bill payment and e-governance

2. Air Quality with less Carbon Monoxide, Nitrates, Sulphates and Particulate matter

3. Intelligent Transport System by avoiding cars and encouraging bicycles, trams, pedestrians, etc.

4. Smart Grid where Electronic power conditioning and control of the distribution of electricity are important

5. Smart urban lighting through system of streetlights that can be controlled

6. Water Management with recycling of waste water to use in gardens etc.

7. Smart parking indicating vacant slots in a public parking area

8. Waste management through Solid Waste Plants, recycling of plastics, etc.

9. Citizen safety during natural calamities and health emergencies like COVID

10. Greening the city by planning for open spaces and public spaces to enhance citizens' sense of belonging and pride in the city

11. Smart Energy including renewable energy from wind turbines, solar photovoltaic panels etc.

IoT plays a central role in several applications, including cellular modules, remote managers, industrial routers, cellular extenders, connected SOMs (system-on-modules), long range radio frequency modules, transportation routers, connected sensor, gateways, short range radio frequency modules, etc. It should be noted that the privacy and security of citizens must be respected while using ubiquitous technologies.

2. Research Methodology

The different methods used in the study of smart cities can be enumerated as questionnaires, focus groups and collecting of documents from the authorities after site visits. In questionnaires, socio-economic data is collected in addition to the smart city aspirations of the individuals. Focus groups are a powerful tool to decide on smart cities in terms of public policies. The research can cover the aspects discussed in Table 1.

Table 1. Smart City Broad Parameters (European Smart Cities TU Delft)

S.No	Broad Parameter	Sub Parameter
1	Smart People	Qualification Level
		Inquisitiveness
		ethnic, social state
		tractability
		creativeness
		Open-mindedness
		Public Life Participation
2	Smart Mobility	Accessibility to Local
		Global Access
		Connectivity
		Eco-transport
3	Smart Environment	Scenery
		Contamination
		Conservation
		Resourcefulness
4	Smart Living	Amenities
		Well-being
		Security
		Liveability
		Academic Facilities
		Tourist Attraction
		Social Unity
5	Smart Economy	inventiveness
		Business Ownership
		Trademarks and the economy Efficiency
		The labor market's flexibility and international
		embeddedness
		Capacity to Change
6	Smart Governance	Taking part in the making of decisions

		Social and public services
		Open-minded leadership
		Political stances and tactics

The researcher has collected documents from smart city officials and studied them for this paper.

The researcher collected data from 4 cities at 11°N latitude: Coimbatore, Salem, Erode, and Tiruppur. Each of these Tier 2 cities has a different climate and geography. While Coimbatore is regarded as the Manchester of South India, Salem is famous for steel and aluminum, Erode is famous for agriculture and dairy, and Tiruppur is a textile hub.

Nodal officers of the Smart City Projects in each of these cities provided data.

TUFIDCO also shared data related to the Government of India ranking of these cities.

The key search terms used are “Smart Cities Mission” (SCM), “Erode Smart City," “Salem Smart City," “Coimbatore Smart City," “Tiruppur Smart City,” and “Smart Cities in India." For the literature review, the keyword “smart cities in India IoT” was used.

3. Review of Literature

Several international papers have been referred to with respect to IoT and sustainable smart cities.

In a typical Internet of Things (IoT) ecosystem, myriad miniature chips and devices compose interconnected systems, generating vast data. These data interact, delivering services to users, as described by Ahad. [3].

All aspects of maintenance, logistics, transportation, agriculture, governance, healthcare, and education are automated in some way and can be accessed, controlled, and managed remotely with the aid of smart devices thanks to the new technology known as the Internet of Things (IoTs), which can be incorporated into daily processes. This has resulted in the emergence of smart ecosystems, as per [4].

Smart devices have given rise to the notion of smart cities, where information, communication, and technology (ICT) converge with conventional infrastructure, all managed and coordinated through digital technology. The author has proposed various frameworks for crafting efficient smart cities. [4].

Ridhawi proposes a Mobile Edge Computing (MEC) solution facilitating node collaboration among IoT devices. This solution ensures dependable and secure communication between the fog layer and the cloud layer, as well as between devices and the fog layer [5].

Chatterjee et al.[6] suggest that cities integrate IoT with Artificial Intelligence (AI) in 'Smart Machines' to mimic intelligent behavior and make dependable, precise decisions autonomously, without human intervention

Sharma's study [7] highlights various challenges within smart city waste management concerning IoT implementation, including financial viability and operational expenses. These challenges encompass issues such as mobility constraints, transparency concerns, inadequate IT infrastructure, internet connectivity issues, as well as privacy and security risks. Additionally, there's a noted gap in technical expertise among policymakers.

Devi's research [8] suggests that population growth correlates with a rise in waste production, affecting both public health and the environment. Urbanization, industrialization, and economic expansion are identified as primary drivers behind this waste generation.

Chatterjee [9] asserts that planners in Smart Cities in India must prioritize the safety of IoT-enabled devices. Ensuring the safety and security of these devices relies significantly on the ethical awareness of stakeholders. Therefore, practitioners should earnestly encourage stakeholders to enhance their ethical consciousness, thus safeguarding IoT-enabled device safety.

Sarin [10] states that it will be feasible to select data access for the purpose of creating a multitude of digital services and interact openly and easily with a great number of heterogeneous and homogenous systems.

The goal of establishing Smart Cities in India will be greatly aided by the usage of IoT technologies, claim Mishra et al. [11].

According to research by Jabbar et al. [12], India's economy is predicted to expand five times by 2030. For India, smart cities are essential. Smart cities incorporate IoTs.

According to Vijai [13], machine learning techniques can be applied to various elements of smart city management, such as smart water management, which involves forecasting and anomaly detection and monitoring of water consumption.

Ahmed [14] asserts that ICT must be embedded, encompassing ubiquity in digital communication networks, embedded intelligence, actuators, sensors, and various software that may act intelligently, accomplish various tasks, and enable various objects to communicate with one another.

Citizens are also expected to use Internet of Things (IoT) enabled gadgets, which will generate massive amounts of data (Big Data) that need to be protected, according to a study by Chatterjee [15]. Businesses must employ preventive technologies effectively in addition to human labor.

According to Ahmed [16], because different residents have access to diverse infrastructures, there are several IoT concerns in smart cities, including as security and privacy. Citizens may thus be vulnerable to various kinds of attacks as a result. Additionally, the government's most important records are susceptible to various attacks, privacy breaches, and other issues. Thus, it must be addressed concurrently with the development of smart cities in order to prevent multi-tenancy risks.

4. Discussion

The Department of Electronics and Information Technology (DeitY) came up with a strategy to develop connected and smart IoT devices and systems for the cities' overall needs through the 100 Smart Cities Project. "Smart Cities" soon became "Smart Sustainable Cities," with an emphasis on climate and a circular economy where all products in the system are recycled and reused.

These smart cities prioritize the beautification of urban public spaces and riverfronts through urban Design. Free Wi-fi facilities are offered in these areas. There are lakefront developments and happy streets projects.

Also, there is a need for sustainable growth. Whatever environmental resources are present today, we must give them intact to the future generation. Only then can we develop smart, sustainable cities. In this context, we must educate children about the choices that they need to make in order to sustain cities for the future.

The Coimbatore Smart City project encompassed a comprehensive array of initiatives aimed at enhancing urban livability and sustainability. This included significant efforts towards the improvement of lakefronts, with the rejuvenation and restoration of 8 lakes across the city. Additionally, the project focused on promoting sustainable modes of transportation, such as pedestrianization and the introduction of e-bikes, to reduce reliance on motor vehicles and alleviate traffic congestion. Furthermore, innovative programs like Happy Streets were launched to encourage community engagement and promote healthy lifestyles. Non-motorized transport infrastructure was strategically implemented in key areas to provide accessible and eco-friendly mobility options for residents and visitors alike. The project also saw the establishment of essential facilities such as a Smart City Experience Center, an Integrated Command and Control Center, and a Knowledge and Study Center, all aimed at fostering innovation, collaboration, and informed decision-making for the city's sustainable development.

Salem Smart City embarked on a series of ambitious projects aimed at enhancing infrastructure and services across the city. These initiatives included the installation of an escalator and the incorporation of crucial safety features such as fire fighting systems, CCTV surveillance, and a public announcement system as part of the redevelopment of the old bus stand. Furthermore, efforts were made to upgrade facilities at Nehru Kalaiarangam, including the installation of HVAC systems, electrical amenities, fire fighting equipment, and interior improvements. At VOC Market, essential infrastructure like R.O. Plants, DG Sets, and goods lifts were implemented to improve functionality. The city also undertook extensive road restoration projects necessitated by the Underground Sewerage System and Water Supply Scheme. Pallapatty Lake underwent development and beautification efforts, while Smart Road initiatives were introduced to enhance urban mobility. Additionally, construction projects included the establishment of an Overhead Tank to ensure round-the-clock water supply to Swaminathapuram and the implementation of bio-capping for the existing Erumapalayam dumping yard. Redevelopment efforts extended to Bose Maidan, and steps were taken to

harness solar energy with the installation of a solar power plant. Through these multifaceted endeavors, Salem Smart City aimed to improve the quality of life for its residents while fostering sustainable development. Tiruppur Smart City worked on the following projects: Design and construction of a Sewage Treatment Plant (STP) of capacity 4MLD, River front development, Construction of convention centre, redevelopment of daily market, water supply and internal plumbing.

Erode Smart City presented a multitude of projects, showcasing its commitment to urban development and innovation. Among the notable initiatives were the implementation of smart roads, the establishment of a solid waste management (SWM) incineration plant, and improvement works around the Erode bus terminal. Additionally, efforts were directed towards the development of Perumpallam Odai, enhancements around the Vegetable Market, and the provision of Underground Sewerage System (UGSS) infrastructure. Through these diverse projects, Erode Smart City aimed to address key urban challenges while promoting sustainable growth and improving the quality of life for its residentsMost of these projects involve wireless technologies and sensors. A simple street lighting project has solar panels on the roof of the lamp. It can be controlled using a device to switch itself off during the day while it is charging and switch on at night. Additionally, if there is no one on the street, the lights will dim. A camera can also be mounted on the street lamp for surveillance.

Other projects in these the cities included street art, solar parks, housing for all, place making in parks, Building Permission Management System (BPMS), lake promenades, Smart LED Energy Efficient Lamps, Multi-Level Car Parking, Biomining, etc.

Traditional methods such as parking in empty lots and monitoring speeding vehicles have been modernized with the integration of technology. Sensors now identify vacant parking spaces, while cameras can accurately record the speed of vehicles. These modern technologies are currently operational in many Indian cities. Additionally, improvements have been made in administrative processes, with services like online payment of property tax and water tax now available.

"Other projects under Smart cities involve the dissemination of information and real-time updates on various aspects such as pollution levels, traffic patterns, available services, and parking spaces. Electronic systems are designed to sense and respond to citizens' concerns regarding city infrastructure issues. In this way, Smart cities actively engage with and impact the lives of their residents on a personal level.".

5. Case Study of Masdar

Masdar is located in Abu Dhabi, U.A.E. has an area of 700 ha; it is designed for a population of 50,000 residents. In addition, 50,000 people commute to Masdar every day from neighbouring areas. Masdar has desert climate. It is a smart sustainable city modelled on the Internet of Things blending Internet and Communication Technology for better citizen services and standard of living. IoT detects snags in equipment and fixes machines remotely, modifies indoor temperatures and switches off unnecessary lights in homes, and provides commuters with information on traffic jams as they occur.

Masdar smart city is the deployment of entirely automated IoT devices like RFID (Radio Frequency Identification), actuators, and sensors with a communicational interface and computational capability connected to the internet with many networking protocols for overall smartness. Internet protocols such as IPv6, HTTP, and UDP/TCP help interact with devices such as washing machine, refrigerator, air conditioner, and other electronic equipment. These equipments can be regulated or switched off remotely. Internet protocols like HART, ZigBee, and Z-wave are used to communicate with non-electronic things such as food, clothing, furniture etc.

6. Ranking of Some of the Cities in Tamil Nadu

Table 2 indicates some of the smart city rankings along with compliance factors.

Table 2. Smart City Rankings of Some Cities in Tamil Nadu

Overall Rank	Name	SCM	Non-SCM Work	Funds Utilization	Last month Expenditure	NIP	OOMF	SCAF	TULIP
37	Coimbatore	156.89	1.15	40	20	0	0	5	6
34	Erode	138.13	35.14	40	20	0	0	0	0
18	Madurai	179.94	60	40	20	5	0	0	2
27	Salem	141.46	56.93	40	20	5	5	0	10
22	Tiruppur	139.33	60	40	20	0	0	0	4

Coimbatore ranks 37th, Erode 34th, Madurai 18th, Salem 27th and Tiruppur 22nd. There is some confusion with respect to Salem and Tiruppur. As Tiruppur has a smaller area, even though its score is less, it has a higher rank. Madurai has completed all its smart city projects on time. This ranking is out of 350 marks. Details are provided in Table 3.

Table 3. Terms used in Ranking

Term	Expansion
SCM	Smart City Mission
NIP	National Infrastructure Pipeline
OOMF	Output Outcome Monitoring Framework
SCAF	Smart City Advisory Forum
TULIP	The Urban Learning Internship Program

7. Disadvantages When Using IoTs in Smart Cities

The citizens churn out chunks of real time data for the smart city and this data analysis is in turn made available for the citizens to use to take decisions say for example in manoeuvring through a traffic jam due to a sudden procession or a flash mob. Some of the data collected in certain situations involves confidentiality to protect the citizens' privacy. This issue came up during the collection of data for smart Aadhaar cards.

Also, a disclaimer was announced by banks that they do not ask for passwords from their account holders. Internet safety issues need to be addressed. Educating the public through campaigns for example about false QR (quick-response) codes and scamming can help ensure a safe experience.

For the COVID app, Arogya Sethu, citizen data was anonymized and then used, in order to protect citizen privacy.

8. Status of Smart Cities Today and Challenges of IoTs in Smart Cities

According to Nallapaneni et al [17], The Smart Cities Mission's deadline is approaching in June 2024. All cities had created special purpose vehicles to undertake both pan city and

area-based development projects in city improvement (retrofitting), city renewal (redevelopment), and city extension (green field development). Smart cities are also ranked by the Government of India frequently.

As on 2023, of the 100 smart cities, 32 smart cities have exceeded expectations by completing more projects than planned. However 68 smart cities have yet to meet the targets set. Meghalaya has not completed any project so far.

The Ministry of Housing and Urban Affairs has set up the Climate Centre for Cities (C-Cube) to drive climate action in Indian cities under the stewardship of NIUA18. The five broad categories of smart cities are air pollution and mobility; water resource management; waste management; energy and green buildings; and urban planning, development, green cover and biodiversity. The scores of the cities were found to be the lowest in water resource management.

Basically, cities hesitate to use IoTs as they are technically challenged. The Government must not only invest in technology but also training.

The challenges faced by smart cities are lack of smart leadership and vision by urban local bodies, lack of technical knowledge and emergent new technologies, lack of awareness of urban design as a discipline, lack of financial investments, lack of citizens' participation in smart city projects and etc.

9. Conclusion

Cities are moulded through experiments. While some experiments fail miserably, others are successful. Smart Cities must try to use advanced technologies for smarter people to benefit from the systems and processes. E-governance is online governance and is the way forward for future cities. Smart cities must be climate and environment conscious. Thus, all buildings should be LEED certified. Net Zero buildings are also encouraged.

As far as data is concerned, India has enormous potential in crowd sourcing as it is a vibrant democracy. Social media and text messaging through platforms like Twitter along with geo-tags are the way to the future.

COVID 19 saw many people work from home jobs and overnight the socio-economic situation became online. Video conferencing can reduce time wasted in travel. Online shopping leaves traces which can be used as data especially for consumer behaviour.

Indian Cities must leverage IoTs in different walks of life. Cities must upgrade their technology and harness the creative human capital to the best advantage for these cities to flourish economically.

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Author's biography

Maya Mohan completed her B.Arch from SRMEC, University of Madras, in 1998 and M.Arch from School of Architecture & Planning, Anna University, in 2000. She was a Principal of Nehru School of Architecture and has been an active and passionate researcher since 2012. Currently, she is pursuing her PhD at the Department of Architecture, Bharath Institute of Higher Education & Research. Her research interests include Smart Cities, Sustainable Urban Forms and Symbolism in Hindu and Buddhist Architecture.

Dr.Hemapriya Mani completed her B.E. and M.E from Sathyabama University, Chennai, and further completed PhD & received Doctorate in the year 2022 from Bharath Institute of Higher Education and Research. Her area of research is about strengthening of RC beams with Hybrid FRP wraps. Has published around 20 papers in the indexed journals. She has completed 8 NPTEL courses and received NPTEL discipline star for the year 2023. She is a research supervisor and guiding around 8 PhD scholars in the discipline of Civil and Architecture.