ICT and Digital Technology based Solutions for Smart City Challenges and Opportunities

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ABSTRACT

Purpose: *Today's Smart Cities are rapidly evolving with the help of the latest tools and technologies and also due to large investment and priority focus by various countries across the globe. Smart Cities while growing also consider the environmental aspects such as producing lower carbon footprint, lower harmful gas emissions, and lower consumption of power. Abiding by this new paradigm, various Smart Cities started focusing on continuous improvement and innovation in their different services. Many Smart Cities have their own pain points such as traffic congestion, water scarcity, energy deficiency, waste management, poor participation of citizens in city administration, maintenance of complex IT Infrastructure, and so on. Such kind of issues may differ in scale and type but mostly common across geographies. While developing, operating, and maintaining Smart Cities, it is necessary to identify the most pressing and urgent issues that Smart City solutions must tackle on priority. In such cases, high-end technologies and tools can help to focus and eliminate the problems. In this paper, we analysed key challenges faced by Smart Cities during the development, operation, and maintenance related activities of various Smart Services and how these challenges and issues are effectively addressed by some of the key technologies with special attention to ICT and digital technologies. We have also reviewed some selected research papers devoted to Smart Cities challenges ad issues and how these issues are addressed using the latest tools and technologies. Finally, we have also specified the future plans about the discussed technical solutions to undertake its full-fledged implementation and addressing of its some of the limitations.*

Design/Methodology/Approach: *This paper is based on the primary data collected while preparing research papers written by us on Smart Cities and a systematic literature review of existing literature including journal research papers, book chapters, dedicated websites, and white papers.*

Findings/Result: *Smart Cities various operational and development challenges are effectively get addressed using various ICT and digital technologies. Some of the key technologies that played an important role in addressing some of the key concerns of Smart Cities include IoT, AI and ML, Blockchain, Data Analytics, Digital Twin, 5G, and Cloud Computing.*

Originality/Value: *The Information presented in this paper is genuine and original and based on own research, data collected from industry professionals, systematic literature review of existing relevant research papers, and relevant data analysis and findings. Most of the information presented in this paper is derived from our own research papers written on Smart City services and solutions.*

Paper Type: *Technology oriented Research*

Keywords: Smart City, IoT, ICT, Analytics, Blockchain, 5G, Big Data

1. INTRODUCTION :

Cities are considered engines of growth for the economy of every country. With growing urbanization, urban areas are expected to accommodate 40% of India's population and can nearly contribute 75% of India's GDP by 2030. [1]. Such impressive growth prospects have fuelled demand and growth for Smart Cities. Setting up a smart city, can't happen overnight. Transforming any city into Smart City or building new smart cities requires careful planning, preparation and a good strategy with a well-documented design framework and necessary approvals from all administrative levels. Refer figure 1 which has presented portfolio of Smart Services offered by Smart Cities and also, the selected technologies used by them. The European council has set certain climate and energy goals to be fulfilled by Smart Cities for 2030 [2], these goals are also presented in the figure 1.

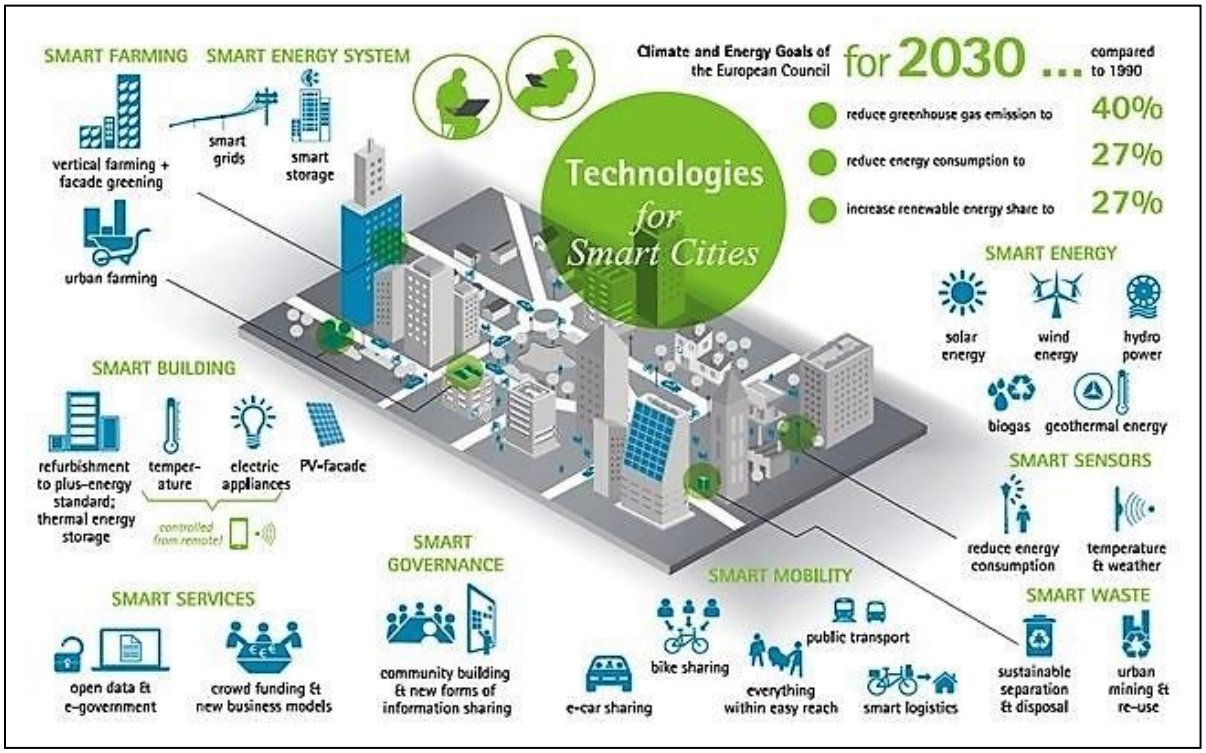

Fig. 1: Smart Cities Smart Services and the Technologies for Smart Cities [2]

Smart Cities requires comprehensive development of social, economic, institutional, and physical infrastructure. All such developments are important and assist in improving the quality of life and attracting investments and people to the Smart Cities. Smart Cities focus on sustainable and inclusive development and better quality of life for their residents by ensuring the following.

- Efficient urban mobility and public transport
- Adequate water supply
- Assured regulated power supply
- Smart and affordable buildings and housing for all the residents
- Robust IT connectivity and digitalization
- Safety and security of citizens, particularly women, children, and the elderly
- Secure online transactions
- Affordable and advanced medical facilities in person and remote for all
- Assured education to all the students in class as well as distance and online
- Good governance, especially e-governance and citizen participation
- Sanitation, including solid waste management

As stated above, Smart Cities offers a lot of facilities and benefits to its residents, but Smart Cities also faces various challenges and issues while offering better services to its stakeholders [3]. Over-urbanization and accommodating the expanding population are putting pressure on the environment and natural resources. Besides this, Smart Cities also face issues related to traffic congestion, scarcity

of water and energies, data privacy concerns of residents, security concerns related to online transactions, climate change, air pollution, etc. Such kind of challenges demands new and smart solutions in infrastructure. Smart Cities thus not only cater to the present needs as well as to adapt to the uncertain future requirements.

2. PROBLEM STATEMENT :

Various new Smart Cities are getting set up across the globe and existing Smart Cities are also evolving rapidly. It is well known fact that Smart Cities are effectively making use of the latest tools and technologies for solving real life challenges faced while developing, operating, and maintaining Smart Cities. Enough number of research papers and literature is there to cover Smart Cities problems and effective solutions, but it is observed that most of the research papers and literature have focused on the individual problem statement and a particular solution based on a specific technology, but there are hardly any research papers who have provided details of the list of problems faced by Smart Cities and portfolio of tools and technologies used by Smart Cities to solve the multidisciplinary issues. In this Research paper, an attempt is made to cover multiple real-life problems faced by Smart Cities and various ICT and Digital technology-based tools and solutions used in Smart Cities to address these problems. We hope that this paper can serve as an excellent reference to Smart City researchers and stakeholders to get relevant information on multiple tools and technologies used to solve Smart Cities problems, in one place.

3. RESEARCH OBJECTIVES :

The Smart Cities domain is very vast and based on a wide variety of tools and technologies for the development, operation, and maintenance of Smart Cities. Covering information of all the tools and technologies used by Smart Cities in addressing their concerns, cannot be possible due to limited available time in hand and budget constraints. Keeping these limitations in mind, the Research paper is limited to the following broad objectives.

- List various issues and challenges faced by Smart Cities during development, operation, and day to day maintenance activities
- Provide details of ICT and Digital Technology based tools and solutions to address selected identified issues and challenges faced by Smart Cities
- Provide details of improvement opportunities and deficiencies if any in the identified tools and technologies used in addressing multiple problems faced by Smart Cities
- Discuss the way forward and future technology trends in the Smart Cities domain

4. METHODOLOGY :

This research paper is based on the primary data gathered over the period of time while preparing multiple research papers specifically on following broad areas and the secondary data collected based on the extensive literature review carried out for selected research papers while collecting the relevant facts and figures on these subjects.

- Smart Cities Smart Services and portfolio of technologies
- Smart Traffic Management in Smart Cities
- Smart Water Management in Smart Cities
- Smart Waste Management in Smart Cities
- Smart Lighting System in Smart Cities
- Smart Parking System in Smart Cities
- Disruptive Technologies for Efficient and Sustainable Smart Cities
- Smart Cities battle with Covid-19 pandemic

Further, the concluded facts based on the collected and generated research data are provided with the help of consolidated facts and findings. The way ahead in the future is also briefly discussed to let the researchers know the future plans.

5. RELATED WORKS :

Smart Cities is a new domain where a lot of research is happening. A lot of issues and challenges faced by Smart Cities are addressed by new tools and technologies. Smart Cities with the help of the latest

tools, technologies, and frameworks are rapidly evolving. Many Smart City researchers have developed new frameworks to classify and address various challenges faced by Smart Cities. In this section, we have reviewed selected research papers and tried to understand the key issues and concerns of Smart City initiatives and how they are addressed.

Zakaria, N., & A., J. in their paper, "Smart City Architecture: Vision and Challenges", elaborated Smart City Architecture based on ICT considering challenges related to Smart Services relevant huge data collection, storage, retrieval, and efficient provisioning of network resources [4]. The authors have proposed a Smart City framework based on a hierarchical data storage model with a clear definition of stakeholder communication and citizen services offerings. The paper has suggested zone-level architecture to deal with water and waste management, electricity management using wireless sensors. The authors have argued that their proposed architecture for Smart Cities shares information departments wise as well as third parties through an open data model. Authors have recommended that Smart City stakeholders should be facilitated with cross-application services.

Andres M. in his paper, "Smart cities concept and challenges: Bases for the assessment of smart city projects" has discussed in detail various challenges faced by Smart Cities. The author has proposed a tool based on the Smart City assessment Project guide for the implementation of efficient Smart Cities to effectively meet the diverse urban challenges without compromising the quality of life of their citizens [5]. The author has clarified that ICT-based solutions can result in potential Smart Cities, however, such solutions must be deployed considering Smart Cities requirements. The author has also confirmed that the Smart Cities development strategies must be run and based on various stakeholder municipally based partnerships and Smart City solutions must be applied with inclusive approaches.

Sameer H. et al., in their paper, Smart City Operations: Modelling Challenges and Opportunities, elaborated various challenges of Smart Cities and also discussed recent developments in Smart City initiatives. Authors have categorized these challenges into three themes namely end-user utility, data access and collection, and economic viability of various solutions [6]. Authors has highlighted following stated challenges of Smart Cities.

- How Smart City Citizens can be encouraged to contribute to Smart City efforts?
- How Smart City Solutions can be built using effective data governance and operating models that can balance privacy rights and data access assurance of end-users?
- How can adaptive operational policies be designed using real-time data and dynamic deployment of resources?
- How can end-user behaviour be updated to ensure maximizing social surplus?

Authors have also given importance to relevant academic literature and feel that it will help to address these challenges. Authors also believe that the Smart City challenges will need a multi-disciplinary analytical approach to solve them.

Belli L. et al., in their paper, IoT-Enabled Smart Sustainable Cities: Challenges and Approaches, have recommended the integration of IoT and ICT into city management to address exponential growth of Smart Cities and to improve quality of life of City residents. Authors have analysed in this paper the key aspects of IoT Infrastructure for Smart Cities, with a specific focus to smart urban mobility [7]. Authors have also proposed taxonomy indicators used to decide smartness level of a municipality. Authors have also systematically identified various challenges faced by Smart Cities specifically with respect to Mobility, Governance, Environment and Smart City Citizens. Authors have also claimed that Smart City residents can greatly benefit from the adoption of IoT-oriented solutions in the urban context, and it can help to improve the quality of life of Citizens.

Paul Pierece and Bo Anderson in their paper, "Challenges with smart cities initiatives – A municipal decision makers' perspective" have explained in detail the challenges in Smart City initiatives from the point of view of municipal decision-makers. Authors have developed a framework based on existing literature and tried to validate it with municipal decision-makers [8]. Authors systematically identified various challenges related to Smart Cities and categorized them into 2 classes as nontechnical and technical. The identified challenges were mainly as follows.

Non-Technical Challenges:

- Issues with respect to collaboration with external stakeholders
- Limited funds,
- formulating the right governance
- Political interference
- Influence of geographical variables

Technical Challenges:

- Information and data security,
- Issues with respect to interoperability of services
- Privacy-related issues

Authors have also clarified and concluded that municipal decision-makers are mainly influenced by nontechnical challenges however the technical challenge such as Information and data security is not considered as a challenge.

Table 1: Summary of reviewed literature

Sr. No.	Summary	Focus	Reference
01	The paper has specified key ICT challenges related to Smart City adaptation and also highlights importance of effective data collection, storage, retrieval, and provisioning of network resources.	Framework based on a hierarchical model of data storage that defines how various stakeholders can communicate and offer various services to Smart City Citizens	Zakaria, N., & A., J. (2015). [4]
02	In this paper various challenges faced by Smart Cities such as Energy scarcity, environmental issues, water scarcity, rapid urbanisation, pollution related issues etc have been discussed with their resolution.	A selection of Smart City initiatives in order to establish relations between the identified Smart City challenges and real Smart City Projects designed to address these challenges	Andres M. (2015). [5]
03	Smart City challenges can be addressed with a multidisciplinary analytical approach and also with the help of academic literature	Classification of Smart City challenges in 3 categories i.e., data access and collection, end-user utility, and economic viability of different solutions.	Sameer H., Zuo-Jun Max Shen, et al., (2020). [6]
04	Smart Cities issues specifically with respect to exponential growth of urbanization and population and in order to improve the Smart City resident's quality of life, integration of IoT and ICT is necessary for Smart City management.	Key aspects of an IoT infrastructure for smart cities with special attention to smart urban mobility	Belli L., et al. (2020). [7]
05	Key challenges of Smart Cities were identified and classified into Technical and Non-Technical Issues. The key challenge was identified with respect to Collaboration between Internal and external stakeholders.	A framework based on existing literature and validating it with municipal decision makers to address key challenges of Smart Cities	Paul P. and Bo A. (2017). [8]

6. SMART CITY CHALLENGES AND SOLUTIONS :

In order to ensure a better quality of life for its residents, Smart Cities employs various Smart Services for its citizens. However, increasing population, limited natural resources, budget constraints, and scarcity of skilled manpower posed various challenges in front of Smart Cities while operating and maintaining its services.

Refer figure 2 which has presented various broad categories of challenges Smart Cities are facing from a quite long time. These identified challenges are related to following services of Smart Cities

1) Mobility
2) Lighting and Energy
3) Public Administration Services
4) Infrastructure Management
5) Information Management
6) Waste Management
7) Water Management

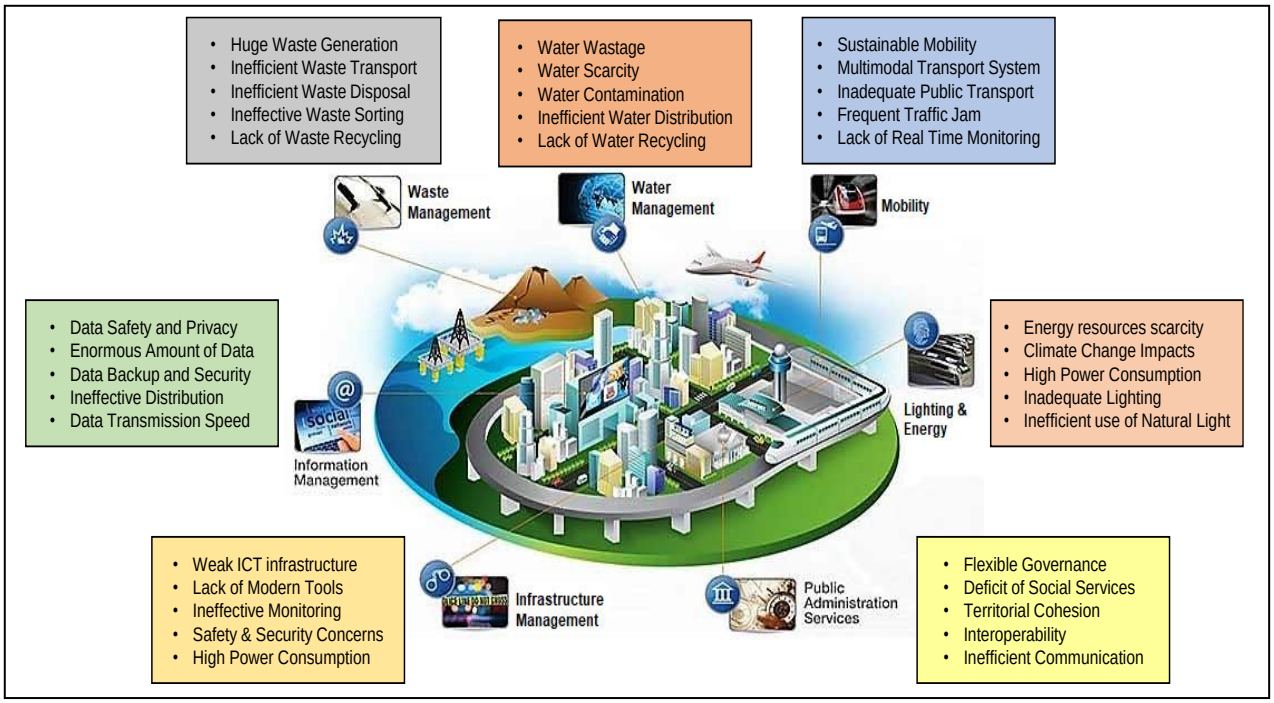

Fig. 2: Smart City Infrastructure, Challenges and Solutions

6.1 Mobility:

Exponential growth in population, affordable 2 wheelers and 4 Wheelers and urgency in reaching to destinations has made owning of 2 wheelers and 4 wheelers a necessity. Though the number of vehicles plying on road has got exponentially increased, in most of the cases road infrastructure has not improved at the same pace. Also, more and more people have started using personal vehicles instead of using public transport, this has increased traffic jams and also stressed the road and transportation infrastructure of Smart Cities to a significant extent. This has posed some of the following challenges in most of the Smart Cities.

- Sustainable Mobility
- Multimodal Transport System
- Inadequate Public Transport
- Frequent Traffic Jam
- Lack of Real Time Monitoring

These challenges are part of the rapidly upgrading landscape of urban mobility as seen by Smart City Planners. Smart City Mobility related challenges are mostly unique to each Smart City and mostly depend upon City road and transportation infrastructure, available land for roads, tunnels and rail tracks expansions, and Smart City layouts. Some of unique strategies to solve the urban mobility problems can involve following

- Implementing promotional policies to adhere to air quality standards and quality of life measures

- Promoting public-private partnership to improve overall transportation infrastructure including traffic monitoring, parking facilities, toll collections, bus stands, etc.
- Facilitate knowledge collaboration among Smart City professionals, researchers, government officers to promote building sustainable infrastructure to support innovative mobility solutions
- Designing and implementing safe and secure public transportation systems and integration with mobility as a service and other third-party platform

To comply with the above stated strategies and to effectively address most of the mobility related challenges, Smart Cities now a days started using STMS (Smart Traffic Management System). Though the name suggests STMS relationship mainly with managing traffic smartly, however STMS doesn't limit itself just to traffic management. Latest STMSs are also effectively carry out other specific functions such as

- Incident Management
- Roadside Assistance
- Traffic Control and Monitoring
- Emergency Management
- Electronic Toll Collection
- Crash Prevention and Safety
- Route Optimization and traffic diversion information

One of the STMSs iSMART is an example of the latest Smart Traffic Management System, which is based on Client-Server Architecture, IoT-based smart sensors, Image Processing, Secure Communication, and Encrypted Database [9]. iSMART facilitates secure access to iSMART Server and provides all the up-to-date details of real traffic situations geography-wise, including accident and disaster management data. Systems such as iSMART facilitate Smart City planners and Smart Traffic Management Service stakeholders to a significant extent to address the Smart City mobility challenges effectively and smoothly.

6.2 Lighting and Energy:

Around 65% of available energy in the world gets consumed by major metropolitan and smart cities, primarily to supply energy for heating, cooling, ventilation, lighting, and transportation. And these cities are responsible for around 70% of greenhouse gas emissions [10]. Smart Cities lighting needs is comparatively far more than typical urban cities. It should be noted that almost 50% of energy in Smart Cities is consumed by streetlights. Apart from Street Lights, there are lot of other places in Smart Cities such as Lawns, Smart Buildings, Residential Complex, Smart Factories, Restaurants and Entertainment Parks, which needs Lighting most of the time. To provide uninterrupted and clean power along with better lighting is not an easy task. From power and lighting perspective, some of the big challenges in front of Smart Cities are as follows

- Energy resources scarcity
- Climate Change Impacts
- High Power Consumption
- Inadequate Lighting
- Inefficient use of Natural Light

To systematically address the above listed challenges, many innovative ideas have been proposed by Smart City researchers, professionals, and consultants. Smart City planners and policy makers have proposed following key points to consider while setting up, operate and maintain Smart Cities.

- Maximize usage of renewable energy sources such as wind turbines, water-driven generators, solar power, photovoltaics, biogas, geothermal to produce heat, hydrogen, and methane production, etc.
- Maximize usage of energy-efficient lighting devices such as LED Lights, IoT based Smart Sensors in Lighting Systems
- Promote and ensure maximum energy efficient Smart Buildings using integrated photovoltaic, thermal, and Solar power-driven systems, use of Smart Meters, well-insulated building, and windows

- Promote Smart energy-saving Networking and IT Infrastructure, HVAC Systems, Industry control systems, and Lighting systems
- Develop hybrid micro-networks considering the possibility of integrating DC current networks
- Develop cost-effective and efficient solutions for storing heat and electricity for the specified duration
- Promote developing industrialized processes to improve standardization and recycling technologies and products to reduce costs and environmental footprint

Most of the above stated key considerations can be easily fulfilled by using Smart Lighting System. In fact, considering significant energy saving and maximum lighting efficiency, many of the Smart Cities have made Smart Lighting Service is an essential service based on Smart Lighting System. One of such systems is iLIGHT which is based on Smart IoT Sensors, Secured Communication, Distributed Control System, Cloud Computing Technology and Embedded Firmware based control units [11]. Using iLIGHT, Smart Cities can achieve following benefits

- Automatic, Scheduled, and Manual control of Lighting
- Instant brightness/lumination control
- Lighting Control based on Seasonal variations and environmental conditions rain, fog, humid, high temperature
- Energy-efficient Lighting Devices and Control Circuits
- Real-Time Alerts and Notifications
- Detailed data analysis and reports including data with respect to the power consumed, power saved, power requirements, peak power details, outage details, maintenance schedule, etc.
- Lighting control considering maximum utilization of natural light
- Predictions and detections related to lighting failures, lighting maintenance requirements, light wastage, etc.

6.3 Public Administration Services:

Public Admin Service is one of the important Smart Services of Smart Cities and responsible for directly influencing Smart City stakeholder's satisfaction for the entire administration, operation and maintenance related activities conducted in Smart Cities. Public Administration Service in Smart Cities aims to bring transparency in operation and keeps Smart City residents and stakeholders more informed [12]. Hence, the biggest issue for admin service is to ensure that right to information is truly available with its all the stakeholders and information should not remain just accessible with few officers and government representative. From public administration point of view following are some of the critical challenges Smart Cities have

- Deficit of Social Services
- Territorial Cohesion
- Political Interference
- Interoperability
- Inefficient Communication
- Transparency and Citizen Participation

The above stated challenges can be systematically addressed by employing certain policies and frameworks in day-to-day administration activities of Smart Cities. Selected such policies and strategies are as follows

- Promoting employing Collaboration Platform to bring admin staff and stakeholders and users of Smart City together
- Maximizing relevant training programs to Admin Staff on regular basis
- Facility to collect and analyse service relevant feedback from its users on regular basis
- Promote SLA driven service execution to ensure timely delivery of Service
- Develop, and Formalize policies to build the liability of decisions made
- Introduce policies, programs, and schemes to promote private and public collaboration.
- Promote legislation and policies to facilitate better growth of smart administration

Now a days, many of the ICT based Application Software and Online Services are available to effectively deal almost all the above stated challenges and issues faced by Public Administration Service of Smart Cities. One of the most sought-after ICT Software services is Smart Governance, which is based on technologies such as Cloud Computing, AI, IoT, Blockchain, Server Client based running with existing IT Infrastructure [13]. Using Smart Governance Service, Smart Cities can ensure following benefits

- Promotes local and democratic practices through public participation and consultation.
- Facilitates open, collaborative, and citizen-centric forms of governance
- Data driven and evidence-based policy framework
- Provides better information and service delivery
- Promotes SLA driven service delivery
- Facilitates alerts, notifications, and progress related information for the delivered service
- Compliance to Information Security, Online Service Delivery, access over mobile
- Promotes financial and social inclusion of all the stakeholders at wider scale

6.4 Infrastructure Management:

Smart Cities uses high-tech tools, sensors, and technologies to deliver various smart services. To deploy the tools and software solutions, Smart Cities uses complex and costly IT Infrastructure containing Servers, Clients, Display Monitors, Networking equipment such as switches, routers, firewalls, networking cables, Wi-Fi modems, mobile transmission-reception towers, and so on [14]. All these infrastructure equipment needs regular maintenance and servicing. There may be a limited budget for new infrastructure projects and approval processes may take a longer duration. Many Cities which are now transforming into Smart Cities are already challenged with replacing obsolete and old infrastructure such as underground low-speed cables, power lines, transportation tunnels, etc. Managing such a dense and complex, IT and Networking infrastructure is a difficult job and definitely poses lots of issues in front of Smart Cities. Infrastructure Management poses following selected challenges for Smart Cities.

- Weak ICT Infrastructure
- Supplying Clean and Uninterrupted Power
- Ineffective Monitoring
- Safety & Security Concerns
- High Power Consumption
- Budget Constraints

It is understood and agreed by many stakeholders that Infrastructure Management is challenging and will remain so while upgrading and expanding the existing Smart Services or while introducing new Smart Services. Though it is difficult to completely rule out key issues in infrastructure management, it is certainly possible to reduce the number of challenges to a significant extent through employing certain policies and strategies as follows

- Keeping reserve budget for expansion activities every year so that separate further approval is not needed
- Maximizing the use of secure high-speed wireless communication infrastructure wherever possible to ensure fast speed communication and avoid communication cabling
- Promoting SLA driven IT Services to ensure IT Maintenance activities are completed within the defined time limit
- Facilitate use of collaboration platform to ensure collaborating all the stakeholders together while operating and maintaining Infrastructure of Smart Cities
- Promote auditing of IT Infrastructure on regular basis, this will ensure infrastructure is up and taken care of without fail
- Promote the use of regulated renewable energy sources wherever possible for powering Infrastructure

The above stated challenges can be easily addressed by some of the infrastructure management software as well as some standard collaboration platforms based on ICT. There are many Smart Infrastructure Management Software available in the market which can be deployed on premises or

cloud based. These software are easily configurable and can be used and customised to meet the specific need. The Smart Infra management solutions are normally based on technologies including but not limited to Client Server architecture, IoT, AI and ML, Blockchain, Cloud Computing, and Digital Twins. Smart Infrastructure Management Solutions offers following benefits

- Storage, Hardware, Software, and Application Software and Server Management
- 24x7 Monitoring
- Automatic Alerts and Notifications either over Email and or Mobile Phone
- Events logging for offline record and auditing purpose
- Cybersecurity compliant, safe, and secure to operate
- Smart and user-configurable dashboard
- Efficient Analysis, Planning, and Documentation
- Backup of all and user-configurable data
- Order and request management
- SLA driven service management
- Easily integrates with existing IT Services of Smart Cities
- Integrated License Management
- Provides better information and service delivery

6.5 Information Management:

Information management is a backbone of Smart City and plays a crucial role while delivering any Smart Service with the optimum performance. While dealing with multiple tasks, action items and relevant responses, massive information gets generated. In case of Smart Cities, the daily generated new information and data from various Smart Services can be easily in multiples of Tera Bytes. To deal with such large volume of data, complex IT Infrastructure is required, besides the generated data needs to be properly filtered, analysed, and processed which can requires sophisticated tools and software [15]. Overall, it is a costly affair and impact of information loss can result into operational deficiency and the disaster kind of situation. Information Management is a critical task that poses following some of the selected challenges for Smart Cities.

- Data Safety and Privacy
- Enormous Amount of Data
- Data Backup and Security
- Ineffective Distribution
- Data Transmission Speed

Information Management can be very difficult considering the large volume of information processing at right time and in right manner. With the help of some of the latest IT Software and Solutions, however this task can be easily doable as per requirements. Besides, right information management practices and policies and by adopting the flexible and customizable information management frameworks, we can minimize the information management issues to a significant extent. Smart City planners and policy makers have proposed following key points to address some of the critical issues while dealing with information management in Smart Cities.

- Maximizing auditing of Information Systems on a regular basis
- Adopting digital transformation practices while dealing with information management processes
- Promote and Adopt the cyber security standards IEC 62443 SL1/SL2/SL3/SL4 compliance and certification procedures and policies for Information Management Systems
- Develop policies and frameworks ensuring the secure storage and backup for information management systems
- Maximize use of the secure communication channels such as HTTPS, SCP, SFTP, etc. while transmitting and receiving the information
- Promote and maximize using information security policies
- Promote using the latest tools and technologies such as Blockchain, 5G, Big Data, AI, and ML-based solutions to manage the information in the most effective manner

Information Management needs to be dealt with key concerns such as information security/privacy, information accessibility by right stakeholders, availability of information and integrity of the communicated information [16]. There are many Smart Information Management Platforms and Software available now a days that are used by Smart Cities to address the key concerns and challenges of Information Management while delivering various Smart Services. Using Smart Information Management Solutions Smart Cities can have following advantages

- Facilitates moving from a paper-based system to secure digital documents system
- Allows manual processes to convert in Automated Workflows
- Facilitates enabling easy implementing document information integration into digital workflows
- Enables central management of digital documents within the organization eliminating chances of losing any information
- Ensures data availability, reliability, and maintainability as per the defined policies
- Improves efficiency and productivity with automated workflows featuring an easy user interface design
- Easy configuration, management, and visualization of user dashboard allowing custom process flow for the management of information
- Manages and maintains audit logs for auditing purposes enhancing transparency
- Easily integrates with existing IT Systems and Infrastructure
- Easy adaptation to cyber security policies complying with information security

6.6 Water Management:

Ever increasing population, limited sources of natural water and exponential growth in water consumption has posed very serious challenges in front of Smart Cities to manage water demand. Ground water extractions have tripled from the past five decades causing a decline in freshwater resources. By year 2030 water supply is expected to get reduced by almost 40% as a result of urbanization and industrial development [17], and thus impacting both the quantity and quality of available water resources. Faced with all these issues and challenges, there is an acute need to improve the existing sources of fresh water with more sustainable alternatives. From water management standpoint of view following are key concerns and challenges Smart Cities have

- Water Wastage
- Water Scarcity
- Water Contamination
- Inefficient Water Monitor and Distribution
- Lack of Water Recycling

Water scarcity is a genuine challenge across the globe and not only for Smart City. Limited sources of water, exponential growth in water consumption, and a tremendous amount of water wastage are the key reasons which have created water scarcity [18]. Natural sources of water are limited, considering this fact, Smart City researchers, policymakers, and city planners have recommended certain policies and practices which can help in saving water to a significant extent and achieving effective water distribution. Some of such policies and recommended practices are as follows.

- Promoting installation of Water Meters for quantification of supplied and consumed water
- Promote installation of water leakage systems.
- Focus and prioritize water recycling and waste water treatment.
- Maximizing the interconnecting systems between the river, channels, and system tanks to facilitate their restoration to their original condition.
- Promoting augmentation of the groundwater across different geographies using artificial recharge
- Maximize using treated wastewater for various permissible uses.
- Maximize Integrating the various sources such as groundwater recharge using artificial recharge structures, treated water from the reservoir, surface water generated from the rainfall, and reuse of treated wastewater to meet the future demand.
- Implement Policies to create awareness among Smart City residents, students, and various stakeholders of Smart Cities about water importance and saving of water

- Implement Policies to maximize restoring of the environment by planting new trees and carrying out activities which can results in to reducing carbon footprint

To address the key challenges in Water Management and to adopt the policies and practices recommended by Smart City researchers and policymakers, Smart Cities have started using Smart Water Management System. Smart Water Management Systems with the help of latest technologies and tools such as IoT based intelligent sensors to sense the water relevant data, Cloud Computing Platform and AI/ML technologies to compute and analyse the water data, Blockchain Application layer to effectively offer cyber security for online water relevant data transactions, Mobile technologies to access the water consumption and monitoring data over Mobile and secure Database for storage and backup of the collected and processed water data. There are various Smart Water Management Systems are in place, one of such systems is "iWMS". Using iWMS, Smart Cities can effectively address almost all the stated issues and challenges related to Water Management [19]. Advantages of using iWMS in Smart Cities for Smart Water Management are as follows.

- Smart control over water storage, supply, monitoring, distribution, water recycling, and water purification
- Water Distribution and supply with automatic as well as manual control
- Water pressure regulation
- Water quantification using an automatic water meter
- User dashboard with data related to water distribution, consumption, storage, distribution, and water purification
- Automatic Water Leakage control and notifications
- inbuilt disaster management systems, alerts, and notifications to stakeholders over mobile and email
- Predictive and scheduled maintenance of various modules of the water management system

6.7 Waste Management:

According to statista.com, by 2050 the global waste generation is forecasted in million metric tonnes in many parts of the world. World bank group has estimated that over the few next decades, the local annual waste generation is expected to jump to 3.4 billion tonnes. Due to over growing population and industrialization, Smart Cities also facing a huge challenge in processing the large amount of waste on daily basis. In fact, to keep the surrounding environment healthy, it is utmost important for Smart Cities to keep the surround clean and maintain hygiene standards. This has made Waste Management Service very important and critical for Smart Cities. Very large amount of Waste Management has posed some of the serious challenges in front of Smart Cities, such selected challenges are stated as follows.

- Huge Waste Generation
- Inefficient Waste Transportation
- Inefficient Waste Disposal
- Ineffective Waste Management
- Lack of Waste Recycling

Waste Management is a growing concern in Smart Cities due to large amount of waste generation on daily basis. Such a large amount of waste disposal is very difficult and needs a systematic process and systems in place to handle it effectively. Policy makers and Smart City researchers have proposed certain policies and frameworks to effectively deal with waste management related issues. Some of the selected policies and suggestions from Smart City stakeholders are as follows.

- Waste segregation at source should be made mandatory.
- Maximizing of the household Waste separation, collection, and processing according to three categories - Dry waste such as paper, plastic, wood, and metal, Organic or Biodegradable waste, and Domestic Hazardous waste such as napkins diapers, mosquito repellents, cleaning agents.
- Promote and maximize involvement of informal waste pickers and rag pickers with municipalities and urban local bodies, in the waste management process.
- Encourage and promote placing a system in place for the industrial sector to collect the packaging waste generated due to their production.

- Strict fines to be imposed for those who litters and are responsible for creating waste in public places
- Encourage and promote placing a system in place for the industrial sector to collect the packaging waste generated due to their production
- Maximizing fines for those who burns garbage or discarding it in public places
- Implement promoting safe disposal of electronic and industrial nonrecyclable waste
- Maximize recycling of applicable of waste
- Implement incentive schemes for the traders and users to trade and use recyclable Items
- Implement methods and mechanism to quantify generated and processed waste

Considering the above stated policies and recommendations, it is clear that waste management not only covers just waste disposal but also includes start to end activities such as waste monitoring, collection, processing, and waste recycling. Thanks to the Smart Waste Management System which makes it possible to comply with most of the policies and suggestions recommended by Smart City professionals for carrying out waste management systematically. There are various Smart Waste Management Systems in place, one of such systems is iSmartWMS which is very effective in meeting the Smart City Waste Management objectives very efficiently and in the most cost-effective manner [20]. Using iSmartWMS, Smart Cities can achieve the following benefits

- Real-time waste monitoring ensures that waste containers are never overflowed
- Real-time alert and notifications for waste collection and hazardous situations due to waste
- Accurate quantification of collected waste
- Automatic separation of a variety of wastes
- Intelligent Route planning for waste collection makes significant cost savings on fuel, vehicle maintenance, and labour costs
- Facilitates healthy environment by keeping surroundings clean
- Optimization of the overall waste management process
- Facilitates landfill modernization
- Facilitates energy generation from permissible waste processing
- Facilitates waste recycling, improving the overall economy

7. SUMMARY OF TECHNOLOGIES AND KEY ISSUES ADDRESSED :

We went through the various challenges faced by Smart Cities and the proposed policies by Smart City stakeholders to deal with such challenges. However, to effectively tackle the Smart City challenges and to minimize its associated impacts, the latest tools and technologies are extensively used by Smart Cities. Refer figure 3 that has shown the Hype Cycle of Smart Technologies which is Gartner's second analysis of the Smart Cities range of technologies [21]. The Hype charts the position of technologies that support Smart City solutions, ranging from water and energy management, mobility, healthcare, parking, waste disposal, big data management, data analytics and so on. The figure has also presented the peak technologies which will be used by Smart Cities to meet the various expectations of Smart City stakeholders. This Hype Cycle states the latest technologies used by Smart Cities to tackle the issues and the business models and the portfolio of integrated technologies that a city needs to be rightly considered as a Smart City. Given the complexity of the Smart Cities requirements and stakeholders expectations to be fulfilled a broad set of technologies and the relevant business models are considered in the Smart Cities Hype Cycle. The list of technologies in the Hype Cycle is not exhaustive, the technologies are selected considering their relevance and usefulness in meeting the Smart Cities requirements. Many technologies stated in the Hype Cycle are critical and matured enough for innovations and transformational benefits for the Smart City residents, government and administration officers, and various stakeholders. There are some of the technologies which are not yet fully explored but have enough potential to tackle various issues faced by Smart Cities and can have an ROI of a few years.

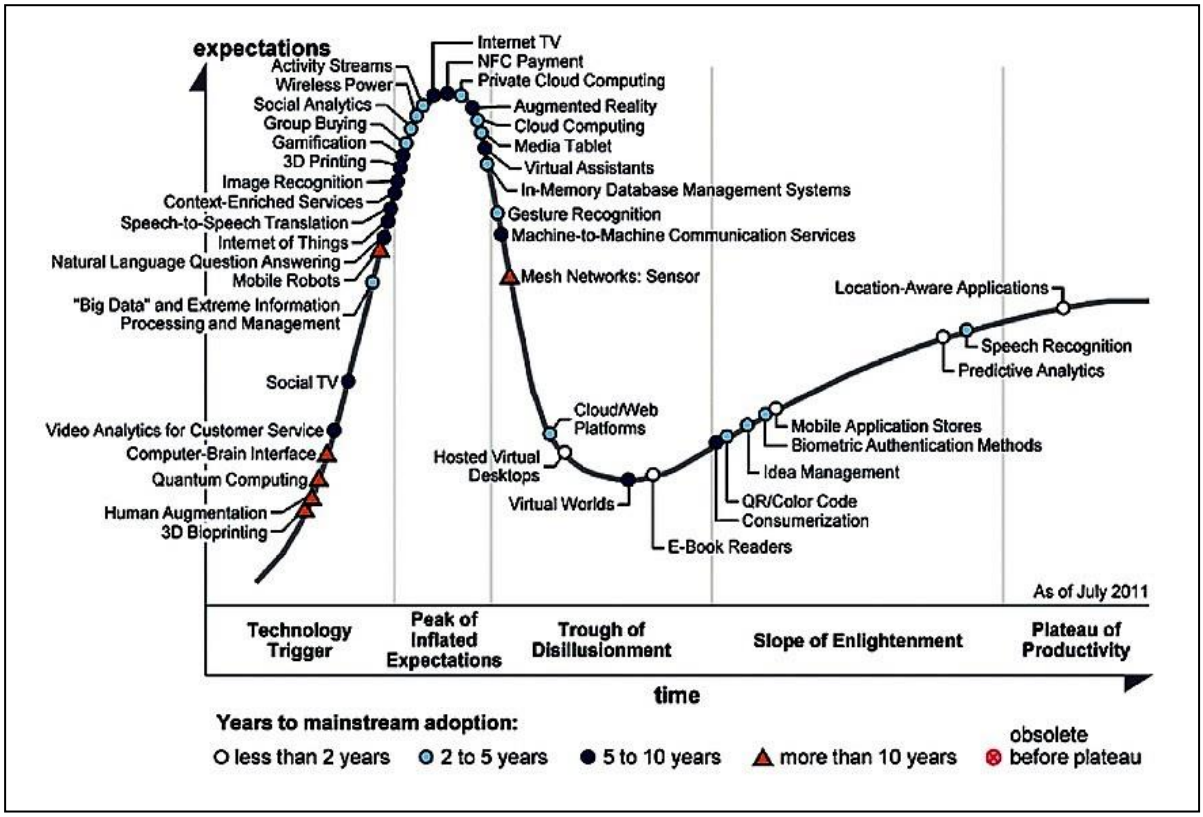

Fig. 3: Gartner's Hype Cycle for Smart City Technologies [21]

Refer table 2 that has summarised the Tools and Technologies used by Smart Cities to tackle various real-life challenges [22-26].

Table 2: Key Tools and Technologies used in Smart Cities to deal with various issues

Sr. No.	Tools / Technologies	Applications in Smart Cities	Issues Addressed
1.	LoBEMS (LoRa Building and Energy Management System)	Energy Consumption Optimization	Improve overall Building energy efficiency
2.	Cognitive Radio	Tackle demand for Wireless Bandwidth	Spectrum-based functionalities
3.	Three-layered architecture cloud, fog, and consumer layer	Deal with Smart Service operational challenges	Minimize the computational and processing cost
4.	CitySim with Tensor Flow Algorithms	To represent energy prices and CO2 emissions	Accurate calculation of Power, financial savings, and demand response, respectively
5.	DMES Stochastic Optimization Model	To represent service demand and response	Identification of transitive energy rate alerts and cash flows
6.	A decision-making framework	To achieve higher service efficiency	Improve energy utilization effectivity and reduce machine running costs
7.	Smart electric powered Meter	Energy Measurement	Accurate Energy quantification and Billing
8.	Smart Water Meter	Water Measurement	Accurate water quantification and Billing

9.	Context-aware Traffic Scheduling (CATSchA) Algorithm	Data traffic ensuing from numerous data applications	Retain the throughput and link efficiency by reducing the delay
10.	IoT	Interconnection of assets and users over Internet and access from wide range of devices	Secure connection of individuals, Organisations, and assets over network
11.	Data Encryption	To maintain confidentiality and privacy	Preserving citizens' privacy and data security while using Smart Services
12.	Big Data	To explore new insights into urban behavioural patterns and infrastructural dynamics	Develop smart urban services and evidence-based policy making in various action fields
13.	Micro Grids	Smart Energy through decentral Micro Grids	Reduce Co2 emission and increase renewable energy consumption
14.	M2M	Make Smart City services smarter	Collect information from various intelligent assets and machines effectively
15.	Smart Platforms such as Sentilo, SmartSantander, IBM IOC, CitySDK	Adaptation of Open Source based Service Architecture	Facilitate Service oriented Platform and infrastructure
16.	eGovernance Software Solutions	Bring Smart City Stakeholders together to participate in Smart City Administration	Promote Smart City citizens involvement in Smart City Administration activities and to maintain transparency
17.	Smart Mobility Software Solutions	Multimodal transport system to deal with traffic congestion	Support Inclusive and Sustainable Mobility
18.	Digital Transformation	Service Automation	Service Delivery and Citizen Engagement
19.	Autonomous Vehicles	Smart Transportation	Traffic Congestion
20.	5G	Media and Entertainment	Faster Audio and Video Communication
21.	Smart LED Light	Automatic illumination control,	Energy Efficient Lighting for Buildings and industries
22.	Smart Drainage	Automatic disposal of wastewater	Efficient treatment of large volume of drainage water
23.	Smart Parking	Intelligently handling of vehicle parking	Efficient monitoring and parking of large numbers of vehicles
24.	Cloud Computing	Digital Infrastructure provisioning for Smart Services	Smart Services hosting and storage and processing of large system data
25.	Artificial Intelligence (AI)	Smart Systems and Automation	Stringent demands of urbanization
26.	Machine Learning (ML)	Intelligent Parking System, Smart Traffic Administration	Dumb Machines to Smart Machines
27.	Digital Twins	Situation Analysis, Fault Predictions, Disaster Management	Scenario Simulation

28.	Image Processing	Smart Monitoring and Surveillance, Smart Traffic Management	Identification Management
29.	Augmented and Virtual Reality (AR, VR)	Smart Mobility and Public Safety	Disaster preparedness and personnel training.
30.	Blockchain Technology	Energy Trading Solutions, Online Financial transactions	Cyber security aspects for online transactions

8. RESULTS AND DISCUSSION :

Smart Cities are expanding and progressing. Regular basis either new Smart Cities are getting established or existing cities are getting transformed into Smart Cities. Smart Cities makes use of the latest tools and technologies while addressing their day-to-day issues and critical challenges. We analysed various tools and technologies and verified that how these technologies are used by Smart Cities to solve their pain points and issues. Refer table 3, based on the literature review, requirements analysis carried out and the relevant information collected as stated in previous sections, following are the popular tools and technologies used by Smart Cities to address some of the notable challenges.

Table 3: Popular Tools and Technologies used by Smart Cities Services

Sr. No.	Smart City Service	Tools/Technologies Used	Remarks
1.	Smart Parking	• IoT Sensors • GPS • Smart Cameras • Smart Mobiles • Client Server • Image Processing • Contact Less Transaction • Fast Tag	• Smart Navigation based Parking • Targets shortest possible route while identifying parking space • Parking fees payment through nearfield communication
2.	Smart Traffic Management	• Smart Cameras • PTZ Cameras • Thermal Cameras • GPS/AGPS • 5G • Image Recognition • Big Data • Simulation • Cloud Computing • IoT Sensors • Blockchain • Data Analytics • AI and ML • Mobile Navigation • Mobile Apps	• Traffic Management through auto monitoring and built-in intelligence while controlling traffic lights • Targets minimum waiting time and maximum movement to avoid traffic congestion • Facilitates real time traffic analysis and updates
3.	Smart Lighting System	• LED Lights • Constant Current Source • Renewable Energy Sources • PTZ Cameras • Thermal Cameras • Power Over Ethernet	• Targets maximum energy savings and maximum illumination • Modular architecture, Facilitating easy installation, operation, and maintenance

		• WAN • Image Processing • Mobile App Control • IoT Sensors • Modem • Client Server	
4.	Smart Waste Management	• Big Data • Data Analytics • Client Server • IoT Sensors • Image Processing • Cloud Computing • Blockchain • 3D Printing • Robotics	• Targets efficient waste collection and maximum waste recycling • Facilitates Real time waste monitoring and quantification
5.	Smart Water Management	• IoT Sensors • Cloud Computing • Client Server • Blockchain • Big Data • Data Analytics • Digital Twins • Simulation • AI and ML • Smart Meters	• Targets efficient water distribution and maximum water savings • Facilitates Real time quantification of water storage, distribution, and recycling
6.	Smart Healthcare Service	• AI and ML • IoT Sensors • Virtual Assistant • Data Analytics • Blockchain • Client Server • Mobile App • GPS/AGPS	• Targets safe, fast, convenient, and hassle-free healthcare service • Facilitates real time health monitoring updates
7.	Smart Education Service	• Mobile App • Augmented Reality and Virtual Reality • Smart Cameras • 5G • Gamification • Cloud Computing • VM ware • Smart Licensing • Blockchain • Simulation and Modelling • Client Server	• Targets secure and efficient online education to larger number of students • Facilitates live and practical simulation-based education to schools based and remote students
8.	Smart Surveillance System	• IoT Sensors • Smart Cameras • Thermal Cameras • PTZ Cameras • 5G	• Targets safe, secure, and efficient surveillance of region of interest • Facilitates real time alerts and notifications

		• Media Tablet • Mobile App • Data Analytics • Image Processing and Recognition • Power over Ethernet • Virtual Memory and Database • AI and ML • Smart Dashboard	
9.	Smart Governance Service	• Social Analytics • Blockchain • Cloud Computing • Big Data • Data Analytics • Mobile App • Smart Dashboard • Gamification • Contactless Transactions • Natural Language Processing	• Targets citizen friendly, feedback based, and participative public administration • Facilitates efficient Service Delivery for all the citizens
10.	Smart Information Service	• Big Data • Virtual Memory and Database • Vulnerability Analysis • Client Server • 5G • Penetration Testing • Blockchain • Mobile Apps • Cloud Computing • Data Analytics	• Targets cyber secure massive data handling and processing • Facilitates information integrity, availability, and data security

9. CONCLUSION :

Wide use of various ICT and Digital Technologies such as IoT, Data Analytics, Big Data, Blockchain Technology, Digital Twins, AI and ML, Image Processing, M2M, Cloud Computing, etc., have addressed various real-life challenges and issues of Smart Cities and have enriched Smart City Services with enhanced capabilities and effective utilization. Such Smart Services with the aid of the digital environment are directly contributing to provide better services to its users, Smart City Residents, and stakeholders. Now Smart City digital services have become an important factor in the City economy and prime important elements in the overall growth of Smart Cities.

10. FUTURE WORK :

The present paper has covered in detail the challenges faced by Smart Cities and how these challenges and issues are addressed by Smart Cities with the help of latest tools and technologies. The information and results obtained through this research paper are very encouraging. Many solutions which are discussed in this research paper are still at POC/MVP level and or at conceptual level. In future, it is planned to undertake full-fledged implementation of some of these solutions which are found very effective at POC/MVP stage. Due care would be taken to address known limitations of such solutions while carrying out its full-fledged implementation. We hope that with complete implementation of selected solutions, Smart Cities can take full advantage of using and deploying such solutions to mitigate certain challenges and issues faced by them.

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