

# Summary of ICT and Digital Technologies used in Smart Cities

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## ABSTRACT

Today's Smart Cities are smarter, more advanced and equipped with latest tools and technologies. Smart City uses Digital and Information Communication Technologies to operate smartly, more efficiently and for sharing information in safe and secure manner with citizens and various stakeholders. Smart Cities always aims to offer good services, better quality of life and welfare to their citizens and it is possible to do so by using advanced technologies. Smart Cities put Digital and ICTs along with data to work and make better decisions to improve the quality of life of their residents. Smart Cities promotes economic growth while improving the services quality for citizens by using smart technologies and data analysis. The effectiveness of Smart Services depends upon how the smart technology is used in offering the services rather than just how much technology is available for use. In this paper, the summary of information with respect to key technology trends in Smart Cities, various Digital and ICT Technologies used by Smart Cities to address their real-life challenges, and also brief overview of some of the prominent technologies that are extensively used by Smart Cities have been provided.

**Keywords:** SmartCity, IoT, ICT, Cloud Computing, Digital Transformation, AI/ML

## 1. INTRODUCTION

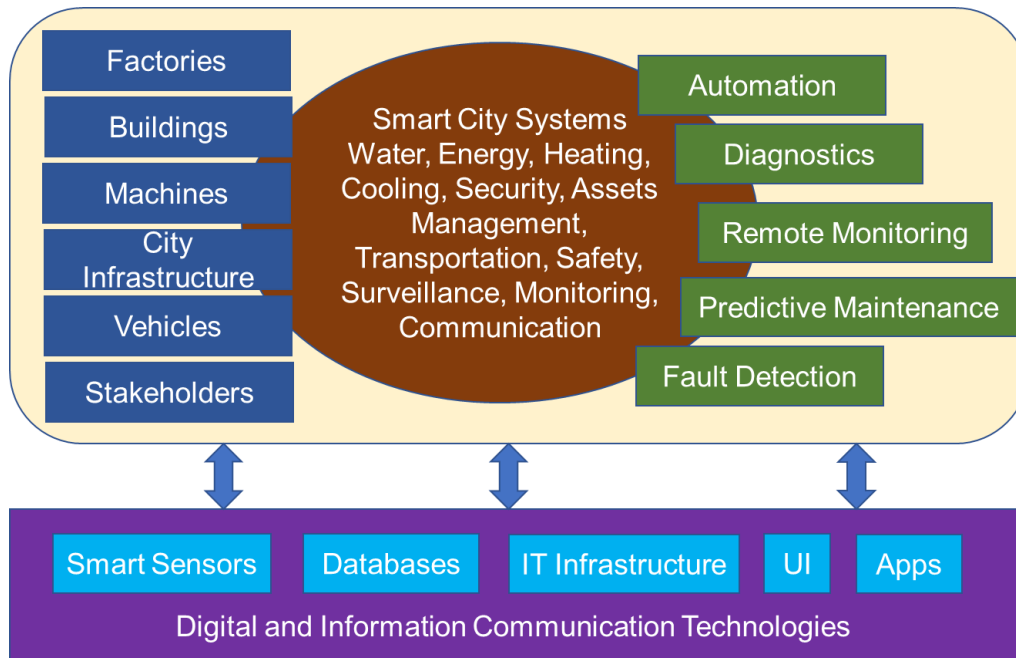
Post Covid-19 Pandemic, world has witnessed true potential in Smart Cities services and capabilities and also experienced how Smart Cities can effectively provide better services to its residents with the help of latest tools, technologies and infrastructure. According to McKinsey research Smart cities are expected to generate 60% of the world's GDP by 2025. Today's Smart Cities are more efficient and smarter, thanks to Digital and Information Communication Technologies advancements. These technologies are helping Smart Cities to provide smarter services, reducing operational and maintenance cost, efficient and a more resilient solutions, reducing and improving sustainability [1]. Solutions based on latest Digital and Information communication technologies often includes IoT, AI, ML, AR, VR, Data Analytics, 5G, Image Processing and Video Analytics, Contactless technologies, Client Server based communication, Blockchain based security layer, Cloud based platforms and Digital Twins [2-7]. With the effective usage of Digital and Information Communication Technologies the smart Cities services and systems have become interconnected, intelligent and instrumental.

- (1) Interconnected: Ability to communicate and interact with wider stakeholders
- (2) Intelligent: Ability to analyze the condition and provide quick response in order to control the situation
- (3) Instrumental: Ability to sense, detect, measure and record the input data

Please refer to the figure 1 which has presented Smart Cities Digital Model specifying various

modules of Smart Cities along with list of sensing and control elements. The Figure has very well depicted that Smart City foundation is based Digital and Information Communication Technologies driven data and infrastructure [8-20]. All the smart activities of Smart Cities such as smart traffic control, smart transportation, smart entertainment, Smart Water and waste management, safety and security, monitoring and surveillance are depending upon the data and control through Digital and ICT.

In this paper we are providing summary and conclusion of various services of Smart City and its various functionalities.



**Fig. 1:** Smart City Digital Systems, Sensing and Control Elements

## 2. KEY DIGITAL AND ICT TECHNOLOGIES FOR SMART CITIES

Smart Cities are data driven connected cities and they work in close collaboration with various stakeholders using latest Digital and Information Communication Technologies. In general, Smart City connects components across the city utilizing IoT sensors, actuators and through data driven technologies that impacts every layer of a city right from the city streets, city environment, to the air that residents are berating. Smart Cities operates on the data trends derived and analysed from the data generated by various Smart Services [21-43]. Let us go through the summary of such selected technologies used in Smart Cities widely, refer Table -1.

**Table 1:** Key Digital and Information Communication Technologies used in Smart Cities

Sr. No.	Technology	Description
1.	AR	It is Augmented Reality, represents enhanced version of the real physical world through the use of digital visual elements, sounds and other sensory stimuli delivered with the help of technology. AR helps Smart Cities in decision making and gain insights into

		data from specific stakeholders and systems.
2.	5G	It is 5th generation mobile network, a new global wireless standard to take over 4G network, to deliver higher multi-Gbps peak data speeds, massive network capacity, ultra-low latency, more reliability, increased availability, and a more uniform user experience. Smart Cities use 5G in smart entertainment service, Smart Communication and for digital multimedia.
3.	AI	AI or Artificial Intelligence is built in intelligence with the help of software and complex algorithms which facilitates software systems to take decisions based on situational data analysis. AI offers preventive maintenance as one of the most important benefits. AI is extensively used by Smart Cities in water management, incidents management, traffic management and for improving the safety of citizens
4.	Big Data	Big Data as the name suggest describes a huge data in size typically in Tera Bytes. It is a combination of structured, unstructured and semi structured data that can be mined for machine learning and information. Smart Cities uses Big Data technology for predicting stakeholders' behaviors, social media data analytics, for analysis of large size collected data generated by various Smart Services for identifying data insights.
5.	Blockchain	Blockchain Technology facilitates open decentralized digital ledger of online transactions which is duplicated and distributed across computer networks on the Blockchain. The transactions recorded over Blockchain is difficult or impossible to alter or hack. Smart Cities uses Block chain Technology to implement Security layer. Smart Cities use Blockchain technology in Smart Governance, Energy Trading, Smart Insurance Service etc.
6.	Cloud Computing	It is basically a bunch of computing services over the internet that includes networking, servers, databases, storage, analytics, software dashboard to offer improved speed, scale and flexibility in the services. Cloud computing is like a backbone of Smart Cities and plays an important role in delivering fast and efficient Smart Services.
7.	Data Analytics	It is a systematic process of analyzing the given data sets and finding out insights of that data set such as data outliers, data control limits, data correlation among various data variables and thereby carry out failure analysis, predictive maintenance and so on. Data Analytics is extensively used by Smart Cities to find out data trends and to take right decisions from the data generated by

		its various Smart Services.
8.	Digital Twin	A Digital Twin is a virtual or digital representation of a system or object that spans its lifecycle based on real time data from the real system. Analyzing the behavior of Digital Twin helps in situation analysis and decision making. Many Smart Cities use Digital Twins of themselves to prepare themselves in case of emergencies and pandemic situations.
9.	IoT	IoT or Internet of Things refers to the collective network of connected devices and technology that facilitates wired or wireless communication among devices and the cloud. With the help of Sensors, IoT facilitates processing ability, software, and other technologies that connect and exchange data with other devices. IoT is considered as one of the prime technologies in Smart Cities to drive various Smart Services.
10.	ML	ML or Machine Learning works on data analysis and applies the ML algorithms on historical data as input to predict the output and assist in gradually improving the accuracy of a machine/Software. ML helps software to become more accurate. Smart Cities uses ML in combination with AI in preventive maintenance and predictive failures for its various services including Smart Factories, Smart Water Management, Smart Waste Management and so on.
11.	Video Analytics	It represents data analytics performed over Videos to identify and detect specific situations, behavior and suspicious activities. Video analytics is extensively used by Smart Cities in remote monitoring and surveillance activities.
12.	VR	It is Virtual Reality, a computer-generated digital environment with visually appealing scenes and objects that appear to be real. It is used to make users familiar with the particular situation or surroundings by using VR Headset or Helmet. VR is extensively used in Smart Education and Smart Governance and trainings in Smart Cities.

### 3. TECHNOLOGY DRIVEN SOLUTIONS FOR SMART CITIES PROBLEMS

Today's Smart Cities are more equipped and advanced however still there are a lot of real-life challenges Smart Cities faces on regular basis. Smart Cities are increasingly seen not just as the engines of economic growth and innovation but also as the solutions to many real-life challenges and in producing comfort to the lives of its citizens. It should be noted that Smart City administrations continuously tries to produce adequate and innovative approaches for the diverse issues by striving on latest tools and technologies. Thanks to the ICT and Digital Technologies

based solutions to solve these real-life challenges. Some of the selected tools/technologies/systems to solve some of the major issues / challenges of Smart Cities are summarized as follows [44-65].

### **(1) Smart Parking Management System**

Due to increasing number of private vehicles, lack of effective use of public transportation and limited parking space availability, Smart Cities frequently face issues of vehicle parking. Sometimes vehicle parking issue is so severe that people have to park their vehicles on one side of road which leads to accidents. To handle these issues, Smart City uses Smart Parking System as one of the most effective solutions to address vehicle parking issues. Smart Parking combines human innovation and advanced technology. Smart Parking System utilizes IoT Sensors, IoT Gateway and Cloud Computing Platform along with client application access over Mobile/Tab/Laptop through secure browser or installed App. Smart Parking System assists Smart Cities to use a parking strategy effectively and efficiently and ascertain allocation and detection of Parking space on realtime availability. A location layout also suggests the Driver about real-time availability of nearest parking space. Smart Parking Systems are quite useful and popular in Smart Cities to deal with Parking management major challenges.

### **(2) Smart Traffic Management System**

Due to exponential increase in number of private vehicles (4 Wheelers/ 2 Wheelers/ Tempo/ Trucks) and limited road infrastructure, Smart Cities often ends up facing severe traffic management related issues such as traffic jams, road accidents, increased pollution and so on. To effectively deal with traffic management related issues, Smart Cities often uses Smart Traffic Management Systems.

Smart Traffic Management Systems are based on IoT Sensors, Smart Cameras, IoT Gateway, Cloud Computing Platform, Public Address System, GPS based route planner and Mobile App based interface. These systems make it possible to monitor and automate traffic control, automatic collection of challans, toll collection as well as disaster management, emergency alerts and notifications and so on. Smart Cities can integrate Smart Traffic Management system into traffic cabinets and intersections with less effort for cost-effective improvements in traffic monitoring and management. These Systems are easily scalable and painlessly upgradable at any given time.

### **(3) Smart Waste Management System**

Due to large growth in population and rapid urbanization, massive amount of waste is getting generated. Due to large amount of daily waste generation, collection and disposal of the waste in Smart City is always challenging and pain. To deal with this problem, Smart Cities started using Smart Waste Management System.

Smart Waste Management Systems, not only systematically collect and securely dispose the waste but also sort the waste and do the recycling of waste wherever possible. It also plays an important role in balancing resource consumption and availability. Smart Waste Management system uses IoT Sensors, Smart Cameras, Smart bins, specially equipped vehicles for waste collection, route planner, GPS for location tracking and Cloud based monitoring and analytics platform for facilitating monitoring of waste collection and processing and for carrying out data analysis with respect to collected, sorted, processed and disposed waste. Additionally, a waste recycling plant is also efficiently controlled and operated by Smart Waste Management System. With the help of Smart Waste Management System, Smart City residents get benefit of timely waste collection, processing and disposing and thereby low hazards and low environmental pollution, reuse of applicable processed waste and thereby balancing between supply and



consumption of certain resources.

#### **(4) Smart Water Management System**

Limited rain and underground water and exponential increase in water consumption due to large population, also uncontrolled water wastage has resulted in to acute water shortage. Today Smart Cities are facing one of the most severe challenges of supplying enough water for consumption and usage for its residents. To effectively deal with water scarcity, Smart Cities are using Smart Water Management Systems. With the help of Smart IoT Sensors, Smart Water Meters, smart water leakage detectors, GIS, SCADA and smart analytics platform, Smart Water Management System manages and controls the water distribution. Additionally, it also takes care of recycling of the water as per requirements. With the help of Smart Water Management System, Smart Cities can receive key insights of water availability, water pressure, water quality, water temperature and so on. Based on the available data and water parameters information, it is possible for the Smart Cities to take data driven corrective measures based on the situational demands. It should be noted that SWMS not only manage the water distribution, it also helps in identifying new underground water sources with the help of GIS, also assists in water recycling and thereby water saving.

#### **(5) Smart Light Management System**

Today's Smart Cities facilitates day and night operation for conducting the professional, personal, educational and entertainment related activities for its citizens. This requires IoT of indoor as well as outdoor lighting specifically during evening and night times. Such requirements not only push the energy consumption limit by Smart Cities beyond threshold, but also causes to increase the operational and maintenance cost of lighting besides adding up light pollution. It is obvious that very high-power consumption and cost due to lighting requirements are few of the biggest concerns Smart Cities have. To address this challenge, many Smart Cities have started using Smart Lighting Systems. Smart Lighting System makes use of Smart IoT Sensors such as light-sensing photocells for lighting control, Smart Cameras for monitoring and IoT Gateway for communicating the lighting infrastructure related data to Cloud Platform which in turn carry out lighting data analytics giving data insights such as daily energy consumption, predicted energy consumption, predictive maintenance, data visualization, data trends, etc. Smart Lighting Systems facilitates real-time lights on/off/dimming control to optimize the power consumption without compromising the lighting illumination. Smart Lighting Systems also facilitate monitoring traffic flow, alerting public through public address system, seismic activity, pedestrian crossing, incidents monitoring and alerts, atmospheric changes. Today's Smart Lighting Systems effectively makes use of Digital and ICT and facilitates the safer city, light efficient city, reduce the energy consumption as well operating and maintenance cost of lighting infrastructure.

#### **(6) Smart Medical Service**

Among all the Smart Services to Smart City citizens, Smart Medical service is the foremost important service and facility considered. Health sector is undergoing a lot of advancements however due to increasing population and urban lifestyle, it is very critical to respond to medical emergencies in a quicker and efficient manner. Specifically, during Covid-19 pandemic, the world realized importance of time and preparedness for responding to the medical emergencies at large scale. To deal with medical emergencies in the most efficient and timely manner Smart Cities have started using Smart Healthcare technology often referred as Smart Medical Service. Smart Medical Service facilitates technology enabled medical facility remotely, securely to geographically distributed patients and stakeholders over mobile, through Web over Internet and

even through remote collaboration platforms like Teams, Web meetings and so on. Not only that, remote medical consultation through BOT, disease analysis using image processing technology over video conferencing, medical predictions using advanced data analytics tools are some of the specialties of Smart Medical Service.

Technologies including IoT, Video Analytics, 5G, Cloud Platform, Smart Wearable Devices, Image Processing, Artificial Intelligence plays a foremost role in disease analysis and healthcare observations and helps in early identification and detection of health issues. In the near future, Smart Medical service is expected to become the norm and will help not only Smart City citizens but entire mankind in personal IoT based health analysis, early diagnosis, preventive measures in curbing medical emergencies, remote health diagnosis and consultation without any geography limit.

#### **(7) Blockchain based Security Layer**

Smart Cities facilitates many services to their residents and stakeholders purely online considering the hassle-free operation and convenience for the users. As there are multiple cyber-attacks and ransomware are happening across the globe for online operations, to boost the confidence of the users while using the Smart Services and performing the online operation, Smart Cities needs a robust secure framework to make the online transaction absolutely safe and secure for their users. Blockchain Technology has provided security to online transactions making it absolutely safe from cyber-attacks. Blockchain is a decentralized open ledger that records online transactions between two parties without needing any third-party authentication. The recorded transaction through Block technology is a permanent transaction, such recorded transactions are impossible to alter illegally and hence Blockchain Technology is very popular in implementing security layer. When Blockchain technology is combined with IoT, it is possible to use it in variety of online services. Considering this Smart Cities have started adopting Blockchain based security layer in almost all the Smart Services. Blockchain Technology has provided robust security to online transactions making it absolutely safe from cyber-attacks. Considering this Smart Cities have started adopting Blockchain based security layer in almost all the Smart Services.

In Smart Cities, Blockchain technology is used in almost all Smart Services ranging from Smart Energy, Water Management, Waste Management, Smart Education, Smart Entertainment, Smart Insurance, Smart real estate, Smart Mobility, Smart City Governance and so on.

#### **(8) Smart Education System**

Smart education is an important ingredient in smart city development. Conventional teaching methodology is not in line with today's student's generation and society demand due to its limited coverage and compulsion of student's physical presence in class room. Also, such teaching mechanism are not effective in covering large number of students requiring different skills to learn and freedom to learn at their convenience. Hence Smart Cities are constantly looking for new ways to improve quality of education and to make teachers' jobs easier. For Smart Cities, Smart Education Infrastructure is must to be in line with the latest digital and emerging ICTs. To effectively deal this important issue, Smart Cities have started using Smart Education Service. Smart Education System makes use of Internet and digital class to deliver the education to thousands of students online irrespective of their geographical locations. Smart Education makes an effective use of online teaching using Virtual Classroom, online meeting platforms, by sharing screens, through online exams and online evaluation of student's response in a secure way. Smart Education has also made it possible to bring SMEs and professionals from across the globe together to deliver online lectures and trainings to massive number of

students across Smart Cities. Smart education service makes use of technologies such as Simulation, AR & VR, Artificial intelligence, Machine Learning, Client Server Technologies, Cloud Platform, Big Data, Smart Cameras and Blockchain Technology to securely deliver the educational contents to right stakeholders.

#### **(9) Smart Governance System**

Effectively serving the needs of large population of citizens is one of the critical challenge today's Smart Cities are facing. Due to complex infrastructure, growing needs of citizens and stakeholders, limited manpower to support, it often becomes a tedious job to ensure timely and securely fulfilling expectations of Smart City stakeholders. To ensure a transparent, inclusive, participative, communication based, sustainable and collaborative environment for its citizens and stakeholders Smart Cities have started using Smart Governance System. Smart Governance System is technology driven and relies upon modern digital and ICTs to run and deliver the efficient public services considering democratic inclusiveness of its residents. To ensure a transparent, inclusive, participative, communication based, sustainable and collaborative environment for its citizens and stakeholders Smart Cities have started using Smart Governance System. Smart Governance System is technology driven and relies upon modern digital and ICTs to run and deliver the efficient public services considering democratic inclusiveness of its residents. Smart Governance System often makes use of technologies like 5G, Big Data, Data Analytics, Cloud Computing Platforms, Digital Twins and, Blockchain technology to deliver public services and facilitates collaboration among government and citizens to carry out services based the principles of good governance.

### **4. KEY TECHNOLOGY TRENDS IN SMART CITY DOMAIN**

Post COVID-19 pandemic, many Smart Cities across the globe made a significant progress in becoming self-sustainable, technically advanced, and enjoyable places to live by increasing financial investments in infrastructure, optimizing natural resources by adopting better tools and technologies and becoming smarter by using advanced technologies. It is sure that better use of data and technology will help to improve the quality of life for Smart City residents.

Based on the systematic literature review carried out for relevant research papers and interactions with various stakeholders and professionals from Smart Cities, following some of the selected technology trends have been identified for Smart City domain [66-74].

#### **(1) Contactless Technologies**

Due to Covid-19 pandemic, there was a necessity to carry out almost all the transactions without involving any contacts. However, due to effective use and applications, contactless technology is going to rule the transaction in Smart Cities even post pandemic. Contactless technology with the help of wireless near field communication mechanism such as RFID, Bluetooth communication can facilitate contactless financial transactions, payments, meter readings, deliveries, preventive health facilities and so on. Contactless Technology is essential and allows both savings in time as well as money and enhances public health and safety very effectively.

#### **(2) Doing Digital to being Digital**

It should be noted that transformation from doing Digital to being Digital cannot be achieved just by deploying Digital Services but it requires fundamentally shifting the operational focus and mindset towards "being Digital".

Smart Cities are using various Digital pivots e.g. Flexible and secure Infrastructure, Digitally savvy, ecosystem engagement, intelligent workflows, unified customer experience. In a nutshell a broad array of assets and capabilities are used to move from "doing digital" towards "being digital". With the help of these assets and capabilities, Smart Cities can transform both digital



service operations and delivery.

Smart Cities Smart Services have realized these techniques and they are becoming more Digital by adopting human-centered design and advanced technologies like ML and AI, Cloud centric solutions to elevate customer experience and radically improve service delivery by transforming service operating models.

### **(3) Smart and Sustainable Infrastructure**

Many Smart Cities are started aiming for smart and Sustainable Building and Infrastructure to improve quality of life of their residents and to meet their present and future needs considering social, economic, environmental and cultural aspects. While doing so, Smart Cities leverage data to optimize various resources consumption including power, water, natural resources and aim to utilize renewable sources in buildings and utilities and to improve urban operations, competitiveness and services. Smart Cities often takes help of technologies like Digital Twins, Data Analytics and Artificial Intelligence to predict the future requirements of resources consumption.

### **(4) Cybersecurity Focus and Privacy Awareness**

Data breaches and service denials are example of cybersecurity attacks that impact personal data security and privacy. Smart City Citizens have now realized the importance of data privacy and security. Smart Cities strive to promote awareness of the importance of readiness for the cyberattacks since Citizens data as well as Smart City services data are considered as an important city commodity. Smart Cities are now taking bigger measures by building Firewalls, secure storage vaults in their IT Infrastructure and implementing Blockchain based Security layers for their Smart Services to ensure utmost safety and security for online data transactions, storage and retrieval.

### **(5) E-Vehicles and shared mobility**

A key value proposition offered by the shared mobility model is the reduced travelling cost due to higher vehicle utilization. The mobility system is rapidly shifting from a product-centric to a service, centric model. From last few years Smart Cities have witnessed the massive jump in the number of privately-owned vehicles. This causes pollution, traffic jam, parking issues, accidents and so on. To avoid these issues, Smart Cities started building shared mobility model by implementing rapid transit system, efficient public transportation system and similar such facilities where shared transport become the new vehicular traffic norm. Also, increased Digital adoption is expected to further enhance shared mobility practice.

Smart Cities are also moving towards adopting E-Vehicles considering their advantages such as zero pollution, less noise, extremely economical operation cost as compare to conventional vehicles running with Petrol and Diesel. Thanks to technologies such as V2V communication, Smart Connectivity, Bi-directional Charging V2G (Vehicle to Grid) and V2H (Vehicle to Home), Smart Battery Banks, it is possible to have collaboration among Electrical Vehicle users making travelling easy and convenient, besides zero pollution and clean environment. It should also be noted that many governments and Smart City authorities started providing subsidy to customers on Electrical Vehicles purchase, this will also boost the EV market and overall usage of EV transportation.

### **(6) Smart Health Communities**

Smart Cities are developing health care ecosystems that are not only focused on diagnosing and treating sickness but also on supporting well-being through early intervention and prevention, leveraging digital technologies. During Covid-19 pandemic it became very clear that for creating a better health environment, community plays an important role. Smart Cities have learnt this

lesson and started focusing on Smart Medical Services, E-Doctor Seva, online medical consultation, etc. to have effective medical facilities for their residents. Many Smart Cities across the globe have started developing health care ecosystems through the interconnected communities focusing on early intervention and prevention of diseases. It is sure that coming days health care and medical services will be offered involving various stakeholders including government Officers, private-sector people and societies.

### **(7) Circular Economy**

Circular Economy is a regenerative system where resources inputs and wastes, energy consumption, emissions are minimized by minimizing, slowing down, closing, and narrowing material and energy loops. Considering resource scarcity and to meet exponential increasing demand of resources, Smart Cities started adopting Circular Models based on a resource sharing or resources circulation, reusing and or restoring, principles of sharing, limiting wasting of resources and increasing locally producing resources i.e. urban farming.

In summary, Smart Cities are developing Circular Economy aspects which decouple economic activity from the finite resource consumption and restricting generation of waste or encouraging waste recycling.

Through Circular Economy, Smart Cities are promoting

- (1) Consume reasonable and reuse/recycle resources like water, power, materials and products
- (2) Stimulate economy of borrow, repair, reuse.
- (3) Nurture sharing mindset such as spaces/car trips/material

Circular economy is boosted through technologies such as renewable energy sources (wind, Water, Solar, biogas, waste, wood biomass, etc.), smart waste management, indoor or vertical farming, roof top farming, hydroponics.

## **5. CONCLUSION**

With the help of latest tools and technologies, Smart Cities put data first for analysis purpose and to make right decisions to improve the quality of life for their citizens and also to offer the better quality of services. Today's Smart Cities focuses more on diversity and inclusion, safety, environmental quality, better health facilities, security, open and transparent governance, social connectedness and civic participation. Apart from effective utilization of technologies, the success of a Smart City depends upon the relationship between private and public sectors since these joint forces only create and maintain healthy operation and data driven environment to effectively run and operate Smart Cities. Smart City's framework predominantly composed of Digital and ICTs to promote, develop, deploy and maintain the sustainable development practices to address growing urbanization and complex ecosystem challenges. To deal with such challenges and to keep itself ready to address the real-life challenges, Smart Cities makes use of technologies such as

- IoT,
- Data Analytics,
- AR/VR,
- Artificial Intelligence in combination with Machin Learning,
- Cloud Computing,
- Blockchain,
- 5G wireless communication,

- Image Processing and Video Analytics,
- Big Data, and
- Digital Twin.

It should also be noted that to deal with problems like water scarcity, environmental pollution, noise, high power consumption, transparent governance, high waste collection and disposal, inefficient lighting, wide education and so on, Smart Cities relies on latest technology driven following some of the Smart Services.

- Smart Water Management
- Smart Traffic Management
- Smart Waste Management
- Smart Lighting System
- Smart Governance
- Smart Education
- Smart Medical Service

Finally, Smart Cities have become necessity around the globe, and a technology benchmark to enable cities to reduce operation and maintenance cost, enable transparency in operation and to conserve resources including power, water and gas.

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