Transitioning from Wired City to Super City: a review of selected ‘Smart City’ case studies

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Abstract The contemporary technological advancements of the twenty-first century are introducing paradigm shifts in every aspect of life. The “Smart City” concept has also brought the latest emerging technologies and their applications to the urban areas. The integration of Nano-technological devices collecting and transmitting data coupled with the availability and penetration of high-speed internet will only raise this potential by providing an easy way to receive and send real-time data more swiftly. The devices could also be connected with each other via the internet under the Internet of Things (IoT), making it possible to establish the machine to machine (M2M) communication between them. This large amount of urban Big Data can also deploy machine learning assisted techniques to ensure robust and precise urban analysis for getting significant insights and desired simulations ensuring the proper deployment as well as utilization of the phenomenon of Urban Intelligence. As the cities are entitled to become “Smart” in due course of time, these Information and Communication Technologies (ICTs) will play a major role in improving the efficiency and effectiveness of urban services and management. Due to their highly versatile and adaptable nature, these technologies can be linked with different components of Smart City thereby enhancing the efficiency and capability of the existing urban systems. This paper discusses the emerging concept of the Internet of Things (IoT) and other associated technologies within the context of contemporary urban scenarios through relevant case studies. It further presents crucial insights based on the influence of these technologies as well as their associated challenges while also exploring the implications of the concepts like ‘Super City’ on the cities of tomorrow.

Keywords Smart City · Information and Communication Technologies (ICTs) · Internet of Things (IoT) · Urban Intelligence · Super Cities

Introduction

In the early 1990s, a new concept of “Ubiquitous Computing” (later known as Pervasive Computing) was introduced by Mark Weiser, which advocated the presence of computers and technology in everything and everywhere either directly or indirectly or visibly or invisibly (Weiser, 1991). In this twenty-first century, advanced technological devices such as sensors, actuators, motion detectors, GPS, RFID, cameras etc.;
as well as communication technologies like the Wireless Networks, Bluetooth, and ZigBee are seen as the beacon bearers of this concept of Ubiquitous Computing (Feki et al., 2013; Mitton et al., 2012). Technology today is highly influencing human life as well as its development across all aspects. It is evident that the world today is urbanizing at an unprecedented rate. As per the estimates, 60% of the total global population will turn urban by 2030, and this figure could further rise up to two-thirds of the total population, or about 68% by 2050; implying that another 2.5 billion people will move to the urban areas, especially in Asian and African region (United Nations, 2019). Also, around 70 percent of the natural resources have their consumption or usage in urban areas which is a serious reason for the environmental destruction, ecosystem imbalance, and lack of energy resources. As the population will increase further, these problems will also become grave; the increased demand for infrastructure and facilities in urbanized future will further put more pressure on natural resources and land availability. To cater to the demands of such a humongous population in urban areas, sustainable, cost and resource-efficient techniques for optimizing resource usage will be required in the future.

The most important challenges which the cities are encountering are due to rampant urbanisation and haphazard development (Macomber, 2013). Sustainable urban development is needed to overcome these challenges, as it’s often reckoned that the roadmap to sustainable urban development goes through Science, Technology, and Innovation while considering the economic, environmental, and social dimensions of urbanisation (General, 2013). It is often attributed that cities are the greatest contributors to the overall economic growth while creating thousands of jobs, raising productivity levels, and constructing new houses (Venables, 2015). If they remain over-stressed, over-saturated, and congested, then they would highly influence the standard of living and cause a negative impact on the health of citizens. It could become a reason for hampering economic development as well. Therefore, smart approaches are needed to address urban problems.

In the past decade, the term “Smart City” became an important jargon in the urban development paradigms which conceptualized the new technologically advanced and sustainable development techniques to enhance the mobility, governance, safety, and living standards of the citizens (Abella et al., 2017). In these Smart Cities, the varied problems impeding the city’s growth can be solved by thoughtfully incorporating the Information and Communication Technology (ICT). ICT is often called as lifeline of the “Smart City” as it emphasizes intelligent management of the city and its resources while being cost-efficient having low-cost capital infrastructure requirement (Allied Telesis, 2020). According to the International Telecommunication Union Report, 2014 “A smart sustainable city is an innovative city that uses ICTs and other means to improve quality of life, efficiency of urban operation and services and competitiveness while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects.” (Cities, 2014).

A Smart City can be referred to as a new industry that combines and integrates urban function with ICT (Park et al., 2018; Sterbenz, 2017). ICT uses a variety of Nano-technological devices like sensors, actuators, Radio Frequency Identification Devices (RFID), motion detectors, and cameras. With the easy access of the internet and the evolution of wireless connectivity, it has been made possible to connect different devices with each other and transfer data easily and swiftly (Gubbi et al., 2013); giving birth to the technology known as the Internet of Things (IoT). The Internet of Things has made M2M (machine-to-machine) communication or machine-to-human communication possible today with minimum or no direct human interface (Gillis et al., 2021).

Relation between the Internet of Things (IoT), Machine Learning and Urban Intelligence

Urban areas today are grappling with issues pertaining to infrastructure, urban management, transportation and mobility, making the cities lack the vital elements like the quality of life as well as the socio-economic development opportunities (Joshi et al., 2016). ICT is seen as an enabling and empowering technology today, as its deployment in different urban fields can change the cities landscape by getting immensely involved in city management and services. ICT uses different devices already available and functioning within the Smart City, and it has made possible to garner and transmit the real-time, precise, and authentic data with the availability of the internet.
Evolution of the Internet of Things (IoT)

According to Kevin Ashton, just like the revolutions observed due to the spread of the World Wide Web (in the 1990s) and the mobile internet (in the 2000s), there is a new revolution (Evans 2011a, b) that is leading us to the potential “disruptive technology” called as Internet of Things. Astonishingly, the term IoT was not in existence two decades ago; however, the idea to connect the devices can be traced back to 1832 when Carl Friedrich Gauss and Wilhelm Weber invented the telegraph to make communication possible between two people at a distant place. In 1967, the extremely valuable technology of the future had its genesis within the idea of developing a “resource sharing” network called ARPANET (Advanced Research Projects Agency Network) (Naughton, 1999), which later became Internet as we refer to it today. But ARPANET was not open for civilian use and was exclusively used in Advanced Research Projects by US Defence. The year 1973 was marked by the development of TCP/IP (Transmission Control Protocol/Internet Protocol) based “Internetwork” which became the cornerstone for the new terminology “Network of Networks”; and as this newly developed network had no restrictions on usability, it was thrown open for the civilian use in 1980.

IoT took its initial steps in 1982 when programmers at Carnegie Mellon University connected the internet with Coca-Cola vending machine while allowing users to check the availability of cold soda-cans (Teicher, 2018). Another major turn came in 1989 when Tim Berners-Lee developed an information system used to identify the document and various web resources through Uniform Resource Locators (URLs) (CERN, 2021). At INTEROP’89, John Romkey came up with a new idea where he connected a toaster with the internet to turn it on and off, which today can be considered as the first IoT device. Weiser (1991) came up with a new terminology “Ubiquitous Computing” and said that “The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it” (p. 1). These lines point out the fact that technology becomes more concise with due course of time, and its implications are observable today in the form of nano-technological devices. These devices are hard to get recognized directly while having the ability to precisely collect and transmit the data. These devices will soon have a substantial influence on human life, and will have their applications and usage in every field and aspect while making them an important part of daily life.

It was during the late 90’s that on one hand the idea to make compact advanced nano-technological devices started budding, while on the other hand the internet also became more accessible as well as affordable as evident in the case of the new trading, marketing, and commercial services with the e-commerce start-ups like Amazon and eBay getting successful. This was when the concept of the “Internet of Things” finally got an existence when Kevin Ashton introduced it to the world. Since then, various researches and innovation have developed this concept of the “Internet of Things” to conceptualize and evolve, while also getting duly recognized by different tech-giants and attributed as the leading future technology. Within such a background, the involvement of IoT in the urban system for making the cities more liveable became a new research domain due to the tremendous amount of potential that the domain holds.

Evolution of Smart City with technological developments

Within the urban systems, the IoT finds its major applications covering various aspects of smart development. The very evolution of the Smart City concept is somewhat similar to the development of IoT and its genesis should be considered as “Wired City”. According to W. H. Dutton, these cities would have a “communication-centric society” that will use the emerging computer and telecommunication technology to collect the humongous amount of data related to households and businesses via the “information highways” aimed to boost the economic and social development (Dutton et al., 1987; Strauss et al., 1996; Targowski, 1990). In the late ‘90s, the Wired City concept transformed into the “Digital Cities”, (Ishida, 2017) which used broadband connections to combine the communication infrastructure and service-oriented computing infrastructure to provide efficient services to citizens (Yavanof & Hazapis, 2009). To quote a significant example of such a Digital City, Singapore built its nationwide broadband high-speed network ONE (one network for everyone) in 1997 aimed to provide multimedia applications and
services pursuant to business, governance, cybershopping, online banking, school, home, etc. (Tan, 1999). With the beginning of the twenty-first century, a new concept of the city referred to as the “Information City” got introduced in the mainstream academia and industry, which made robust use of the advancements in the ICT to command and control the large corporations and was thought to be path-breaking concept to restructure the global economy (Stolfi & Sussman, 2001). Quite interestingly, with the advent of wireless technology came the concept of “Ubiquitous City” in which city authorities in central/local government monitored the things happening in the city through a citywide network (Shin, 2009). It utilized the embedded urban infrastructure like sensors, actuators embedded in streets, roads, bridges, building, etc. ensuring a ubiquitous availability of data (Lee et al., 2014). From these paradigms onwards, the technological advancements started booming exponentially and their implementation within the urban environment became increasingly evident as the urban areas now had a lot of devices installed in different services all over the spread of the city. Figure 1 as shown below reflects this exponential increase in the number of devices having internet connections (Evans 2011a, b), landmarking the start of the IoT revolution within urban settings.

It is expected that the number of IoT devices will overpass the number of non-IoT devices by 2022, and it is expected that there will be 21.5 billion IoT devices will be available by 2025 as shown in Fig. 2 (IoT-Analytics, 2018). With such a huge amount of IoT devices getting operationalized within the next decade, it is believed that everything related to human life will come into surveillance of these IoT devices. Also, these IoT devices will continuously sense

![Figure 1](image1.png)

**Fig. 1** Comparison of Global Population and Number of Internet connected devices

![Figure 2](image2.png)

**Fig. 2** Projected number of IoT devices (2015–2025)
various attributes of our surroundings and life while garnering humongous amounts of data during their regular operations, which can bring a revolutionary change into modern city life if it is harnessed properly for finding insights and perspectives which could not have been observed before.

“Sensing City” was another concept that advocated for a city where sensors are installed to keep a check on activities or changes that are happening in the city. For example, sensors can be installed to monitor air quality, temperature, humidity, precipitation, pedestrian flow, noise pollution, intelligent street lights, and parking spots (Mone, 2015). Another contemporary terminology used in the smart city concept is “Intelligent City”, which characterised a specific area having the potential to support learning, technological development and innovation procedures on the one hand; and digital spaces, information processing, and knowledge transfer on the other hand (Komninos, 2012). The physical environment of this Intelligent City consists of embedded information and communication technologies with sensor systems placed in objects and surroundings; often attributed as the areas having a high potential for learning and innovation (Komninos, 2008). Additionally, an intelligent focus in such cities was also deliberately kept on encouraging and ensuring innovation in three-dimension viz. 1) Intelligence, inventiveness, and creativity; 2) Collective intelligence and 3) Artificial intelligence (Lee et al., 2014).

From the aforementioned literature review, it can be concluded that different interpretations have existed and still exists for the term ‘Smart City’; and that the usage of distinct technologies in various examples of Smart Cities makes it a really versatile term. However, it can also be perceived from the same literature review that the prevalent ‘Smart City’ concepts were all based on the contemporary Information and Communication Technologies which were in existence during that era. Thus, it can be summarized that the meaning and implications of the term ‘Smart City’ has transformed along with the evolution and adaptation of these technologies in the projects undertaken by the cities for becoming ‘smart’.

Immersion of future technologies in Smart Cities

The current generation of ICT is witnessing a phenomenal period of transition, where its development and advancement are leading to the innovative technological paradigms such as the Internet of Things (IoT), Big Data, Machine Learning, and eventually Artificial Intelligence; finding its interdisciplinary applications across diverse domains. In the same context, it has become evident today that both the complimenting fields of ICT and Urban Development are converging in the Smart Cities, which will surely help in making these cities liveable, sustainable and efficient (Joshi et al., 2016). And in spite of the many concerns and challenges that do exist in these cities, they can surely be overcome by gradual incremental technological improvements.

As more and more IoT devices will be deployed in the Smart Cities under the transport, energy management, meters, healthcare, and monitoring system sectors, it will generate enormous, heterogeneous, noisy, variety of data which can specifically be defined as “Big Data” (Marjani et al., 2017). As per Gartner (2021), “Big data is high-volume, high-velocity and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation”. The urban Big Data collected as such can be robustly analysed by the urban administrative and governing bodies for deriving useful inferences and imperatives through the application of Machine Learning or Artificial Intelligence-assisted data analysis techniques.

IBM defines Artificial Intelligence or “AI” as a human thought simulation process by adopting and applying machine learning-based systems (IBM, 2021a, b). Machine learning is a subset of Artificial Intelligence, an advanced form of AI through which a system can learn from data without the requirement of explicit programming. While machine learning works to generate precise models to automatically deal with data and situations by using its algorithms; these algorithms in turn need a large amount of data as a training dataset for building a model (IBM, 2021a, b). As such, data is actually the lifeblood of AI (Maryville University, 2021), and thus Big Data assists in applying AI and machine learning concepts to understand the hidden inferences and virtualize the humongous data so that meaningful and insightful knowledge can be extracted from it that can aid our decision-making. These advanced technologies like Big Data analytics, Cognitive Internet of Things, Deep Learning,
Machine Learning, and Artificial Intelligence also find promising applications in Smart Cities.

Increasing the Urban Intelligence

Intelligence implies the ability to learn or understand, or deal with new situations (Merriam-Webster, 2021). It is the capacity of an individual to improve and modify their thinking and mental adaptability as per the changing requirements to tackle the new challenges (Gautam, 2021). Human intelligence has certain specific characteristics which can be described as perception (ability to understand and to become aware of something through sensing), communication (exchange of information), learning and memory (acquisition of knowledge, skills, and storing information), and planning and feedback action (defining goals and progress evaluation) (Komninos, 2008). In contrast, the term “Urban Intelligence” is formed by combining the urban areas with intelligence which means to simulate or create the human intelligence pattern in the urban areas so that they can overcome their dynamic problems.

As technology gets more advanced and further finds its implementation in the urban areas, it will make them intelligent while providing the capability to resolve and manage the urban problems by itself. The integration of various technological paradigms like the Internet of Things, Big Data, and Artificial Intelligence holds the potential to revolutionize the urban management systems as well as urban lifestyles by bringing a very minute level of urban granular details into the consideration of city planners and administrators, which was not possible before. The sensor driven Internet of Things itself can significantly assist in creating the digital perception of the entire city by collecting data from different interconnected devices over efficient wireless communication technologies like Wi-Fi, 5G, Radio Frequency Identification Devices (RFID), and others. Such a humongous quantity of urban Big Data collected by the IoT devices, if analysed and visualized correctly through artificial intelligence assisted algorithms and frameworks, can tremendously assist the city planners and administrators in the decision making processes while providing user friendly and citizen centric services. In this regard, it can be considered that the revolutions in the Information and Communication Technologies can empower the cities to imitate the human intelligence vis-à-vis the IoT sensors serving like the human sensory organs feeding the urban Big Data to AI assisted algorithms trying to mimic their processing like the human brain.

This sort of technological development subsequently paves the way forward for building a future city referred to as the “Super City” (Rathore et al., 2020). As a successor of Smart City which acts as its precedent in terms of the technological adaptation and its application towards the urban contexts, the Super City represents a city where the near ideal urban condition can be realized, i.e., where people can access the state of the art technology-driven urban facilities through the utilization of advance technologies like the IoT and Big Data analytics.

Implementation of IoT and contemporary technologies in Smart City

It has been established by the literature review that ‘Smart City’ is a holistic term comprising of and incorporating different core components such as governance, energy, building, mobility, infrastructure, technology, environment, healthcare, and last but not the least, the citizenry themselves in a technologically assisted ‘Smart’ manner (Frost & Sullivan, 2013). Since all these core components considered together assist in making the city ‘Smart’, necessary advancements and improvements are required in each of these components to transform the city from its existing character and function. The following sections and subsections seek to highlight various case studies which integrate technological paradigms like the IoT with the core components of the Smart City.

Applications in smart governance

Smart governance platform

Yang et al. (2019) have shared an incisive study based on the usage of big data analytics and visualization to an create IoT-enabled air-quality and traffic management system and deployed it at the smart governance platform of Science Park in Taipei, Taiwan. The study revealed that the deployed systems used multiple IoT-sensors that collected air quality and traffic related data while using APIs as interface. The collected data was then analysed and stored at the back-end
platform of the database. Statistical analysis tools were then used to predict the models, and data visualization technologies were incorporated to make insightful inferences from the simulations performed by the models. The outcomes of the analysis were then shared with the users concerned via dashboards. It established a Smart Governance Platform for managing the big data and for providing smart application services to the end users. The platform provided a user interface through which the users can have access to real-time and historical data of air-quality and traffic flow. Likewise, the Smart Traffic Monitoring services used predictive models to give insights about the influence of traffic flow and weather on traffic volume, and helped to decongest roads by administering the traffic lights. Similarly, the Smart Air Quality Monitoring Services used Chatbots to give warning messages to users if the air quality deteriorated and reached threshold limits.

**Smart levee management**

Brous & Janssen (2015) highlighted innovative use of IoT for levee management through “LiveDijk Utrecht” project in Utrecht, Netherlands. These sensors collected a wide variety of data related to height measurements, water and groundwater levels, soil saturation, temperature, etc. For monitoring the water pressure in the dykes, sensors were also embedded at the bottom. The collected data was then stored in a centralised database; its analysis was done and real-time visualization of results was performed using the dashboard. This real-time and historical data was also shared with the concerned authorities so that they can make efficient decisions while increasing the data transparency. When the project was deployed and started functioning, it resulted in significant savings in running cost deferred investment for water management authorities. The system also served as an information and warning system during the tides, storm surges, and flooding as the sensors collected real-time data related to the water levels.

**AI for efficient communication**

Androutsopoulos et al. (2019) proposed an approach to enhance the communication between citizens and government by facilitating an extensive use of AI and delivering information through a Web-based platform. The proposed digital channel exploited three types of services:

- Data management services that handled the data collected from varied sources,
- Knowledge processing services that adopted different data mining techniques and further utilized Machine Learning algorithms like Neural Networks, K-means, Decision Trees, Naive Bayes and Support Vector Machines to extract essential information fragments, hidden patterns and associate them according to the requirement of citizens and governmental decisions, and
- Application services that enabled citizens to express their views, get information related to the data provenance, and trust issues by providing recommendations or feedbacks.

The obtained data from citizens could also be used by the chatbots to build “Conversational Interfaces” that assisted in better-informed sense making and decision making.

**Applications in Smart Environment**

**Smart Energy Management for smart home**

Tastan (2019) proposed an IoT based Smart Energy Management (SEM) System comprising of NodeMCU controller embedded with Wi-Fi which used Blynk Server for communication and power measurement, wherein the controlling operations were done through Pro Mini controller, Blynk SEM interface, and Blynk Server. The power measurement and controller unit recorded the current, voltage, and power values while sending it to NodeMCU which further forwarded the recorded data to Blynk Server via through local wireless network. The data was finally received at the Blynk interface where power values were calculated and subsequently displayed on the display module. The system-related data was continuously received from the Blynk Server to the SEM application installed in the android device. As the data flow through the SEM Interface, and NodeMCU, and vice-versa; it provided remote connectivity to turn the devices on/off. This application thus displayed the current, voltage, instantaneous power, and energy consumption of different electronic devices.
**Smart water quality monitoring**

Thiyagarajan et al. (2017) highlighted a framework for smart water quality monitoring system using an IoT environment. It used a multi-sensor interface to gather information and its remote transmission. The proposed system comprised of:

- Ultrasonic sensors,
- pH sensors,
- Digital thermometer sensor,
- Turbidity sensor,
- CO₂ sensor,
- Radio Frequency module,
- FPGA (Field Programmable Gate Arrays) board,
- Different processors and programming languages.

When the sensor system was turned on, it recorded the data related to different water parameters and wirelessly transmitted it to the computer; the statistics of parameters were displayed on the Water Quality Management dashboard. It further collected and displayed the real-time data and monitored it constantly. Machine learning algorithms were also used to compare the collected data with the water quality standards and decisions were subsequently made to train the data set for further operation.

**Storm Water Smart Grid System**

The study by Mercer & Cholkan, 2018 used Artificial Intelligence and IoT to prepare a Storm Water Smart Grid system, which provided information related to storm water to network administrators and property owners through an operational interface. It consisted of a quantitative precipitation algorithm prepared by correlating the weather data, address, roof area, and cistern volume; a sensor for recording temperature, barometric pressure, and cistern volume; an electrically actuated valve for drainage, and a data visualisation dashboard. The level sensors comprising of ultrasonic or pressure transducer sensors transmitted data to the controller via Power over Ethernet (PoE) cabled connection or wirelessly, which was embedded in each smart cistern. Residents could visualize data on a dashboard, which also displayed information related to the available storage in the cistern, valve condition, five days of predictive weather forecasts, and real-time information of cistern’s location, temperature, and barometric pressure.

**Application in smart transportation**

**Smart bus local transportation system**

Pawar and Bhosale (2018) described the state of the art IoT technology to build a Smart Local Bus Transportation (SLBT) system. The core unit of this system was a micro-controller, which used different sensors to collect real-time data. This information was then displayed on LCD to the passenger and was further sent to the cloud server. The SLBT system comprised a depot administered by the manager, who had access to the real-time data collected over the cloud server as mentioned above from the micro-controllers, on the basis of which the manager could perform the analysis and disseminate the obtained output to citizens through mobile application by using cloud services. The continuous updating of the real-time data also ensures the real-time display of information continuously being passed on to the passengers. Different sensors used in this system were:

- Temperature sensor to detect the engine temperature,
- Alcohol sensor to detect the alcohol consumption by the driver,
- Infrared sensors, LEDs to record the number of passengers,
- Fuel sensor to detect fuel amount, and
- Speed sensor to detect the speed of the bus.

**Smart Traffic Management for Emergency Vehicle Drivers**

Lalitha and Pounambal (2020) proposed a traffic management system wherein the driver of an emergency vehicle can get the signal status and traffic density, based on which they could modify their routes. The system used the concept of mobile node to imitate the vehicles using Raspberry Pi and Wi-Fi. The mobile nodes were further classified into different vehicle types, like passenger vehicles, fire vehicles, public transport vehicle, and others. These different nodes were then assigned a priority which gave them permission for crossing the traffic signals. By
utilizing the movement times at the traffic junction and associated assigned priority, the system used the observational and predictive probabilities to automate the traffic management system.

**IoT based route optimization**

The study conducted by Sang et al. (2017) proposed to develop a group based route optimization technique for vehicles having similar characteristics. The technique required data related to the vehicle location, vehicle type, driving behaviour, and roadside condition; and exploited the benefits of the Internet of Things, for vehicle-to-vehicle as well as vehicle-to-infrastructure communication technology. If the local authorities got information that the urban traffic reached the “dangerous” level, then the central management system used the group based approach to redistribute the urban traffic flow based on similar characteristics of vehicles. It utilized the Q-learning algorithm with MDP (Markov Decision Process) to find the best group route which significantly reduced the travel time.

**Safe Driving System**

Road accidents are one of the major concerns in cities, wherein the prime reason for most of the accidents take place is drinking and driving and rash driving. Jesudoss et al. (2018) presented a study where they used the alcohol detection sensor, eye blink sensor, and over-speed control sensor to detect whether the driver is in a condition to drive and conscious enough while having the alcohol levels under limits. The eye-blink sensor and alcohol detection was placed on the steering of the car and it charged the alarm if the driver’s eyes were closed for 5 s. The alcohol consumption limits were to be measured by the alcohol detection sensors, which would have triggered the alarm if it was found to be above the permissible limits. Furthermore, the speed control sensors were programmed to cut the fuel supply if the vehicle crossed the speed limits. Here, the IoT enabled sensors played a major role where the information of the driver was sent through a mobile application to the relatives of the driver and the local police station. The location of the vehicle could also be tracked via the GPS, which assisted in preventing the fatal accident by taking preemptive measures.

**Application in smart economy**

**Retail management**

Intel and Levi’s apparel brand joined hands to make an IoT based real-time inventory monitoring and management system to keep a check on their stock availability and sales. Products were embedded with RFID tags that recorded the data of the products and send it to the Intel gateway. This gateway further transmitted it to the cloud-based system for data analysis. This system continuously monitored the product’s sales, and collected the data; and if the stock of any product was found to be low, then it sent an alert. This system proved to be beneficial by significantly cutting the inventory costs while providing a better understanding of customer behaviour and experience (Intel, 2015).

**Banking system**

The IoT in banking can be adopted to provide easy-to-access services to debit and credit card customers. Banks were able to keep a check on the frequency of usage of ATM kiosks in particular areas. The IoT also provided the customer’s data to the banks, which they could utilize to identify the customer’s business needs for providing them the required value-added services, financial assistance as well as customized products.

**Application in Smart Living**

**Smart healthcare system**

The smart health monitoring proposed by Vippalapalli and Ananthula (2016) used the concept of a body sensor network that connected different medical devices and sensors (like the temperature sensor, pulse rate sensor, and blood pressure recording strap) to provide flexible operation, efficient monitoring, and cost-effective technique to patients and healthcare professionals. It utilized an Arduino Fio based Zigbee development platform, wherein different sensors placed on the body were connected to it. The recorded value from the sensors were transmitted wirelessly to the Arduino Fio receiver, which further sent it to a central station computer. The collected values were stored therein in the form of excel sheets and were compared with the threshold
values to detect any abnormalities. The results were subsequently shown using the LabView (software), which put the LED on if any abnormal condition was detected. This system provided real-time information about patients to a remote location, through which a healthcare professional or the caretaker could keep a check on a patient’s health conditions.

**Smart IoT infrastructure for independent senior citizen**

Stavrotheodoros et al. (2018) proposed an innovative use of the IoT to a support infrastructure primarily meant for independent senior citizens while seeking to assist their informal and formal caregivers to monitor the healthcare while being at remote places, and ensuring that they are able to respond promptly in the case of any emergency. The IoT infrastructure of the support system was based on the three-layered architecture, with each layer performing the data collection, transmission, and analysis creating an M2M (machine to machine) network via Internet connection.

- The Perception layer was the initial layer composed of various wireless sensors, and health devices. It used Zigbee, Bluetooth, and Z-wave to transmit the data to the aggregation point in next layer called as Gateway Layer.
- The Gateway collected all the data from the Perception layer in a device named an aggregation point, which further transmitted the data to a tertiary layer known as the Cloud layer.
- The Cloud layer was comprised of the software architecture, which stored the collected information, analysed it, and a decision support mechanism was provided to the end-users via advanced data analytics and visual analytics.
- The system also took due care of data anonymization and confidentiality of data by preventing it from potential unauthorized third parties.

From the aforementioned review of the selected case studies, various applications of IoT and associated contemporary technologies within an urban environment gets exemplified and highlighted: from managing the governance of the city by building efficient communication between citizens and government, to providing smart homes. All such interventions as mentioned above seek to make the city infrastructure more robust while enhancing the service delivery. It is making living smart by integrating technology into a person’s life, it endeavours to make city life more comfortable. It is leading us to a new generation where smart citizens will use information and communication technologies to ease their life and do their routine tasks. As the IoT is finding applications in almost every aspect of life, it becomes essential to make people aware and to understand it so that they can get benefitted. The challenges in the implementation of IoT and other technologies in the Smart City can also be appropriately addressed through constant innovation and appropriate modifications upon their gradual adaptation. In this regard, it will be appropriate to perceive the Smart City as living labs where different IoT based projects can be applied on a pilot basis, and on the basis of feedback they receive, they can be implemented in the city. Knowledge sharing platforms should be created where innovative IoT based case studies and projects should be shared through which cities can learn from each other and create a healthy environment for development (Table 1).

**Use of technology to counter COVID-19 by Smart Cities**

COVID-19 pandemic has caused widespread disruption in the economies, administration, management, and healthcare services; it also revealed the vulnerability of mankind against highly contagious viruses such as SARS-CoV2. COVID-19 claimed millions of lives and forced people to go into isolation or lockdown to control the severe spread of the virus. In such challenging times, prompt actions were taken by the government, and city-level authorities highly relied on the latest technologies. Smart cities leveraged their technological infrastructure edge to control the spread of virus and to provide essential services to its citizen.

Sharifi et al. (2021) provided an in-depth discussion about the use of disruptive technologies such as Information & Communication Technology (ICT), Artificial Intelligence (AI), Machine Learning (ML), Deep Learning, Cloud Computing, Blockchain, and innovative smart solutions in building technological arsenal to fight against the COVI-19 pandemic. The availability of technological infrastructure helped
| Smart City Component | References | Application | Brief |
|----------------------|------------|-------------|-------|
| Smart Governance     | Yang et al. (2019) | Smart Governance Platform | The research highlights the use of IoT, Big data analytics and visualization in air-quality and traffic management system in Taipei, Taiwan |
|                      | Brous & Janssen (2015) | Smart Levee Management | The “LiveDjik Project” made use of IoT in levee management in Utrecht, Netherlands |
|                      | Androutsopoulo et al. (2019) | AI for Communication | The study proposes an efficient web-based platform that makes extensive use of Artificial Intelligence for two-way communication with citizens |
| Smart Environment    | Tastan (2019) | Smart Energy Management | The study proposes the use of IoT in management of energy system in home |
|                      | Thiyagarajan et al. (2017) | Smart Water Quality Monitoring | The framework proposes a smart water quality monitoring system using IoT devices |
|                      | Mercer & Cholkan (2018) | Storm Water Smart Grid System | The study make use of AI and IoT to administer and manage the storm water |
| Smart Transportation | Pawar & Bhosale (2018) | Smart Local Bus Transportation System (SLBT) | SLBT system uses IoT to share, collect, analyse and disseminate information related through mobile applications |
|                      | Lalitha & Pounambal (2020) | Smart Traffic Management for Emergency Vehicle Drivers | The study proposes an efficient traffic route management service for emergency vehicle |
|                      | Sang et al. (2017) | IoT based Route Optimization | The study highlights the use of IoT and analytics in managing urban traffic levels |
|                      | Jesudoss et al. (2018) | Safe Driving System | The proposed system aims to reduce the traffic accidents by detecting the driver’s condition |
| Smart Economy        | Intel (2015) | Retail Management | The study highlights the use of IoT in monitoring and management of stock |
|                      | Infosys (2018) | Banking System | The study endeavours to provide the swift and easy to access bank services to the customers |
| Smart Living         | Vippalapalli & Ananthula (2016) | Smart Healthcare System | The healthcare monitoring system make use of body sensors and other medical devices to provide efficient services to patients and healthcare professionals |
|                      | Stavrotheodoros et al. (2018) | Smart IoT Infrastructure for Independent Senior Citizen | The proposed system provide IoT based healthcare services to senior citizens |
the city administration and government to critically examine and monitor the pandemic situation, it also provided support in formulating action plans, strategic management of the prevalent conditions, and predicting COVID-19 cases. Across the globe smart cities came up with innovative ideas to tackle the grievous condition. In the subsequent paragraphs, case studies of COVID-19 management by South Korea and India are discussed.

South Korea

Sonn and Lee (2020) provided keen insights into South Korea’s pandemic management strategy. When across the globe nations were grappling with the pandemic, the Government of South Korea efficiently managed the pandemic situation. The preventive tech-driven measures taken by the government to control the surging COVID-19 cases brought down the death rate to 5 per million population and made South Korea one of the least COVID-19 affected economies.

The three pillars of the smart strategy were credit & debit cards, mobile phones, and CCTV cameras. South Korea is an almost cashless economy with 96% of transactions happening online, the locational data collected when a transaction was made helped in tracking and providing the information relating to the mobility of people. Further, precision was achieved by the use of mobile phone location for keeping a track record of the movement of citizens.

Also, the high surveillance technology due to a dense network of CCTV cameras helped in identifying the face of COVID-19 affected patients. The data collected from these devices were used in spatio-temporal analysis and mapping. It also helped health authorities to identify the infected person and provide timely treatment to the patient.

The analyzed information is then dispersed to citizens and local governments through government websites and mobile apps. The robust collection of data, its analysis, and swift dissemination of information provided the latest updates about the prevailing situation to local governments and citizens, it further helped in checking the spread of fake information.

India

The government of India’s strategic tech-enabled handling of the COVID-19 pandemic situation has won applause globally. Being a country with a large population and healthcare-related constraints, the management of the COVID-19 situation was quite challenging for India. India harnessed its smart city infrastructure for swift response and took immediate measures to mitigate the pandemic situation. Most of the smart cities in India have Integrated Command and Control Centre (ICCC) that proved to be an epicentre in pandemic response and management. ICCCs were established to create, monitor, and manage ICT services as well as to provide tech-driven solutions to local government and municipalities of smart cities. ICCCs are well equipped with a data visualization and analytics system that provided quick insights about the COVID related data through dashboards that helped in containing the virus and management of services (Ministry of Housing & Urban Affairs, 2022).

The pan-India website and mobile application ‘Aarogya Setu’ developed by the Government of India provided huge support in contact tracing and dispersion of important information to citizens (Aarogya Setu, 2022). The ground-level information relating to the present situation in local areas is fed by the local authorities and app users, then it was collected by the servers and after performing the analysis, visual insights are provided through dashboards on websites and mobile applications.

The reliance on technology in the successful management of the COVID-19 pandemic has shown the importance and potential of smart cities against any susceptible healthcare emergency. The innovations through integrating the data and harnessing disruptive technologies are bringing a paradigm shift in the field of healthcare and services. The evolution of telemedicine as a cutting-edge technology would not only help in dealing with any contagion but also help in providing universal healthcare services to society.

Challenges faced by the Smart City

It is observant to acknowledge that every city across the globe today is striving hard to achieve the Smart City tag. However, getting transitioned to the level of technologically advanced urban settlement makes a city face some challenges also. Though every city is unique in itself and has a distinct set of problems that need to be confronted, a Smart City faces few
particular challenges in transforming into a ‘Super City’. Such challenges faced by the Smart City are briefly summarized below:

Infrastructural challenges

The ever-increasing rate of incorporating the technology with every component of Smart City has brought many infrastructural challenges to cities. As Smart Cities will heavily rely on data for their efficient functioning, decision-making, and providing services, it becomes cardinal to develop a truly ‘Digital Infrastructure’. Digital Infrastructure refers to the framework of digital technologies such as sensors, IoT, applications, data centres, labs, and networks; that enable the urban administration to improve the productivity and efficiency of the urban services while ensuring the optimal usage of the city resources.

It is quite implicit that the Smart City inherently requires a huge network of complex digital devices; nonetheless converting the existing infrastructure to tech-driven infrastructure will need a complete overhaul. As digital infrastructure will be comprised of different digital layers vis-a-vis urban sensors, connectivity, data analytics, and automation, at each level proper infrastructure development is imperatively required (United Nations, 2016). It is evident that cities are ready to deploy tech-driven approaches, but they lack a systematic digital transition strategy. And even though the Smart City Labs in these Smart Cities are coming up with innovative urban solution using disrupting technologies, the projects that they run are on a pilot basis while catering to the demands of only a small area. To implement these projects on the scale of a city, a robust infrastructure is required so that the optimum usage of technology and efficient service delivery can eventually take place.

Challenges concerning security and digital forensics

The tech-driven new-age cities use data quite vigorously, and thus it is quite apt to refer data as an important asset for the city management and services. It is expected that Smart Cities will produce an enormous amount of heterogeneous data from different components such as data from smart homes, smart transportation, intelligent building services, smart vehicles, smart grids, and smart healthcare. Also, the collection, transmission, storage, and analysis of such data is crucial for ensuring efficient decision making and implementation. Since data is often attributed as ‘new-oil’ in the contemporary world and is the foundation of new-age technology, hence it becomes quite essential to protect and secure the data from potential threats (Ismagilova, 2020). Any security breach or cyber-attacks in a Smart City has the potential to harm citizens, city management, the economy, and national security. Baig et al. (2017) and Ma (2021) asserts that different components of Smart City are vulnerable to different potential threats and cyber-attacks, as mentioned follows in Table 2.

With the increase in implementation of the smart technologies into the urban components, the data acquisition is bound to get increased while putting a significant amount of the acquired data on high risk or threat. As the data will go through multiple-digital environments, advanced data management, encryption, authentication, and authorization are extremely important to tackle hackers, cyber-threats and data-stealing (Townsend, 2013). Thus, a rigorous security, threat-identifying, and risk management mechanism is recommended to make Smart Cities resilient to cyber-attacks. While the cybersecurity and its application in Smart City are still in a nascent stage, the notion of ‘Digital Forensics’

| Component          | Threats                                                                 |
|--------------------|-------------------------------------------------------------------------|
| Smart Homes        | Data theft, Exfiltration                                                |
| Smart Grids        | Denial of Services (DoS), exploiting vulnerabilities in protocols, Delay in service |
| Smart Transportation| Suspended message, Physical threats, Interception threats, Abuse threats, Malicious code, Data threats, Forgery of Identity |
| IoT sensors        | Confidentiality and Integrity Compromise, Eavesdropping, Data Loss, Availability Compromise, Remote Exploitation |
| Data stored in Cloud| Data Leakage, Insecure APIs, Malicious Insider threats, Denial of Service Attacks, Malware Injection, System and Application Vulnerabilities, Data Locations and regulation Boundaries |
is still waiting to get introduced in the framework of Smart City. Digital Forensics, which is also known as, Cybercrime Forensics, is the process of identifying, preserving, analysing, and documenting digital evidence. As forensics is used in identifying and producing legit evidence of the crime science, similarly digital forensics comes into play when any data or cyber-related crime is committed. The vulnerability of Smart Cities to cyber-attacks and the lack of digital forensics currently engaged in the frameworks of the Smart Cities is a major issue, as any infringement in data security can put the citizens at risk since the data possibly contains critical personal information related to an individual.

Challenges concerning citizen privacy

It is quite evident that data remains an indispensable aspect of the concept of Smart City, and such data garnered by the Smart City frameworks also include the personal data of citizens. Although the data is of pivotal importance for a Smart City’s functioning, but protecting the citizen’s privacy should also be the utmost priority of any Smart City government. If any data that can provide information about a citizen’s personal life and way of living gets breached, then it has the potential to cause grievous harm to an individual. For example, an individual’s smart home’s data can reveal a lot of personal information such as living habits and working hours; further, the transportation data can provide the real-time location and mobility pattern of a user. Being cognizant of the concerns that can arise from the data breach of similar personal information, the citizens may perceive the ‘smart’ interventions with scepticism and apprehensions. Thus, it becomes extremely important and highly imperative that such a concern of the citizens should be appropriate and timely addressed by the government prudently by ensuring citizens about the safety of the collected data while clearly stating the objective of such a data collection and full accountability and transparency. Additionally, the governments must also ensure robust threat control mechanisms in place so as to assure about its clear intention to keep the citizen’s privacy with the utmost concern, regard, and safety.

Challenges in citizen and community engagement

The ultimate aim of a Smart City is to provide efficient services to its citizens. But to use the tech-driven services at their full potential, “smart citizens” are imperatively needed. The innovative tech-services thus require upskilling of the citizens so that they can assimilate themselves with the new technological services. However, the extreme reliance on technology also creates a distant possibility to engender a digital divide, and any case of a digital divide will further hamper the efficiency of services and restrict it to work at their full potential. Smart Cities are meant not only for the tech-savvy, young, and affluent people, but the tech-solutions should instead be developed such that it will help to reduce any possible digital divide among its citizens.

People are the very heart of the city, hence their contribution and engagement with city administration in decision-making are of crucial importance. Community engagement also focuses on inclusivity, as the participation of people from all spheres of society empowers the citizen while giving the opportunity to the deprived and disadvantaged groups to represent themselves. The active participation of citizens in decision-making also allows the government to respond to their queries and needs appropriately, and such a two-way interaction allows the citizens to raise their voices, share their opinions and grievance, and give advice and positive criticism to the government while further enhancing the governance and implementation of changes ensuring the benefit for all.

Challenges in funding and financing

The innovative and ambitious projects of overlaying the digital technologies on the existing infrastructure of a city require huge funding and financing. Most of the Smart City projects are either funded by the government or financed by banking or private institutions. The whopping amount of investment required to overhaul the city infrastructure is one of the biggest concerns for the city and local governments. In this regard, while the developed nations show more readiness to adopt the Smart City initiative due to their ability to fund and attract financing opportunities; the developing nations find it quite daunting to receive the adequate amounts of finances and funding. The recent pandemic of Covid-19 has also affected the
Smart City projects almost all across the globe, resulting in cities facing a crunch of funds, finances, and investments. Therefore, a collaborative approach having inter-governmental ties with financing institutions and private investors is needed in this regard to support, fund, and finance the Smart City projects.

Conclusion

The term Smart City has come a long way from the concept of Wired City to Intelligent City, and finally towards the promising concept of ‘Super City’. Since its very genesis, all efforts have been made to enhance the city services and management by adopting and applying contemporary technological advancements. The IoT is the latest technology that is readily being adopted by various Smart Cities across the globe, and it has exhibited positive results when applied in urban areas as discussed in the selected case studies briefed in this paper. However, considerable challenges also exist in the application of these technological advancements across various components of the city, which require appropriate identification and redressal. Since the majority of these technological advancements within the ICT like the IoT, Big Data, and Machine Learning are heavily based on data collection and transmission, there are also significant security as well as privacy concerns related to it. Additionally, since the ICT collects heterogeneous data on an extremely large urban scale, the analysis process of such data gets quite cumbersome while the transmission of this humongous data also depends on the availability and penetration of swift communication services. Thus, the evolution of IoT and other associated technologies in the context of city components is imperative to overcome all these challenges, while combining IoT with other technologies like machine learning, artificial intelligence is also essential to improve its overall efficiency, especially in the context of Smart City.

The Smart City will only harness the true potential of technologies and services if its citizens have the essential literacy and knowledge of using them. Thus, the citizens of an urban area should also be adequately trained and imparted with the required digital literacy so that they can make efficient use of all these technological advancements and interventions, which is entitled to provide them with significantly better urban services and quality of life.

It is expected that a complete transition from traditional labour-intensive urban management to a technology-driven efficient digital citizen-centric urban management will bring a new era of “Super Cities” within the next decade. Time is not too far when the citizens of the urban areas will live in highly technical cities, where most of the services will be availed digitally at fingertips and where the network of devices connected via the internet will provide efficient and effective urban services while making urban lifestyle comfortable, and more importantly, sustainable.

Availability of data and material Literature from different research papers, articles, documents, and information taken from online sources are properly cited in the paper.

Declarations

Ethical approval The paper reflects the authors own research and analysis in a truthful and complete manner. This material is not currently being considered for publication elsewhere.

Consent to participate Authors give their consent to participate in the Springer’s GeoJournal Special Edition: Urbanism, Smart Cities, and Modelling based on the submission of the paper.

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