Evaluation of the role of smart city technologies to combat COVID-19 pandemic

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Abstract:
Digital transformation is deemed a necessity and no longer an option. Proposing economic stimulus plans and digital investments are an integral part for the government today. A digitized world needs to create a new economy, new infrastructure and new technology. Smart cities provide the medium to create and influence the society to build a better future. The COVID-19 pandemic has had a vast impact on the global economy and digital transmission has created a path for hybrid education models, smart healthcare treatment, safeguard and smart security. However, there is no research reported on the role of smart cities technologies play in managing the COVID-19 outbreak. Therefore, this paper aims to address this research gap by exploring how collective intelligence and smart cities technologies applications provide cities and communities with an approach to fight COVID-19. The paper follows a systematic literature review to understand smart city technologies and the challenges faced in developing these technologies under the Indian Smart Cities Mission (SCM). The paper focuses on the smart city technologies and applications designed by the Indian smart cities and the role it plays in combating a worldwide pandemic. The research progresses with a theoretical emphasis on the concepts studied and understands the implications of smart cities, COVID-19 and smart applications. The paper also describes the challenges faced by smart city technologies in resourcefully developing smart, secure and sustainable cities for better quality of life for citizens. The study answers the research question - How collective intelligence and smart applications provide cities and communities with an approach to fight COVID-19? It further concludes that smarter and safer cities focus on leveraging information to make better decisions, anticipating and resolving problems proactively and coordinating resources to operate more efficiently.

Keywords: Smart city, Technology, ICT, smart city applications, COVID-19

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Introduction

Cities are classified as smart cities with intensive and advanced technologies to connect people, information and technology to create better quality of life for citizens. Smartness is not delivered only with technology; it requires collaboration of technology and data persistently to make better decisions and deliver better. Urban settings face unique dynamics that have a direct impact on the achievement of preparedness for all types of health emergencies, including COVID-19 (WHO, 2020). The world is in the era of digital transformation and cities are gearing up for this change. Digitalization in simple words process of using digitized information to make the working of business simpler and more efficient. Digital transformation is changing the way cities are being transformed and revisiting the way things are done. A key element of digital transformation is understanding the potential of developed technology.

Since the announcement of the SCM Statement and Guidelines in 2015, Narendra Modi, the Prime Minister of India has moved a step towards the digital and technological development of the country. The purpose of the SCM is to drive economic growth and improve the quality of life of citizens by enabling local area development and harnessing technology especially that leads to smart outcomes (Ministry of Housing and Urban Affairs, Government of India, 2020). The Indian cities need to be developed to provide adequate quality of life and focusing on retrofitting – city improvement, redevelopment – city renewal, greenfield development – city extensions and pan-city initiatives with smart solutions. The purpose of the SCM is to resolve the urban problems through urban infrastructure developed by advancing Information and Communication Technology. The mission aims to revitalise structural imbalances, create a sustainable city and a liveable environment with economic prospects.

Cities and communities are beginning to develop new ways of responding to the COVID-19 pandemic that seek to make the most of the collective intelligence of urban areas. This research paper looks at the different technologies adapted by smart cities, smart city applications and COVID-19, the challenges faced and understanding the correlation between smart cities, technologies and applications for smart cities. The paper follows a systematic review of literature research methodology. The first part of the paper works on a literature review to review and understand the different technologies used for smart cities around the world and discusses about the solutions and challenges faced using the smart city literature and research experience. In the second part of the paper author provides a theoretical emphasis on the concepts studied and understands the implications of smart cities, COVID-19 and smart applications and answers the research question on How collective intelligence and smart applications provide cities and communities with an approach to fight COVID-19? The research emphasises on the COVID-19 pandemic and how resilient and efficient smart cities could have a preparedness strategy in the future.

Literature Review

Smart City

Smart Cities are designed to improve the traditional services provided to citizens to create and develop challenging ones. The transition has been from a city to a smart city, from a smart city to a smart and sustainable city and evolved into developing environmentally sustainable smart cities (Abdala et al, 2020). Planning for urbanization and better management of cities is therefore not only important for the quality of life for those living in our cities and towns, but also because it contributes to a better investment climate. Smart city is an understandable

concept based on the ideologies for citizens and industries. Cities need to be efficient, sustainable, equitable and liveable. Defining smart cities based on a considerable context is challenging and provides a challenge to the society dependant on it. The following Table1 provides a distinctive approach to define smart cities based on different context:

Table 1: Smart City Definition

Author	Definition
Giffinger et al., (2007)	Simplified the definition to six simple characteristics smart economy (competitiveness); smart people (human and social capital); smart governance (participation); smart mobility (transport and ICT); smart environment (natural resources); and smart living (quality of life).
Chourabi et al., (2012)	Provided a framework for analysing smart city progress with eight dimensions focusing on management, technology, governance, policy, people, economy, infrastructure and environment.
Smart Cities Council (2014)	"A smart city is one that has digital technology embedded across all city functions".
Mohanty (2016)	"A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operations and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects."
Yigitcanlar et al., (2019)	"A city is smart when investments in traditional infrastructure, social development and modern (ICT) communication infrastructure fuel sustainable growth and a high quality of life, with wise management of natural resources"
Ministry of Housing and Urban Affairs, Government of India, (2020)	"Building and promoting cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment, and the application of 'smart' solutions."

Smart cities have been defined based on characteristics, dimensions and applications. It is important to define the term as the revitalisation of a city depends on the understanding of the people involved. The different definitions in Table 1, provides an understanding of the diverse domains emphasised based on ICT, business-led urban development, community development and social capital and sustainable development. The conceptual smart city definition needs to provide an approach the cities are looking to provide for their citizens. A smart city may therefore be more prepared to respond to challenges than one with a simple "transactional" relationship with its citizens. The term itself remains unclear to its specifics and therefore, opens to many interpretations.

Smart City Challenges

The recent emergence of the concept of smart cities presents challenges to city administrators for planning, managing, and governing modern cities in the digital age. Smart cities provide cities and organisations with added advantages. Despite the benefits, many challenges remain

when it comes to the deployment, due to the unique city requirements and differing interpretations of deployment concepts. Different governments worldwide developing smart cities face different kinds of challenges and aspirations to drive economic growth. The challenges faced by smart cities in developing countries like India include poor infrastructure planning and management, population pressure, financial investments, technology dependence, inefficient local governance, citizen perspective and social divergence (Shetty et al. 2019). Some of the most important challenges faced by developed countries worldwide in the development of smart cities are infrastructure, privacy concerns, security, education for engagement and social inclusion. Providing viable solutions with implementation of innovative technology would provide a right pathway for the development of smart cities to deal with the COVID-19 pandemic. Smart cities are working on varied technological and implementation-based solutions to combat the virus (Abdala et al, 2020).

Smart City Technology

Academicians and professional researchers attribute an interest to technological leap that influences both architecture and infrastructure for future smart cities (Arroub et al., 2016). Smart cities are characterised with technological innovations, policy innovations and also the management innovation (Pattaro, 2013). The utilisation of Information and Communication Technology (ICT) enhances quality, performance and interactivity of urban services, reduces costs and resource consumption and increases contact between citizens and government (Hammons and Myers, 2019). Smart city applications are developed to manage urban flows and permit for real-time responses. As a challenge to urban sustainability, smart cities are gaining the attention and momentum positively. ICT forms the main concept in smart cities that integrates and connects physical devices to optimize the efficiency of city operations and services to connect citizens. Smart city infrastructure has become an important tool in combating against coronavirus. Technologies are developed that are being used to monitor the affected areas and maintain a closure on the further spread and a slowdown in the cases with heavy resilience on data infrastructures. The smart cities mission is critical in the decision-making process and providing real time data.

IOT

Internet of Things (IoT) is the emerging technology in the context of smart cities and is being set up for different projects. Diaz- Diaz (2017) describes the use of IoT as a technology to connect between the physical and virtual world could help in significant and fundamentals ways. As described by Mehmood (2017) the Internet of Things is a novel cutting edge technology that proffers to connect a plethora of digital devices endowed with several sensing, actuation, and computing capabilities with the Internet, thus offering manifold new services in the context of a smart city. IoT means all the devices are capable of interconnecting and communicating with each other over the Internet. IoT has seen a huge success in providing technology revolution to smart cities.

IoT will affect the various aspects of the smart city citizens' life like health, security, and transportation. On the other hand, it can play an important role at the national level regarding to the policy decisions (like energy saving, pollution decrement, etc.), remote monitoring and required infrastructure, etc. (Arasteh et al., 2016). But, besides the advantages, IoT is still evolving and facing many challenges. Literature review identifies challenges associated with the development of smart cities using IoT as identified by Jenssen et al., (2019). Privacy, security, safety, ethical and societal issues always arise with the innovation and implementation

of new technology. Policy makers and project managers face challenges with IoT projects and have been working on different levels to understand the inter relationships between them. The main conclusion is that in order for technology to incentivise shifts in societal behaviour, towards more sustainable travel, it needs to be: open, context-aware (situated, timely, energy-aware), accurate, integrate disparate IoT systems, be usable, and be intelligent to target appropriate uses and users (Poslad et al., 2015). Cities need to be more resilient and the citizens knowledge aware to make the best use of technology. IoT poses the importance of logical planning to cities to develop IoT based smart cities.

IoT has been used in different cities around the world due to the advantage of reduced energy consumption in different projects. The IoT innovative technology foresees a new generation of devices (sensors, both virtual and physical) that are connected to the Internet and provide different services for value-added applications (Kaur, 2016). IoT being the popular technology provides a wide range of user enabler platform to build applications. Applications for smart tourism, smart healthcare, smart waste management and other smart cities-based applications uses IoT for better connectivity of devices.

Cloud-based

Revolutionising of information technology has put forth a fundamental change in the world of ICT hardware and software are invented, developed, deployed, scaled, updated, maintained and paid (Kakderi, 2016). Technology that delivers on demand computing services from application to storage and processing power on software as a service and internet as a service is defined as cloud computing or cloud-based technology. IoT and cloud computing technologies are organised in the same platform to provide a feasible journey for smart cities at every level of public and private sector. Cloud computing is used for provisioning and management of the resources with minimal effort and high user-based applications (Kaur, 2016). With cloud-based technologies the scalability, agility, security, total cost of ownership ecosystem is defined effortlessly and the usability of smart city services for citizens is provided through tablets, laptops, phones and other devices with internet connectivity (Agarwal, 2017). Cloud-based solutions allow cities to use managed services to scale their limited resources and reduce the total cost of ownership for smart city solutions.

Big Data

Data described in terms of volume, velocity and variety is a simple yet complex definition to understand the concepts of big data (Reyas et al., 2020). Integrating, managing and analysis lies in the heart of smart city innovation. Collecting data from connected devices, public agencies, private citizens creates volume. Big data applications provide better customer experiences and services (Al Nuaimi et al., 2015) and enables efficient data storage and processing (Hashem, 2016) enhancing smart city services and help businesses achieve better performance. With smart city applications producing continuous large data from heterogeneous sources, existing interactive database technologies are inadequate to handle such huge amounts of data given the limited processing speed and the significant storage expansion cost. To address this problem, big data processing technologies, which are based on distributed data management and parallel processing, have provided enabling platforms for data repositories, distributed processing, and interactive data visualization (Kang et al., 2016). Big data applications serving smart cities in different services such as smart education, smart traffic lighting, smart grid and intelligent traffic management. For municipalities aspiring to be truly smart cities, having a sturdy data strategy in situ is paramount. The information and data

accustomed to streamline and optimise operations must be rich and abundant. A holistic approach to data collection and sharing is very important to entail public-private collaboration and continued reserves in analytics capabilities.

AI

Artificial Intelligence (AI) has been the forefront in the current industrial 4.0 revolution and for the explicit deployment of smart city services. Frankfield (2021) describes AI as "the simulation of human intelligence in machines that are programmed to think like humans and mimic their actions" including learning, reasoning and perception. Artificial intelligence and cognitive computing have emerged in the process aimed at designing and optimizing smart service supply and utilization in urban space (Chui et al., 2018). AI is used for processing, analysing and viewing of raw data making it easier to manage growing volume of data being captured. AI machines are designed to recognise faces, read license plates establish traffic patterns and track speed. Municipalities are working with private organisations to deploy the technology and improve urban life.

Blockchain

Blockchain is a specific type of database which stores data in blocks that are then chained together. It allows individuals and organisations to make instantaneous, secure transactions over a distributed network. Picturing a city as a smart network of connected urban objects (streetlights, meters, parking lots, waste bins, Wi-Fi hotspots, video surveillance cameras, etc.), blockchain allows all components and devices to be linked to each other by the same cryptographic chain of trust and enable accurate, secure, immutable information exchanges among them (Ibba et al., 2017). Providing ultimate cybersecurity, blockchain has the highest possible levels of data integrity, validity and immutability making commissioning and operational procedures over smart urban infrastructures intrinsically secure. Integration of blockchain technology with devices in a smart city will create a common platform where all devices would be able to communicate securely in a distributed environment (Biswas and Muthukumaraswamy, 2019). Securing the city and public integrity and data provides a sense of satisfaction and better resilient cities.

Smart City Applications

The success of the smart city paradigm has created a widespread adoption in cities worldwide (Schleicher et al., 2016). Many modern cities endeavour to integrate information technology into every aspect of city life to create smart cities. Smart cities rely on a large number of application areas and technologies to understand multi-layered interactions between citizens, third parties, and city departments (Echoff and Wagner, 2018). With available technology putting it into application is a major task faced by smart city administrators around the world. Using the right technology for the different smart city services is a major road ahead. Smart city applications are characterised on the aspects of social, economic and environmental aspects of the country (Abdala et al., 2020).

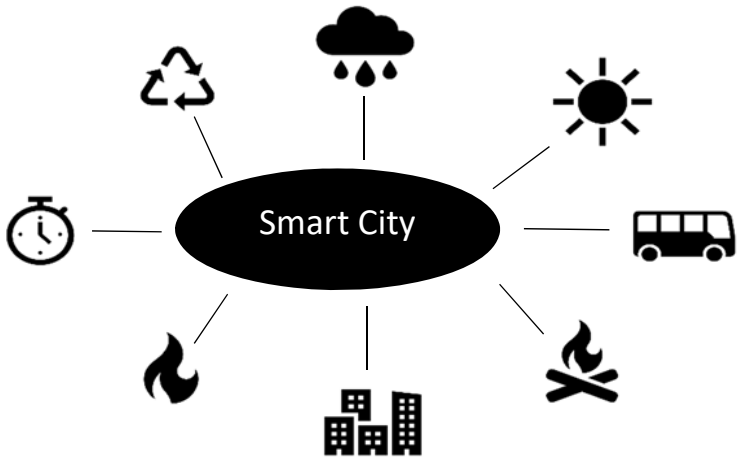

Figure1: Smart City Applications

Smart city applications are largescale distributed systems that react and control, as well as analyse and reason about their physical environment, by using the underlying infrastructures. The inherently dynamic nature of smart city applications poses several challenges when running and managing such applications (Schleicher et al., 2016). The number of smart city applications is large, ranging from smart card services for easy authentication and payment on the go, to smart resource management of water or electricity, to smart mobility applications that improve traffic efficiency and reduce CO2 emissions. The effectiveness of these and other smart city applications heavily relies on data collection, interconnectivity, and pervasiveness. Smart city application has played a major role in combating COVID-19 in many cities worldwide.

COVID-19

The world has undergone unprecedented change because of COVID-19 outbreak. On December 31, 2019, China informed the World Health Organization (WHO) of a cluster of cases of pneumonia of an unknown cause in Wuhan City in Hubei province. On January 9, 2020, the WHO issued a statement saying Chinese researchers have made "preliminary determination" of the virus as a novel coronavirus. More than 123,216,000 confirmed cases of COVID-19 and 2,714,517 deaths reported as of 20 March 2021(WHO COVID-19 Dashboard). The WHO has declared COVID-19 to be a pandemic and the vital need to manage this crisis.
The current situation of COVID-19 pandemic has put organisations at a more volatile risk environment than expected (Renukappa et. al 2021, Jallow et. al., 2020). The unprecedented crisis has posed a significant setback on socio-economic development outcomes. Organisations globally are required to prepare and respond to reduce the significant impact the pandemic has caused on the businesses and economy. Control risks benefit organizations to prepare for, respond to and recover from a full range of disruptive events. To navigate through the COVID-19 related challenges organisations need to focus on the changes to workforce, deployment and enforcement of business resumption protocols, mental health considerations, threat assessment and management, information, technology and cyber risk mitigation. Yigitcanlar et al., (2020) noted that the adaption of smart urban technologies as increased infrastructure capacity for creating new services, reduce emissions, improved citizen engagement, improved decision-making, and supporting sustainable development of cities.

Research Methodology

The research focuses on smart cities and the role of smart city technologies to combat COVID-19. This research paper focuses on the literature review and authors described the basic concepts and understanding of smart cities, smart city technologies and smart applications. Review of literature provides an in-depth knowledge of the subject (Creswell and Creswell, 2018) which was a desktop-based search. The paper follows a systematic review of literature methodology covering publications on smart cities, smart technologies, COVID-19 and smart city applications. Fink (2005) described structured literature review as a systematic, explicit and reproducible design for identifying, evaluating, and interpreting the up-to-date recorded documents. The importance of a structured and multiple-stage system for reviewing voluminous academic literature is accredited and as a significance deemed appropriate given the aim of this article (Thorpe et al., 2005; Pittaway and Cope, 2007). The Seuring and Golds (2012) systematic literature review methodology is used considering the literature analysis and challenges faced in collating data. Following a predefined process to conduct the systematic literature review as proposed by other methods provides the research team with clarity and feasibility to review the literature.

A systematic literature review was conducted following Seuring and Golds (2012) four main steps: material collection, descriptive analysis, category selection and material evaluation.

Material Collection

Academic peer reviewed journals articles were collected from different databases. The articles comprised English-speaking literature review papers covering a period of 10 years 2011 to 2021. For compiling the article, a literature search was conducted using the combination keywords of at least two strings “smart city technology”, “smart city application”, “COVID-19”, “smart cities” and “smart cities India”. The search was conducted on foremost databases like Science direct, Scopus, Sage and open access journals Elsevier and University library repository. Based on a sufficient sample reached at the title, abstract and keywords level the selection of papers were done. The initial search resulted in 183 papers. After removal of duplicates, 145 unique papers were identified. From these, 81 papers were removed because they were exterior to the thematic scope, book reviews, non-English contributions. The process resulted in 64 unique papers for a comprehensive review. Only papers with the main focus on the phenomenon of smart cities, technologies, COVID-19 and smart applications passed the detail review for inclusion. The final sample included 14 research papers.

Descriptive Analysis

Stentoft (2016) defines descriptive analysis as “an assessment of the formal characteristics of the material, which is used to provide a base for subsequent content analysis. Table2. under the material evaluation part of the methodology, shows the analysis of the reviewed articles. The full text of the selected articles was read to determine the significance with respect to the objective of the study.

Category Selection

As described by Stuart et al., (2002) category analysis is derived from aim of research, method of data gathering, method of data analysis and quality measure. A basic frame of categories is established base on existing literature. Publication journal, study methodology, aim and

objective of the study and analysis/ understanding from the research are the categories identified for this research. The final categorization scheme was determined primarily by the content analysis of the articles that are included in this review, and the collective interpretation of these by the authors.

Material Evaluation

The selected research paper sample has been analysed based on the categories identified. The results are presented and discussed, to conduct theoretical literature review. The consistency of this process has been enhanced by discussions within the research team and by ensuring documentation of this process. By systematically comparing interpretations and findings between reviewers, it is possible to minimize errors and produce a more robust data set. The research team consists of three researchers (two senior researchers and one PhD researcher) in collaboration and effective interactions on all aspects to conduct the literature review for the study.

Table 2. Analysis of the reviewed literature

Reference	Title	Journal / Conference Proceedings	Methodology	Aim/Objective	Discussion
Mora et al., (2019)	Strategic principles for smart city development: A multiple case study analysis of European best practices.	Technological Forecasting and Social Change	Multiple case study analysis	Divergent hypotheses on how to enable smart city development	Build a smart city strategic framework and boost the digital transformation by establishing a smart city accelerator
Ahlgren et al., (2016)	Internet of Things for Smart Cities: Interoperability and Open Data.	IEEE Internet Computing	Single Case study demonstration	Demonstrating the idea of interoperability and open data for smart cities.	The concept of open systems enabling innovation in public services is important and requires IoT infrastructure to maximise the benefits for society.
Del Esposte et al., (2019)	Design and evaluation of a scalable smart city software platform with large-scale simulations.	Future Generation Computer Systems	Comprehensive set of experiments	Leverage the use of city resources to improve the quality of life of its citizens	Requirement of advanced support for the development and operation of applications in a complex and dynamic environment.
Tcholtchev and Schieferdecker (2021)	Sustainable and Reliable Information and Communication Technology for	Smart Cities	Conceptual and theoretical approach	A structured way of providing and maintaining an open and resilient ICT	Reliable, dependable and trustworthy ICT infrastructure forms the main core and fundamental

	Resilient Smart Cities			backbone for a smart city.	need for smart cities.
Dhungana et al., (2015)	Aspern smart ICT: Data analytics and privacy challenges in a smart city	Paper presented at the IEEE World Forum on Internet of Things, WF-IoT 2015 - Proceedings	Multiple case study	Security and privacy challenges within the urban data analytics.	Residents distinctive willingness to cooperate and provide personal data for adaptation of new technologies in smart city.
Vitunskaite et al., (2019)	Smart cities and cyber security: Are we there yet? A comparative study on the role of standards, third party risk management and security ownership	Computers and Security	Review and Case Study	Smart cities and cyber security measures focusing on technical standards and regulatory framework.	Regulated framework encompassing technical standards, compliance assurance and government input to ensure secure smart cities.
Hamalainen (2020)	Smart city development with digital twin technology	33rd BLED e-conference Enabling Technology for a Sustainable Society	Literature review and interviews	Addressing the concepts of smart city and digital twin technology as means to foster more sustainable urban development.	Optimizing urban metabolism of the city and infer on more efficient and intensive resource and material use in smart and sustainable cities.
Ismagilova et al., (2020)	Security, Privacy and Risks Within Smart Cities: Literature Review and Development of a Smart City Interaction Framework	Information Systems Frontiers	Systematic Literature Review	Technological solutions to improve security, privacy, and operational threats.	The importance considering factors such as legal regulations and costs of providing confidence to citizens on the security and privacy aspect of smart city technological infrastructure.
Elmaghraby and Losavio (2014).	Cyber security challenges in Smart Cities: Safety, security and privacy	Journal of Advanced Research	Categorical structuring - Analysing determinants	City infrastructures and services are changing with new interconnected systems for monitoring,	Privacy protecting systems that gather data and trigger emergency response when needed are technological

				control and automation.	challenges that go hand-in-hand with the continuous security challenges.
Kummitha (2020)	Smart technologies for fighting pandemics: The techno- and human- driven approaches in controlling the virus transmission	Elsevier – Government Information Quarterly	Systematic literature review	Smart technologies and the use of digital technologies in controlling the transmission of COVID-19	Human interaction with the technology is mediated by the political and institutional context in which the technologies are implemented
Yigitcanlar et al., (2020)	Contributions and risks of artificial intelligence (AI) in building smarter cities: Insights from a systematic review of the literature.	Energies	Systematic literature review	Artificial intelligence and SC	Generate insights into forming a better understanding of how AI can contribute to the development of smarter cities using knowledge maps
Schleicher et al., (2016)	Enabling a Smart City Application Ecosystem-Requirements and Architectural Aspects	IEEE internet computing	Abstract Concept	Challenges and building blocks of a Smart City Application Ecosystem	The fundamentally dynamic nature of smart city applications poses several challenges when running and managing applications.
Eckhoff and Wagner (2018)	Privacy in the Smart City—Applications, Technologies, Challenges, and Solutions	IEEE communications surveys & tutorials	Systematic Review and Multiple case study	Too better understand smart cities and their privacy implications.	Introducing taxonomies for application areas, enabling technologies, potential attackers, data sources and citizen privacy presented a holistic analysis of privacy threats and possible solutions.
Abdala at al., (2020)	Managing knowledge in the context of smart cities: An organizational	Journal of Entrepreneurship, Management and Innovation	Systematic Review	To explore organizational cultural transformation needed for managing	Managing and implementation of smart city for urban planners, policymakers and scholars

	cultural perspective			knowledge in the context of smart cities	require to prepare for the organisational challenges, the cultural transformation required for the development of smart cities and the ability to integrate, create and reconfigure both internal and external competences to manage knowledge.

The analysis of the research papers provided with a systematic approach to conduct a review of the literature on smart city applications and technologies to combat the pandemic. The research focuses on COVID-19 and the smart city applications under the smart city mission program in India. It further understands the smart city applications and the technological challenges faced by smart cities. The research summarises the different types of smart city applications correlating the applications to combat COVID-19. The research was conducted focusing on the emerging economies and the lack of knowledge and challenges in adoption of smart city technologies and applications.

COVID -19 Smart City Applications

With the announcement of the Smart Cities Mission (SCM), Narendra Modi, the Prime Minister of India has moved a step towards the digital and technological development of the country. The purpose of the SCM is to drive economic growth and improve the quality of life of people by enabling local area development and harnessing technology especially that leads to smart outcomes (Ministry of Housing and Urban Affairs, Government of India, 2020). The Indian cities need to be developed to provide adequate quality of life and focusing on retrofitting – city improvement, redevelopment – city renewal, greenfield development – city extensions and pan-city initiatives with smart solutions. The purpose of the SCM is to resolve the urban problems through urban infrastructure developed by advancements in ICT based technology. The mission aims to revitalise structural imbalances, create a sustainable city and a liveable environment with economic prospects. The Indian smart cities are working at the forefront in managing the COVID-19 outbreak. Technologies are developed that are being used to monitor the affected areas and maintain a closure on the further spread and a slowdown in the cases with heavy resilience on India's data infrastructures. The smart cities mission is critical in the decision-making process and providing real time data.

Smart City and COVID 19 – India

The Government of India (GoI) has created 100 smart cities and in those cities, the citizens are expected to have high speed internet connectivity along with use of internet enabled devices such as: Internet of Things, sensors, processors, wearables, electronics, software, actuators, vehicles, cell phones and computers thereby operates at the interface to the real world (Mora, et al., 2019). The country is working with smart cities to combat the COVID19 pandemic.

Different smart city applications are garnered to provide cities with better healthcare management, surveillance, Innovative applications, waste management and data management. The Integrated Command and Control Centre (ICCC) set up under the smart city mission in different cities in India, helps in mapping each COVID-19 positive case using Geographic Information System (GIS), tracking health care workers and drawing up containment plan by using heat mapping technologies. The COVID-19 control room managed the tracking of coronavirus patients, lockdown violations, supply of essential items and health supplies. The Ministry of Electronics and Information Technology (MeiTY) – India, has officially launched the new tracking mobile application called 'Aarogya Setu' that aims to alert people in close contact with someone infected with COVID-19. This has been designed to help the government take necessary and timely steps for assessing the risk of the spread of infection and ensuring isolation where required.

Cities are acting and working on best practices during this crisis. For instance, in Bhopal City a microcontroller based Smart Restroom Monitoring System (SRMS) was deployed to monitor the public washrooms to ensure cleanliness, hygiene and social distancing amidst the COVID-19 pandemic. Institutes like Indian Institute of Technology at Madras are working on IoT enabled smart bin system to prevent the spread of COVID-19 through waste generated at vulnerable contagion points such as hospitals, clinics, public bins and quarantine hotspots. Robotics and telemedicine have shone during the virus spread as doctors in facilities around the world have resorted to using robots in isolation units for treatment of COVID-19 cases.

With social distancing a key measure to fight this contagion, telemedicine has emerged as an important technology (Ministry of Housing and Urban Affairs, Government of India, 2020). The Smart Clinic initiative by Pune Smart City provides primary health check-up and diagnosis, free sample collection and lab services and free medicines for common ailments to citizens. Pune city (PCMC) has a dedicated helpline platform SARATHI (System of Assisting Residents and Tourist through Helpline Information), wherein, citizens can request for any assistance with respect to service delivery. All calls received through the helpline are saved as an audio file and documented with respect to the date and nature of request, responsible department and zone, status of closure of request. Cities in Kerala are following the contact tracing of COVID-19 patients involving virus detectives, ground-level human workers who go door to door tracing the movements of positive patients, besides using CCTV footages for clues. Smart Cities like Bengaluru deploy technology, including smartphone apps with geotagging features to ensure strict observance of home quarantine during lockdown. The work started on smart cities in 2015 helped to prepare a foundation to implement digital technologies as a foundation for managing the COVID-19 pandemic.

Smart City - Technology Challenges

Technology innovation is the enabler that improves the possibilities and efficiencies of each smart city project. Each new technology brings with it an enormous new possibility. Since every city has its own culture and infrastructure and funding policies, technology adoption can vary in diverse ways. However, that means it is not always possible to rely on other proven smart city projects to act as a blueprint for success. If smart cities are to become the new normal, local authorities and key decision makers need to navigate such difficult areas as technology, communications, data and security, knowing that costs can be difficult to predict and that the project will grow in complexity. Cities cannot afford to underestimate the internal challenges, such as the need to engage other stakeholders, drive collaboration and break down silos.

With digital revolution, smart cities and smart technologies face ubiquitous amount of challenges. Some of these challenges could be advantageous to technology developers to advance and understand the systems better. Governments and administrators need to look at the policy and decision-making thoughts to improve the smart city services based on the technology challenges.

Interoperability

The Internet of Things (IoT) has become a scalable technology for addressing societal challenges by connecting smart devices and leveraging Big Data analytics to create smart cities worldwide (Ahlgren et al., 2016). With developed IoT devices arises the protocols and standards to be maintained. This scale-up in technology has resulted in the importance of interoperability among numerous devices. Smart applications could be complex with different silos connected to one. Designing data models to use a single platform to provide variety of services is an onerous task for technology developers. Smart Cities need to provide the urgency and applicability of these to domain centric solutions rather than vertical solutions. Connecting different systems and signing up with one vendor or one network to work the systems is the major problem faced in smart city applications. Concepts and techniques need to be developed that facilitate semantic interoperability among existing platforms encouraging open and dynamic IoT systems.

Scalability

Smart City initiatives start at a slow pace and grow fast and scale big. To handle huge amount of data and devices necessitates an ICT technology that is scalable by design. The early adoption of ICT in the context of urban problems has significantly impacted multiple application domains (Del Esposte et al., 2019). Although several of the mentioned systems handle scalable data processing and services, they do not offer an integrated infrastructure to facilitate the development of other smart city applications through facilities that can be shared across multiple domains and services. Scalability varies on the city characteristics and applications and services. However, demonstrating the actual scalability of smart city platforms presents significant challenges due to the lack of available infrastructure for real experimental setups, as well as the lack of comprehensive datasets.

Dependability

Efficient, effective and reliable quality is essential for providing smart city services. Dependability and dependable systems have been discussed in many fundamental research studies. Dependability encompasses the various types of non-functional requirements for designing high-quality systems as well as the means to achieving these requirements and the major threats or impairments in the ICT context (Tcholtchev and Schieferdecker, 2021). The systems, services and processes need to be developed, deployed and monitored. Key security aspects such as availability, integrity and confidentiality play a vital role for urban ICT since only trustworthy processes and infrastructures will be adopted widely. Cities need to be developed with caution as the services are dealing with the real world.

Privacy, Security and Safety – Need of local high-end computing

Smart cities are defined with the concept of being safe and secure for the citizens. Dhungana et al (2015) and Vitunskaite et al., (2019) describes privacy and security within smart cities,

highlights the threats from poorly defined roles and responsibilities of different parties, lack of common understanding of key security requirements not shared between parties, flexibility of privacy policies, anonymity, and data provenance as key factors and risks associated with smart cities. Safe and secure smart cities are need of the hour. During a pandemic like COVID-19, cities and communities are looking for privacy and security and technology related to this understanding is very important for citizens. Better operations decision-making helps provide with privacy infrastructure for smart technologies.

Cities need to be more resilient in the future. Preparedness and planning for better management of resilient infrastructure is the key to developing smart cities. Security and privacy issues, lack of interoperability, legal issues, lack of IoT governance and management support, ethical and societal issues, costing issues, mobility-related problems, complexity problems, lack of reliability and robustness, lack of resources, issues related to data quality and scalability, lack of expertise and knowledge, stakeholder engagement and collaboration issues, technological problems, public awareness and acceptance issues and standardisation and network flexibility issues.

Smart City, Technology, Applications and COVID-19

How collective intelligence and smart applications provide cities and communities with an approach to fight COVID-19?

The research provides a clear understanding on smart city strategies and new developing technologies to provide further challenges which need to be addressed. Advanced digital technologies like sensor and IoT technologies, data analytics and AI are viable tools to assist cities in their efforts to enhance urban metabolism and the design of more sustainable cities (Hamalainen, 2020). Disease outbreak response management solution provides real-time details about the outbreak. Smart cities could plan their resources better when the lockdown solutions are integrated with other solutions such as smart data management, smart surveillance, smart waste management and smart healthcare. Similar solutions could be developed by other cities and other developing countries to overcome the current COVID-19 challenges. Combining people, technology and data to solve the current pandemic and identify new potential infections in future to half the spread of the disease in time.

The analysis of the existing literature highlights that the use of technology to provide the infrastructure and interaction to deliver services to inhabitants whilst developing new platforms alienates the key population. This creates a challenge to innovators, designers and planners to sustain humans in the loop to stimulate the required levels of trust in security and privacy from citizens (Ismagilova et al., 2020). Human factor plays a huge role in the substantial advancement of smart technological infrastructure and implementation of the same. Open sharing with citizens about the spread and management of COVID -19 using the technology and applications provides citizens with the increased public awareness and effectively disseminate disease information. Collaborative models to work between different cities with collective intelligence approaches for managing COVID-19. This provides a valued lesson for how citizens using technology could solve social challenges.

Cities need to be ready with improved solution for a better economic gain. Improved citizen interactions, connected residential communities and creation of smart, efficient workspaces (Elmarghraby, 2013) are the foremost elements that form the technology roadmap for smart

cities in the perspective of COVID-19 recovery for cities and citizens. Collaborative economy in increasing in the need for service from resource delivery by vital suppliers due to social distancing measures. Crowdfunding has seen a substantial improvement to get short-termed targeted funding opened by the COVID-19 crisis. Technology, applications and collective intelligence as a whole process has made it easier for smart cities around the world to fight the pandemic. It also recognises that effective pandemic management by cities relies on critical mechanism as much as it would involve collective intelligence. Coordinated national response, effective governance and leadership, multi-sectoral approach and community involvement (Kummitha, 2020) are imperative factors that are not built on technology to fight the pandemic. With smart city applications providing COVID-19 combating benefits in different parts of the world, Table3 summarises the different smart city applications discussed in the paper, how the smart city applications are used to fight the COVID-19 pandemic and its advantages and limitations.

Table 3. Summary of different smart city applications

Application	**Specific Use**	**Devices**	**COVID-19 Application**	**Advantages**	**Limitations**
Smart Healthcare Management	Health Monitoring	Sensors, smart wearable devices, Smartphones	Robotics, telemedicine, Smart Clinic initiative	Early diagnose the disease	Lack of precision
Smart Waste Management	Efficient waste management techniques	Sensors Cameras, RFID, Smartphones	IoT enabled smart bin system to prevent the spread of COVID-19	Automatic Waste Management Clean Sustainable safe solution	Network dysconnectivity can cause serious interruptions
Smart Data Management	Improved decision making	Smartphones, cameras, sensors	Smart City platform – informed decisions on COVID-19	Awareness in terms of citizen needs	Collection, discretion and security of data seem difficult task
Smart Surveillance	To manage safety and security	Cameras, Sensors, Face detection devices	Contact tracing of COVID-19 patients, CCTV footages, smartphone apps with geotagging features	Helps Monitor Crowds, Readiness for extreme conditions, Reduced Crimes	Expensive Privacy related issues

Conclusion

Smart cities are evolving through technology advancements and growing. The effects of enabling technologies on our lifestyles could be drastic. Smart cities are complex and interdependent and are being developed to improve quality of life for residents. The research paper understands the concepts of smart cities, smart technologies and smart city applications to fight the current pandemic. It further understands the importance of technology advancements and the smart city technology challenges and the role it plays in combating a worldwide pandemic. Resilient infrastructure planning could benefit in combating not just

COVID-19 pandemic but any future pandemics like climate change or biodiversity which would be real in the near future.

The paper focuses on the smart city applications designed by the Indian smart cities mission to fight COVID-19. Technology has played a prominent role in information, prevention and treatment. Data management, health management, waste management and safety converging with technology provides a future inherent to combat outbreaks. Cities are moving towards collective knowledge management to enable smarter approaches to COVID-19. Technology challenges like interoperability, scalability, dependability, privacy and security need to be focused on with appropriate legal regulations and regulatory frameworks. The paper provides a theoretical review on smart cities and COVID-19. It understands the conceptual journey of collective intelligence, cities and COVID-19.

The research findings indicate the importance for policy making, practical contributions and theoretical implications. From a theoretical understanding the paper focuses on the use of technology and applications to solve current and any future pandemic situation. It provides a perspective on the importance of further research and innovation in the field of smart cities. The research implicates an originality in understanding the importance of a digitalised city to provide decision makers and city planners to develop upgraded business models. Smart regulatory frameworks would address issues at different levels from the decision-making at city level to interoperability of devices. From a practical contribution point, the research provides an insight on the importance of efficient, effective and innovative infrastructure development for smart cities. It gives importance on how innovation provides a major step towards developing smart and sustainable cities. Smart Infrastructure, smart governance and innovation economy accelerate the process of becoming a sustainable, smart city.

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