Environment and Big Data: Role in Smart Cities of India

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Abstract: The intention of India's Smart City Mission program is to achieve better living conditions in a sustainable environment with smart solutions. This program identifies the key challenges of urbanization and the environment. The mitigation of these challenges depends on the monitoring and assessment of multiple factors, including demography, education, health, and the environment; however, the inclusion of environmental factors are limited. The monitoring and assessment of environmental factors will continuously generate big data and hence would require scientific and technological innovation for a sustainable management plan. This study identifies six environmental factors, which should be integrated in the development of smart cities. These environmental factors include indicators of landscape and geography, climate, atmospheric pollution, water resources, energy resources, and urban green space as a major component of the environment. This paper also discusses the importance of these environmental components and the maintenance of big data in the management of smart cities.

Keywords: smart city mission; environment sustainability; big data; ICT

1. Introduction

According to the United Nations, by 2050, 60% of the world's population will be living in urban areas [1]. The opportunities for economic and social benefits could be important reasons for the urbanization and movement of people from hinterlands to big cities [2]. This would also increase the burden on the environment and the urban areas' natural resources. The issues that accompany the burgeoning population in cities need an immediate solution to ensure the sustainable coexistence of our society, economy, and environment, which will require a paradigm shift in the management of our cities. Management processes will have to focus on creating unique, innovative, and sustainable solutions [3]. The evolution of the concept of the Smart City has, over the years, comes to be recognized as a way to adapt to the changing dynamics of the present cities.

Traditionally, "Smart City" has been widely used to refer to innovative, technology dependent, sustainable, efficient, and livable cities of the future [4]. Information and communication technology (ICT) and big data has been identified as the most important component, as it integrates information from the rest of the components to help in the decision-making process of the management of smart cities [5]. In smart cities, ICT and big data provides the integration of developed infrastructure, consisting of data from public services, authoritative sources, society, and the participation of private sectors to gain a better understanding for better decision-making for various services. However, it has been accepted that there is no universal definition of "smart cities" [6]. According to Dameri

(2013) [7], smart cities follow a "bottom-up" approach, suggesting that the concept of a smart city is oriented towards local needs and challenges rather than global, as each smart city may have its own environmental and socio-economic structure. Six dimensions of a smart city have been identified in the literature; a smart economy, smart people, smart mobility, smart governance, smart living, and smart environment [8,9]. Making cities sustainable, along with an improvement in quality of life through use of ICT in our daily life, have been identified as key objectives of smart cities [3,9,10].

According to the World Cities Report (2016) [11], cities should focus on creating a just environment to ensure justice and equity for an improvement in our quality of life, and also for a sustainable development. Making cities just will require focusing on things such as equal access to resources, poverty alleviation, disaster and hazard management, land use to reduce biodiversity loss and deforestation, and creating a low-carbon and energy-efficient society. The above goals have been integrated from the sustainable development goals, and goal number 11 particularly focuses on making cities more sustainable and livable [12,13]. However, creating sustainable cities will need to use big data to overcome the dynamic challenges of cities [5,14,15]. Use of big data, generated from environmental and socio-economic sources, has the potential to prepare a better disaster plan, ensure equitable distribution of resources among people, to improve the livability of cities, and to provide a rapid response to a changing environment [16].

The growing population and burden on the scarce resources of Indian cities has led to several social and environmental problems [17,18]. The management of infrastructure and resource needs of the urban areas imposes several challenges on policy makers and governments [19]. These challenges include governance, greenhouse gas emissions, lack of infrastructure, unemployment, high waste generation, unplanned land use, ecosystem degradation, and loss of green space [17–19]. Recognizing the immediate needs of the urban areas of India, the Indian government created the Smart City Mission [20]. However, after the announcement of the Smart City Mission, there has been limited literature on understanding the need for integration of the environment and big data [21].

The objective of this paper is to assess the integration of big data technology and environmental components in the Smart City Mission of India. Hence, for the purposes of this paper, the authors have considered smart cities as being a technology-driven urban area to overcome environmental challenges. This paper has been arranged in the following format to address the said objective: the second section of the paper addresses the inclusion of big data and environmental components in the Smart City Mission—for this purpose, key words such as "big data", "IoT", "ICT", "environment", "green space", "climate change", "air pollution", "energy", "water", and "land" were searched in the Mission Statement and Guidelines document [20]; the third section identifies the well-recognized environmental components of smart cities from recent literature and discusses the need of integrating these with big-data opportunities to achieve environmental sustainability in the smart cities of India.

2. Big Data and Environment in Smart Cities of India

2.1. Smart City Mission: Objectives

Recognizing the importance of smart cities for the country's development, the Indian government has initiated a Smart City Mission to provide basic infrastructure to ensure quality of life, a sustainable environment, and "smart" solutions to the current issues in our cities [20]. The main objective of the Smart City Mission of India is to develop a core infrastructure of water and electricity supply, solid waste management, improved urban mobility, e-connectivity for governance and services, monitoring for public safety, health and education, and a sustainable environment. The overall aim is to achieve efficient space management with access to physical and social infrastructure for the public. The above goals will be achieved through implementation of institutional sustainability, maximizing efficiency and public participation. Each Indian smart city, announced in 2016 under the first phase of the Smart City Mission program, has a population of one million and above [22]; hence, the governance and availability of resources is likely to become a major concern in these smart cities [18].

2.2. Big Data in Smart Cities of India

Big data use involves ICT, and the Internet of Things (IoT) can be used extensively for management and planning in smart cities [15,19]. It is important to focus on collection, segregation, filtration, and gathering tangible information from big data. IoT is an important part of the big data initiative, where it helps in the intercommunication of devices and environmental monitoring. Big data sources have been successfully integrated into various aspects of environment, such as in the monitoring of air pollution in China, Zurich, and Serbia [23–25]. In India, various studies have proposed its usage in healthcare and epidemic surveillance [26], e-commerce [27], and traffic management [28].

The use of key terms, such as "big data" or "IoT", is absent in the mission statement and guidelines of the Smart City Mission of India, while "ICT" appears only once in the text. This is reflective of limited planning in regard to the inclusion of big data opportunities in smart cities. However, this document does include usage of ICT in e-governance and public participation. The use of ICT for environmental management is only limited to water management, while the rest of the environmental components are neglected. Research in big data initiatives and its use in the environment are in a nascent stage in India [29]. The challenges regarding big data needs in India include the following: (i) lack of communication and data-sharing between government and private entities; (ii) data-mining and extraction of meaningful data from various sources; (iii) utilization of meaningful data for policy planning and governance.

2.3. Environment in Smart Cities of India

Under the Smart City Mission of India, a city is selected as a smart city if it satisfies the basic criteria on the grounds of its transportation system, water availability, water management, solid waste management plan, safety and security, energy availability, and housing situation [22]. However, despite the well-recognized importance of environmental components in smart cities [11,12,29–31], the Smart City Mission has very limited environmental parameters in its selection process [20]; for example, there is no mention of key terms such as "green space", "biodiversity", and "climate change" in its mission statement and guidelines [20]. The term "environment" appears four times and "air pollution" only once in the document, while "energy", "water", and "land" is mentioned numerous times. A comparison of sustainability indicators of the Smart City Mission with the United Nations Department of Economics and Social Affairs (UN DESA) indicators of sustainability, including environment, economy, equity, and implementation, shows a lack of focus on environmental sustainability in the Smart City Mission [21]. UN DESA includes six components: natural hazards, atmosphere, water, ocean seas and coasts, biodiversity, and land, while the Smart City Mission only identifies three components—energy, atmosphere, and water—as indicators of urban environmental sustainability [21].

3. Environment and Big Data: Opportunities for the Smart Cities of India

Smart cities aim to make their cities sustainable [3,9,10]. Hence, authors suggest the inclusion of the following environmental components, as these have been identified as key components of sustainable cities in the World Cities Report 2016 [11] and sustainable development goals (SDGs) [12], which are: (1) Land and Geography, (2) Climate (3), Atmospheric pollution, (4) Water Resources, (5) Energy, and (6) Urban Green Space and Biodiversity.

3.1. Land and Geography

With ever-growing demands of housing, agriculture, roads, and industries, land will be one of the most crucial components in making cities sustainable [32]. Climate-change adaptability and food security will be one of the primary challenges which need to be addressed through land-use management [33]. Geography is a limiting factor in land development and the management of cities. Understanding the geography of the land will be of paramount importance when planning sustainable

cities [34–37]. Smart cities of India are to be located in diverse geographies [22], and hence the "one-size-fits-all" method will not work in land management. The management of each city will need its own planning to overcome the challenges posed by geographical conditions. For example, cities located close to desert areas will face challenges of water scarcity and particulate matter pollution; hence, the management policy of such cities will need to focus particularly on efficient water-harvesting technology and control of particulate matter pollution. However, management will require big data on relief, soil, rock, land use, disaster vulnerability, historical land uses, and social dynamics of the land (see Table 1). This large collection of data will include research-based data, monitoring data, Geographical Information System (GIS) data, and official records. This big dataset should be utilized for land evaluation processes for the development of Sustainable Land Management (SLM) [38]. This land management plan should be based on the Framework for Evaluating Sustainable Land Management (FESLM). The management of smart cities should include developing a database, such as the World Overview of Conservation Approaches Technologies (WOCAT) global data, to evaluate the cost benefits of SLM. WOCAT has been useful in the cost-benefit analysis of Sustainable Land Management Technologies [39].

Table 1. Data sources of environmental components in smart cities.

Source of Data	Environment Component	Indicators *
Geographical Survey of India	Land	Relief, Elevation, Contour Maps
Indian Agriculture Research Institute	Soil Quality	Nitrogen and other nutrient content, pH, soil fauna
Geological survey of India	Geology	Rock composition, geological stability,
Indian Meteorological Department	Climate	Temperature and Rainfall
NASA	Productivity	Biomass production
Central Ground Water Board	Ground Water	Water Table
CPCB	Air Quality	Ozone, GHG, PM, Pb, AQI, Aerosol
CPCB, Local Water Board	Water Quality	DO, BOD, pH, Heavy Metal
World Energy Council	Energy	
Electricity Boards		Bioenergy, Coal, Hydropower, Solar, Nuclear
Ministry of Energy		
Global Forest Watch	Green Space and Forest	Tree Cover, Forest Cover,
Forest Survey of India		Areas under garden and parks,
Municipal Corporation		Plant diversity, bird diversity,
Local Forest Department		Insect biodiversity
		LULC,
Research Articles	Miscellaneous	Biodiversity,
		Invasive Species

* These indicators are commonly used by international/national or local agencies for the purpose of environmental monitoring. Abbreviations: NASA: National Aeronautics and Space Agency; CPCB: Central Pollution Control Board; GHG: Green House Gases; AQI: Air Quality Index; DO: Dissolved Oxygen; BOD: Biological Oxygen Demand; LULC: Land Use Land Cover.

3.2. Climate

According to goal number 11 of the SDG's, future cities need to implement policies that will make cities more climate-resilient [12]. These cities will need mitigation measures to reduce air pollution, urban heating, and vulnerability to natural disasters. Smart cities of India are located in variable climatic conditions, and hence are prone to different climatic challenges and risks [22]. Understanding these risks should be the first priority of smart-city managers. In order to devise policies to mitigate the effect of climate change on cities, climate data from global and local organization/institutes will be needed. Historical and present climate data are both crucial in planning, and hence, climate information should include real-time, as well long-term monitoring data on changing climatic conditions [40,41]. Information on the cities' climate will primarily be needed in regard to rainfall, temperature, humidity, evapotranspiration, and wind velocity. These can be obtained from the Indian Meteorological Department (IMD), the National Aeronautics and Space Administration (NASA), and the Indian Space Research Organisation (ISRO). A few of the cities are already doing real-time monitoring of the climate for purposes of devising policies [42].

3.3. Atmospheric Pollution

Major cities are continuously facing the challenges of air pollution which blanket it from time to time. Air pollution is often caused by a lack of policy and forecasting in transportation, industries, energy use, and waste generation. The polluted air is known to affect large populations throughout the world. According to a World Health Organization (WHO) report, more than seven million people die prematurely due to air pollution each year [43]. India has one of the highest numbers of people affected due to air pollution in the world [44]. The rapid increase in population and its unsustainable policies had made cities in India amongst the most polluted in the world. It is imperative to know that a healthy body can be more productive and be an asset to society and the economy. Smart cities in India needs to have better policies and frameworks for tackling air pollution. Continuous monitoring, identification of sources, and finding solutions to air pollution is a prerequisite for creating sustainable smart cities.

Institutions such as the Central Pollution Control Board (CPCB) and the State Pollution Control Board (SPCB) should have an adequate number of monitoring stations, and the Air Quality Index (AQI) should be maintained continuously. Satellite data can also be used to obtain more information about atmospheric changes, western disturbances, and also regarding areas adjoining smart cities. Many agents or pollutants combine with other entities in our environment to give rise to smog or acid rain, which can travel long distances [45]. Such pollutant movement, if predicted in advance, can help the authorities in suitable actions to control the negative impact of the pollutants. In smart cities, air pollution can be reduced effectively using green transport, separate lanes for bicycles, more green-belt areas, more renewable energy, and discouraging burning of municipal and agricultural wastes. The rapid collection of big data, modeling, analyses, and forecasting, and converting it to tangible information is important for the benefit of the smart city citizens.

3.4. Water Resources

Water is known to be one of the most important natural resources, and in the wake of global climate warming, its sustainability has become one of the biggest challenges of the 21st century. The decade from 2005–2015 was celebrated as the "International Decade for Action 'Water for Life'" by the United Nations, indicating the relevance of the question of water availability for our survival in the future. With the changing climate pattern around the globe, studies have shown that 25 per cent of the world's river basins are running dry before reaching the oceans [46]. The over-sharing of water in the world has become an important component of international relations, and India is known to be depleting its surface water resources at a much faster rate than other countries [47]. Water fulfillment is one of the main necessities of peri-urban and urban societies; scarcity of water can have catastrophic effects on country's economic and living conditions [48].

The depletion of ground water tables, pilferage during supply, and issues of economic valuation and allocation for agriculture and households are the major challenges that smart cities are going to face. It is important for smart cities to try and be water-sustainable and to look for various avenues in doing so. Watershed management, maintenance of wetlands, renewal of step wells, and water harvesting are some important measures that are needed in India [49]. It is essential to use limited water judiciously, and the onus should be upon the various governmental bodies responsible for collection, maintenance, and supply to the needful. Citizens should be made aware about the importance of water, the need for its conservation, and keeping water bodies clean. Organizations like the Central Ground Water Board (CGWB), water resources department, irrigation and flood control department, and Ministry of water resources, river development, and Ganga rejuvenation should work in tandem to conserve water resources.

3.5. Energy Resources

The influx of a huge urban population is going to generate huge energy demand for housing, lighting, transport, and water management. India needs to fulfill the demands of this urban population, where energy management could prove to be a crucial point. Per capita energy consumption is known to have a strong correlation with the human development index (HDI) [50]. With the formation of 100 new smart cities and power to all by year 2022, India's target is to generate 175 GW of renewable energy, which can be used mainly for fulfilling the energy demand in smart cities [51]. The reliance on green energy for most of the demand fulfillment, as well as efforts at trying to minimize the carbon footprint, could turn out to be an arduous task if not carefully planned in advance. The promotion of electric vehicles for transport, use of photovoltaic panels (PVCs) for street lighting, and other avenues like commercial space is important. The other important role of smart cities could be to decrease the demand of energy. The green building concept should be promoted to reduce energy consumption. World over increased construction using asphalt for roads and other concrete structures has led to the formation of urban areas where the average temperature is much higher than their surroundings, which is also known as urban heat islands (UHIs) [52]. Energy consumption in the cities needs to be in balance with its surroundings and the environment. Planning needs to be done in advance by gathering information using ICT, communication, and various platforms, and for it to be in sync with state electricity boards, the Ministry of Power, and the Ministry of New and Renewable energy. The energy generation in the smart cities of Singapore and major cities in China could be studied and used as models for planning out energy efficiency, as they have succeeded in lowering their carbon footprint [53,54].

3.6. Urban Green Space

Urban green space (UGS) is important in providing several ecosystem services [4,55]. UGS includes natural forests, grasslands, wetlands, parks, and gardens. The conservation and maintenance of UGS ensures equity and environmental justice through ecosystem services [56]. These ecosystem services range from fisheries, agriculture, carbon sequestration, health benefits, tourism and recreation, pollination, air purification, wetland and water purification, urban cooling, and noise reduction. The above ecosystem services are very useful in overcoming several problems that come with cities.

Nearly 27% of the total Gross Domestic Product (GDP) was spent on health due to air pollution in India [57]. UGS can significantly reduce the impact of air pollution on people. Vegetation removes air pollutants, including ozone, sulphur dioxide, nitrogen dioxide, carbon monoxide, and particulate matter from the atmosphere [58]. One major problem in smart cities will be noise pollution, which can easily be mediated through the well-planned development of urban green spaces. Plants and trees can absorb, reflect, and deviate noise pollution [59]. Wetlands will also be helpful in controlling floods, providing fisheries, and buffering municipal wastewater. The natural forest is a native gene bank for plants and other biodiversity, and hence will be useful in the restoration of a degraded ecosystem, as well as for the development of new urban green spaces [60]. Planning and development of UGS must be done through scientific and social evaluation; random and uneven development of UGS may lead to ecological or social problems.

The planning and designing of UGS will require data of a social, ecological, geological, geographical, and biological nature. Social data will involve demography distribution and the need for UGS. Scientific information will be needed to plan and design UGS. One example of scientific development of UGS is biodiversity parks in Delhi [61]. Tools such as Global Forest Watch, Wetland Atlas, and GIS will be useful in planning. Information on plants, animals, and micro-fauna can be obtained from published research, forest departments, and local research institutions.

4. Conclusions

The growth of smart cities in the future will depend on the success of the inclusion of big data and the management of our resources for society's use. The importance of our environment and its dependence upon ecosystem services means that it needs to be sustainably managed. Efficient use of environment is going to need good evaluation, monitoring, feedback, and policy formulation, which is only possible through meaningful information. Information on the environment of smart cities can be obtained from several international, national, and local authorities or agencies. Information collected will be big, and will thus require technological expertise for it to be processed. Prior to establishing infrastructure for smart cities, the formation of data centers is paramount, which will lead to the identification of problems and also help in providing solutions. A continuous monitoring system of land use changes, water quality, green space, and energy consumption should be made public through an online platform to ensure that the society is also able to participate.

There are several technological and environmental challenges, which are obstacles to the success of the Indian smart city mission [19,20,22], where policies are still lacking but are essential for each smart city. The first challenge is how presently undervalued environmental components, such as geography, climate, and green space, can be clearly defined and how they can be included in the criteria of the smart city mission for the identification of smart cities. Secondly, in view of increasing natural hazards and climate-related challenges, how to find an equitable way of using resources and provisioning for the future is another challenge which should be the core of the formation of smart cities.

It is imperative that we include various components of the environment's ecosystem, as these parameters provide a holistic view to the Indian mission of smart cities. A majority of the cities are already reeling under the stress of high pollution, and are amongst one of the most polluted cities in the world. As the majority of the Indian population will be living in cities in the future, the Indian government needs to make preparations in regard to the equitable use of resources to promote sustainable development. This initiative would require inclusion of the parameters discussed in this paper as a vital component of smart city governance, as well as the generation of real-time spatial and temporal data. The digital ecosystem, consisting of big data, ICT, and IoT, should be integrated into our natural environment, which could well make the Smart City Mission in India a success.

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