A comprehensive study on smart cities: recent developments, challenges and opportunities

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Article Info	ABSTRACT
	This paper presents the importance and applications of smart cities in view of taxonomy in urbanization particularly in Asia and Africa economies. It describes the characteristics and architecture of smart cites and reviews on the recent technological developments. The paper analyses the social impacts due to up-gradation of existing cities. The implementation goals like policies and standards are still in progressive state. The international organizations like IEEE, ISO, IEC etc are focused in this emerging area and prepared road map for successful deployment of technologies in cities. In this way of development, there are some interesting challenges like visualization, integration, privacy etc, need to be addressed with specific and innovative solutions. The paper highlights the opportunities in developing and governance of smart cities.

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1.   INTRODUCTION

As per world energy outlook 2017, it is estimated that the global population is going increase to 9.1 billion by 2040; whereas the same is 7.4 billion in 2016 and this problem will affect the growth rate of global gross domestic product (GDP), which is less than 5% per year currently [1]. The statistics from various valid sources say that fifty percent of the world population is living in cities and the number is going to double by 2050. Of course, the urbanization growth rate is slow in Asia and Africa when compared to western countries [1]. Due to increment in population of cities, the following basic needs are also to be increased with better improvements; food, water, energy, home etc., which are already problematic issues in the current scenario. Moreover, the high cost of living, increment in crime rates, exponential growth of data, community clashes, large investments in infrastructure etc. will become as important challenges to be addressed in the near future. This situation opens up significant opportunities to develop necessary infrastructure and technology for building a smart and sustainable society. In 2013, Guadalajara at Mexico was selected as the first city for the reason of establishing an organization called Ciudad Creative Digital (CCD) to drive the transition to a smart city [1].

The smart city idea centers on utilizing technologies and data that permit government and stakeholders to make connected live able and sustainable urban areas. The drive for smart urban communities has quickened as the remarkable quality of diminishing society's carbon impression has expanded, especially in a way that can give natural equity. Connectivity refers to using smart gadgets and data to provide the best clever metropolis solutions. Livability complements give a superior private pride for metropolis population by giving access to an agreeable, secure, and sound way of lifestyles. Improved workability implies to positive financial improvement, i.e., more and better jobs, wherein valued factors consist of clean and reliable energy, resilient infrastructure, and efficient transportation. More desirable sustainability approach giving

citizen's access to the sources they want in a sustainable way. Alternative energy sources, progressed physical infrastructure, and energy performance are few of the crucial elements of sustainability. The overlap of these three focus areas represents a sweet spot for smart town projects [2].

Key layers and design of a smart city include latest advancements and smart infrastructure framework which shapes the establishment of purpose. ICT infrastructure is the core layer on which every single other part depend. Smart foundation involves fast wired and remote system network, top of the line server farms, physical space improvement with smart gadgets, sensors, actuators and considerably more. Smart Government layer support the advancement of vital associations among different improvements of open part association [3]. This layer details the approaches, enactment, standards and controls to enhance the systems and execution of government associations, organizations and offer potential advantages to nationals. Contingent on the foundation and approaches defined at e-administration layer, different open administrations will be offered to residents and other partners, in a proficient and viable way, universally [4].

Customarily, the administration association and offices working freely share just a restricted measure of data with different offices in general city. ICT framework advances the work in different divisions concentrates just on its task. This technique for system brings about disorder and deferral in usage and execution of national administrations. Residents confront hardships where data from various offices is required. Each self-reliant submachine is hooked up to central data management system (CDMS), which is integrated and interconnected with all sub systems. Each subsystem collects facts from one of a kind zone throughout the metropolis. Traditionally, town is split in zones for administration and each zone ha its very personal public issuer workplaces. The proposed structure suits properly on this kind of scenario wherein public provider and utility has a zone example. A region internet site is an environment that offers processing, garage, networking, management of data inside vicinity [5]. A smart town ought to utilize information technologies to:

a)   Make more proficient utilization of physical framework (streets, fabricated condition and other physical resources) through man-made brainpower and information investigation to help a solid and sound financial, social, social advancement.
b)   Engage viably with neighborhood individuals in nearby administration and choice by utilization of open advancement procedures and e-support, enhancing the aggregate knowledge of the city's foundations through e-administration with accentuation set on resident interest and co-plan.
c)   Learn, adjust and advance in this way viably and instantly for changing conditions by enhancing the knowledge of the city.
d)   Make more productive utilization of physical foundation (streets, fabricated condition and other physical resources) through computerized reasoning and information investigation to help a solid financial and social advancement.

Engage viably with neighborhood individuals in nearby administration and choice by utilization of open advancement procedures and e-cooperation, enhancing the aggregate knowledge of the city's organizations through e-administration with accentuation set on subject interest and co-outlines [6].

The remainder of this paper is organized as follows: Section 2 presents the detailed description of smart cities technologies. The integration and transformation of smart cities is described in Section 3. Section 4 presents the operation and maintenance of smart cities. Opportunities and applications described in Section 5. Finally, conclusions are described in Section 6.

2.   SMART CITIES TECHNOLOGIES

Advances in new innovation are utilized to enhance city applications and administrations. There are correspondences, scientific and control advances that allow changing the method for getting things done while impacting better arrangement and urban administration. Underneath sections featured the part of little cell innovation in savvy urban communities – there is the possibility of "expanded broadband abilities, enhanced adaptability and simple sending of versatile multi-benefit arrange models" [7].

The wireless sensor network (WSN) comprises of a gathering of heterogeneous and spatially scattered self-ruling sensors conveyed in expansive numbers either inside the marvel or near it. The WSN is developed from countless sorted out into a helpful system, where every hub is associated with one or a few sensors. These sensor hubs have the ability to gather and process information, every hub can self-ruling detect, process, and convey information about its prompt condition to other adjacent hubs and PCs. Remarkable qualities and imperatives for sensor systems: thick hub sending, battery controlled sensor hubs, serious vitality, calculation, and capacity limitations, self-setup, application particular outline necessities, problematic sensor hubs, visit topology change, many-to-numerous activity design, information repetition, and nonexistence of worldwide tending to plot. The reason for these systems is observing and recording of physical or ecological conditions, for example, temperature, sound, weight, and so forth., and to agreeably go related information through the system to a principle area [8]. Similarly as the Web

enables access to computerized data anyplace, sensor systems will give huge ranges of continuous, remote collaboration with the physical world. Dispersed knowledge from the sensor to the system will move toward becoming as basic as the web - remote sensor systems give the open doors for the grouping of information which is fit for the reason supporting the production of savvy urban areas. Each from a couple to a few hundreds or even a large number of hubs in the system comprises of handling capacity given by at least one programmable microcontrollers for controlling hub conduct and preparing information. Propelled innovations have permitted little organization, battery-controlled, sensor-empowered PCs, which can play out the capacity of sensor hubs that could be worked effortlessly. These sensor hubs could hence be built up from these small coordinated gadgets, which fill in as a methods for detecting, information handling, and imparting, use the possibility of sensor systems set up on a synergistic exertion of an expansive number of hubs. This subsystem incorporates different sorts of memory, a radio (RF) handset for correspondence with an inner reception apparatus or association with an outside receiving wire, an electronic circuit for interfacing with the sensors and an on-board bate pack for control [9-10].

The internet of things (IoT) is a trending intercommunication paradigm that envisions a close to future, wherein the devices of regular lifestyles might be geared up with microprocessors, micro-controllers, digital signal processors (DSP), trans-receivers and clouds for digital communique, and appropriate protocol stacks so as to lead them to able to communicate with each other and with the users, turning into an integral part of the internet [11]. The architecture of IoT technology based on smart cities includes sensing layer, data layer, interconnecting layer and application layer. The function of sensing layer is to realize ubiquitous sensing. Apart from RFID, it's sensing enabled by WSN. People-centric urban sensing is recent functioning sensor technology which includes personal sensing, social sensing, and public sensing. A popular communicating device i.e. smart phone is equipped with various sensors such as camera, compass, accelerometer, GPS and ambient light. Further, a new community sensing technology called Mobile Crowd Sensing is emerging [12-14].

2.1. Smart meters

Smart meters with inbuilt IoT technology can improve leak detection and enhance productivity by reducing time consumption in data entering and analyzing [15]. A typical artificial intelligence (AI) perceives its surrounding environment using its large-scale and deep learning brings into implementation with aid of reinforcement learning and robotic devices that maximizes its chance of successfully achieving goals [16-18].

2.2. Healthcare

Artificial Intelligence is influencing its effect in health industry. For diagnosis and treatment procedures in hospitals, AI is playing a significant role by reducing the need of multiple machines and equipments and bringing cost down [19].

2.3. Smart transportation

The main objectives of smart transportation include:
a) Perceive traffic patterns by exploring real time data.
b) Lessen principle city streets blockage by foreseeing movement conditions and modifying activity controls. Through big data, the smart city will have the capacity to reduce traffic and mischances by opening new streets, upgrading and enhancing the infrastructure based on congestion data, and collecting information on car parking and alternative roads.
c) Diminish store network squander by partner conveyances and upgrading shipping developments.
d) Empower information spilling to process and impart movement data gathered through sensors, smart traffic lights and on-vehicle gadgets to drivers by means of smart phones or other communication devices.
e) Big data can be utilized to send input for particular elements to make a move to ease or resolve an activity issue [20-21].

Device to device communication (D2D) technique goes about as an essential strategy to advance the city's green smart improvement. The uplink sub-carrier task [SA] and power designation [PA] issue in single-cell D2D hidden cell organize, intends to limit the vitality cost of the considerable number of clients in the framework while ensuring the required throughput of both gadget client hardware and cell client gear, by this a completely dispersed substance conveyance framework was composed in a basic and effective way, in which every gadget just uses neighborhood data to settle on choices and execute its own particular plan independently. This Innovation is gainful in vitality proficient substance conveyance framework by means of the D2D interchanges for brilliant urban communities [22].

In wireless powered sensor networks for harvesting the optimal energy beam forming and time task in radio recurrence vitality gathering remote fueled sensor systems for shrewd urban areas, where sensor hubs first reap vitality from a sink hub, and after that transmit their gathered information to the sink hub by means of time division various access (TDVA) way by utilizing the collected vitality. Furthermore additionally to accomplish

green framework outline, the minimization of vitality necessity for the sink hub to help the transportation between sink hubs and sensor hubs under information cum imperative and vitality collecting requirement this innovation advances savvy condition, shrewd vitality, and smart human services and brilliant network [23].

Machine learning (ML) prepares PCs to learn and decipher without being expressly modified to do as such. In machine learning PCs are presented to new arrangements of information, they as needs be adjusting autonomously and gain from prior calculations and decipher accessible information and distinguish and speak to concealed examples. This is finished utilizing information examination and computerization of scientific models utilizing particular calculation. ML empowers PCs and figuring machines to scan for and recognize shrouded bits of knowledge, without being customized for where to search for, when presented to new data indexes. Machine learning in smart cities use real time inputs analyze and interpret them and accordingly to apply to real world applications in smart city [24].

2.4. Smart energy

Machine learning is as of now being utilized as a part of the vitality division to advance power matrices and could bolster decarburization by giving utilities all the more wisely. For instance, the home learning indoor regulator utilizes machine figuring out how to take in a mortgage holder's inclinations and timetables, upgrading home warming and cooling. This 'home knowledge' may likewise goad changes in utility plans of action, implying that clients could pay for administrations, for example, versatility, solace and tidiness instead of items like power, gas and water [25].

Because of the quick increment in the populace development rate step by step brings about increment in methods for correspondence along these lines bringing about increment of number of cell phones, customary concentrated distributed computing is attempting to fulfil the nature of service for some applications. With 5G organize innovation upcoming, edge figuring will turn into the key answer for comprehending above issue. One of significant difficulties related with 5G innovation is the radio-access network (RAN). In RAN, portable edge registering gives continuous data. By utilizing the ongoing RAN data, the system suppliers can enhance nature of experience for end clients, since constant RAN will offer setting mindful administrations. As it is specified previously, the edge figuring stage permits edge hubs to react to benefit requests, decreasing data transfer capacity utilization and system inertness. Along these lines, the system administrators can execute this running into the edge to be taken care of by outsider co-administrators, quickly expanding the sending of new applications. Then again, the calculation hubs are working under various outsider co-administrators, making it hard to send comparable security plans to guarantee a similar level of security. In this manner edge registering could be the arrangement of security challenges for shrewd city [26].

3.   INTEGRATION AND TRANSFORMATION

A smart city system influences from the current lawful, monetary and specialized condition and affects the social and administration perspectives in a supportable way, and it has been shown in Figure 1. Setting a smart city vision and adequately moving towards it with a frameworks based approach is basic to guarantee ideal asset effectiveness and security, alongside protecting socially comprehensive development. Based on the features considered above, an integrative structure is conceptualized that clarifies the connections between these elements in a more rational manner [27].
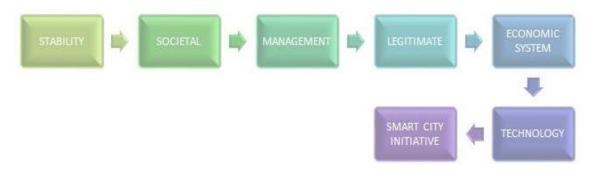

Figure 1. Auto transformation of a smart city

These variables empower both general society and private segments to plan and actualize smart city activities all the more admirably. These components give a premise to coordinating how extraordinary urban communities are visualizing their smart activities, utilizing shared administrations, and the related difficulties. This structure additionally examinations the real effect of various factors on the accomplishment of smart city activities. The system demonstrates that each factor is both influencing and getting influenced by each other factor. It likewise shows that a few elements might be more powerful than the others relying upon the specific circumstance. The system can be bifurcated in two levels. The inward level comprises of the components which have more noteworthy effect on the savvy city activities. This comprises of innovation which is the establishment of smart urban communities [28]. The external level components are the ones which may get affected by the internal level before affecting the smart city activities. This incorporates administration and the socio adjust of the network separated from manageability which ought to be the premise of any advancement [29]. The outline demonstrates the streams took after by urban areas in view of the change factors recognized. The multifaceted nature, financing and smart goal factors are normal to stage. This investigation of the savvy change procedure of urban areas enabled to:

a)   Recognize the components that influence the change of urban communities.
b)   Make an essential framework to quantify how quick urban communities build up that incorporates conventional task based estimations and an exhaustive structure estimation (settled estimation frameworks).
c)   Demystify the gigantic speed of the progressions that are occurring globally including smart wonders.
d)   Demonstrate that the administration is fundamental to the smart change of urban areas.
e)   Broadly expound on every one of the change factors and sub-components to build the determination and investigation ability.
f)   Measure the proficiency of the change as far as venture, amortization and return.
g)   Concentrate how data influences every one of the stages. In particular, it will take a shot at models that characterize the data that is applicable to the advancement of a city.

It may have been excessively interested in reporting, making it impossible to the whole world how smart our urban areas are and the amount they have been changed. It's abruptly in a rush to change, and to do as such on time scales that are preposterously short. Take, for example, the city of Paris, which in 1800 spread out the change venture that gave us the glorious city we presently appreciate, however in which it contributed almost twenty years. Or on the other hand consider the megacity of New York would have been if the lung that is focal stop had not been arranged at its inside. Urban communities are made awesome not just by what number of individuals live in them, by their size or by how much innovation they have executed; rather, they are made extraordinary by the vision of their pioneers and organizers, who knew to actualize an appropriate model. There is still much to do before viewing our urban communities as savvy: gigantic sending of the IoT, solidification of city working frameworks, interoperability arrangements, and proficient data administration. It appears to be more sensible to ponder pretty much nothing or how far we have progressed in what will fundamentally be a long haul process [30]. Table 1 demonstrates the Low/Medium/Completely Savvy cases, considering just the stages included and accepting a blended level of coordination [31].

Table 1. Coordination level of smart city

Phase	Transformation Factor	Transformation Sub Factor
Organization		conventional coordination
	Level of coordination	Smart coordination
		Assorted coordination
	Intricacy	---
	Financing	---
	Smart Destination	---
Scheduling	SWOT	---
	Models	---
	Standards	---
Implementation		Face-to-face services
	Services	Electronic services
		Unlocked services
		Smart services
Cross-cutting		Assortment
	Information	Open Data
		Big Data
Cross-cutting	Technology	E-government
		Platform City OS
Measurement	Conventional measurement	---
		Inclusive measurement (Measurement Framework)
	Project Indicators	Indicators Problem-Solution
		Scope of the smart solution People's assessment

4.   OPERATION AND MAINTENANCE

Moving towards smart structures is less demanding said than done. Making incremental ventures without an unmistakable perspective of the return on initial capital investment and breakeven period is a vital test and inhibitor of smart building apportionment. Furthermore, it is as yet thought to be 'something to be thankful for to have' as opposed to fundamental by most planers and engineers, in light of the fact that there are no reasonable orders to push the smart building idea [22]. Table 2 comprises of urban communities vitality necessities are intricate and bounteous. In outcome, current urban communities ought to enhance exhibit frameworks and execute new arrangements coordinately and through an ideal approach, by benefitting from the collaborations among all these vitality arrangements. Reproduction models have been produced to help partners in understanding urban elements and in assessing the effect of vitality approach options. In any case, all the time these endeavors address vitality zones independently, deficient with regards to the 'full picture' and, along these lines, creating problematic arrangements. A complete smart city display that incorporates all vitality related exercises while keeping the size and many-sided quality of the model reasonable is exceptionally alluring so as to effectively meet the expanding vitality needs of present and future urban communities [22].

Table 2. Operation of a smart city

Goal	Local/Federal Government	Technology and Domain Suppliers
Ease of CO_2 emissions	State, federal directives; citizen demands	Corporate social responsibility
Reduce energy usage	Cost reduction, resource conservation	Corporate social responsibility
Improve maintenance resorce deploy ments	Staffing cost regulation; quicker time to issues	Long time upkeep contracts
Visibility into operation	Handle changes formore productive operations	Opportunity to upsell innovations, streamlining prepare and strategies and administration of buildings
enumerate energy proficient efforts	Meet citizen demands and city targets	Monitor progress towrds csr/sustainability goals
Improve predictibility of energy and resorce needs	Better budget accuracy and financial and resorce planning	Enabling automation and analytics platformsto support predictive analytics

Vitality framework models have been around for a very long while and are encountering steady development to fuse new advances, ideal models, and externalities, (for example, natural concerns). For the vitality point of view just, this sort of model is usually utilized for control framework arranging or for activity and administration. A case of the previous which shows a model for circulation organize extension arranging, thinking about the estimating, arrangement, and timing of appropriated age speculations and system fortifications. The task of intensity frameworks can be exemplified where a smart matrix is reenacted in light of programming operators; the reproduction endeavors to reproduce the dynamic conduct of a smart city, yet it thinks about just power. Different illustrations can be found in the conveyance organize activity ventures supported by the European Commission. As indicated by electric framework displaying is regularly completed utilizing a type of stochastic programming, which includes limiting a target work subject to specific limitations. Be that as it may, different methods in view of man-made reasoning, hereditary calculations, amusement hypothesis, are likewise accessible [22].

5.   OPPORTUNITIES AND APPLICATIONS

Presently, many towns compete to be smart towns in hopes of reaping some of their advantages economically, environmentally and socially. As a result, might are eying the opportunities made possible by using the usage of huge inputs analytics in smart town applications. Consequently, it will also discussed here some of the advantages, opportunities and applications that could assist in making the choice to transform or remodel a town to emerge as a smart town. With such decision, it could be possible to acquire enhanced degrees of sustainability, resilience, and governance. Further to enhancing the citizen's high-quality of lifestyles and introducing wise management of infrastructures and herbal sources [7-9]. A number of the blessings of getting a clever town encompass the following:
a)   Efficient resource utilization: With many resources turning into either scarce or very highly-priced, it is vital to combine solutions to have higher and greater controlled usage of those resources. Beginning with technological structures such as enterprise resource planning (ERP) and geographic information system (GIS) could be useful. With tracking systems at work, it will likely be simpler to identify waste points and better distribute resources whilst controlling expenses, and lowering energy and herbal resources consumption. Further, one of the crucial intentions of smart city applications is that they're designed for interconnectivity and data collections which also can facilitate better collaboration throughout applications and services [7-9].

b)   Higher quality of existence: With better services, greater efficient work and dwelling models, and much less waste (in time and resources), clever town residents can have a better excellent of existence. This is the result of higher planning of living and work spaces, extra green transportation structures, higher and quicker services, and the provision of sufficient data to make knowledgeable choice.

c)   As of now, numerous urban areas contend to be smart urban communities with expectations of receiving a portion of their rewards monetarily, ecologically and socially. Accordingly, may are peering toward the open doors made conceivable by utilizing huge information investigation in smart city applications. Consequently, the advantages and openings that may help in settling on the choice to change over or upgrade a city to wind up a savvy city. With such choice, it might be conceivable to accomplish improved levels of manageability, versatility, and administration. Notwithstanding enhancing the subject's personal satisfaction and presenting savvy administration of foundations and regular assets [26].

A portion of the advantages of having a savvy city incorporate the accompanying:

a)   *Productive asset use:* With numerous assets winding up either rare or exceptionally costly, it is essential to coordinate answers for have better and more controlled use of these assets. Beginning with mechanical frameworks, for example, venture asset arranging and geographic data framework will be helpful. With checking frameworks at work, it is going to be easier to spot squander focuses and higher disseminate belongings while controlling prices and lessening vitality and common assets utilization. What's more, one of the critical parts of smart town applications is that they may be meant for interconnectivity and information accumulations which can likewise encourage better cooperation crosswise over applications and administrations.

b)   *Better individual satisfaction:* With higher administrations, more proficient work and residing models, and much less waste (in time and belongings), smart town citizens can have a advanced personal pride. That is the outcome of better arranging of dwelling/work areas and areas, greater effective transportation frameworks, higher and quicker administrations, and the accessibility of sufficient data to decide knowledgeable preference.

c)   *Larger quantities of straight forwardness and transparency:* The requirement for better administration and manage of the various smart metropolis views and applications will power the interoperability and receptiveness to greater accelerated quantities. Data and asset sharing could be the standard. Additionally, this could construct data straightforwardness for everyone covered. This will energize joint effort and correspondence amongst elements and making more administrations and applications that further improve the smart city. One illustration is the US government that gathered and discharged an extensive variety of information, productions, and substance for the sake of straightforwardness and transparency. These offered the natives and the administration substances the opportunity to trade and utilize the information successfully.

6.   CONCLUSIONS

This paper has presented a comprehensive study on smart cities including technologies, integration, transformation, operation, maintenance, opportunities, applications, and policies. It presents about the smart cities which are principal for a strong foundation that has the capacity to back the rising populace. It illustrates about future growing needs such as water, sanitation and (24×7) power to inhabitants in a proficient way. The smart demonstrate advances improvement of little commerce, instructive teach and commercial spaces. Generally, these offices increment business and in turn upgrade the residents' quality of life. Although a smart city may be a boon, there are certain obstacles that can influence the execution of the Smart City Mission. Further, the paper has discussed about several challenges of smart cities and solutions.

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