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Conceptualizing Smart Cities: Developments, Technological Advancements, and Challenges

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***Abstract* - The ICT enabled changes are so pervasive that they are affecting almost every aspect of our lives, and people's livelihood e.g., managing of energy, public space, underground pipelines and street illumination, construction, security, buildings, public transport etc. The governments are changing their functioning based on the changes to make the lives of the people comfortable. Some countries have already implemented policies and programmes to support and others are on their way for the same. The use of "Internet of Things" technology is being increasingly used to manage the homes and improve the lifestyles of the people. Based on the changes in light of smart city project undertaken by the Government of India, implementation and challenges were discussed and suggestions made.**

Key Words: Information and Communication Technologies (ICT), Smart Cities, Internet of Things, New Delhi, Jaipur, wifi connectivity, waste management

I. INTRODUCTION

The advent of the Information and Communication Technologies, also referred to as ICT, has affected how governments, businesses, and societies work. The Internet has played an extremely important role in this development. IBM, in 2008, coined the term "*Smart Cities*" (*Government of Hong Kong, 2015*) to study how the functions of a city can be optimized to promote the development of a talent-based economy and to improve the quality of life of the people.

A smart city refers to a city, which focuses on capitalizing on new technologies and insights to transform the traditional style of systems, operations, real estate, and services (*IBM Institute for Business Value, 2010*). ICT plays an important role in bringing together systems and services, improving the quality of life of the citizens, whilst reducing the environmental footprint, in support of a low-carbon economy.

The concept of smart city covers almost every aspect of society and people's livelihood, e.g., monitoring of public space, and management of underground pipelines and street illumination in respect of municipal facilities; construction, security, energy management and internal communication in respect of buildings; public transport service such as signal management, road traffic and parking monitoring; home automation and remote management; high-speed network and cloud storage; and electronic public and business services (*Yang, Jim-Hueok 2012 & Reis, Michelle 2014*).

In a rankings list by Boyd Cohen of smart cities around the world in 2013, the top 4 smart cities constituted *Singapore, Tokyo, Seoul, and Hong Kong*. Such rankings are based on factors influencing various frameworks, used to devise whether a city is smart. A smart city must consist of the following six components (*Madakam, Somayya and Ramaswamy, R. 2014*):

Smart Economy: It advocates innovation and entrepreneurship, focusing on developing new and high technologies, and encouraging innovation to foster closer links between the domestic economy and the global economy, with a view to maintain the buoyance and competitiveness of a city.

Smart Mobility: It aims to manage traffic flow, pedestrian flow, and cargo flow in real-time and also, involve the enhancement of efficiency and service quality of urban transportation, through the use of traffic monitoring technologies, video surveillance schematics, etc. It also helps administer the integration of plethora of modes of transport, including public transport, clean-fuel vehicles, cycling, and walking.

Smart Environment: It involves the implementation of green urban planning, through the use of web-based technologies, to fully understand and analyze the distribution of public spaces, green belts, etc. It also throws light upon energy conservation, emission reduction, greening of channels, and revitalization of water bodies.

Smart Citizen: It refers to the involvement of human resources, to promote social plurality, flexibility, open-mindedness, and creativity. People are encouraged to participate in public affairs through online platforms and other appropriate channels.

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Smart Living: It means the improvement of people's living environment and quality of life through the use of "*Internet of Things*" technology, and through online social platforms as an enabler for people to connect, and manage their homes and lives. The purpose is to promote a healthy, happy, and vibrant lifestyle.

Smart Government: It means strengthening connections within the Government, and between the Government and the people as well as enterprises through integration of networks and provision of public information and services.

This method of segregating the idea of smart cities into different aspects works in a way, that it covers every aspect of a citizen's life. The *diagram* below represents Cohen's broader view towards the characterization of smart cities:

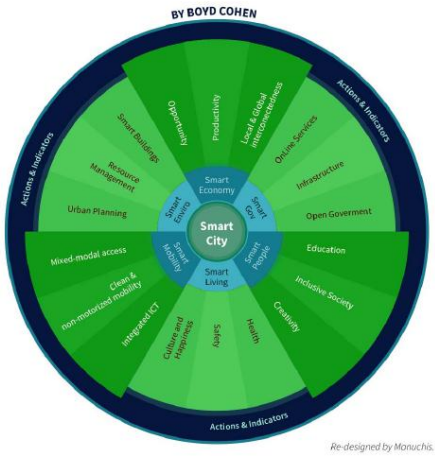

Fig. 1: Boyd Cohen's broader view of Smart Cities

Moreover, according to a research done by an American Consultancy Firm ISH (Government of Singapore), the number of smart cities in the world in 2016 was about 30, which would increase to about 90, by the year 2025.(*https://www.mfa.gov.sg/content/mfa/media_centre/archived-singapore-headlines/2012/201210/news_20121011.html)*

The *phase-wise evolution of cities from 'good' to 'smart' (Enterpriseinnovation.net)*:

- *Inception (1990's):* Information via cities' websites
- *Good governance (2000's):* City portals for online information services
- *E-governance (2005's):* Online web-based e-learning systems integrated and inter-operable with other cities' platforms.
- *Smart Governance* (2010's): E-learning, participatory governance, digital support inclusion, intelligent buildings, energy and environment efficiency, and pollution-controlled city development.

The idea of smart cities has been in the works for quite some years, and in this paper, we've tried to present its conceptualization, keeping in mind both local and global factors. Our objective was to work on inferring ways to compare the development of Indian smart cities with Singapore, which ranks in the list of the most livable cities in the world (*Govt. of India*). Singapore is also marked as a leading smart city in the world (*mfa.gov.in*). We have compared a plethora of factors in finding out the key factors that make a smart city, smart.

II. OBJECTIVES OF THE PAPER

With the aim to figure out the conception of smart cities in India and world, the following objectives were analyzed:

- Conceptualising India's Smart Cities Mission
- Comparing global level smart cities (Singapore) vs. India's select cities
- To explore the challenges faced during development of smart cities
- To spread awareness about the idea of smart cities
- Devising how Internet of Things would play a role in Smart Cities
- Working on an IoT Project

III. RESEARCH METHODOLOGY

A *literature review* of varied reports from governments and institutions from around the world has been done that are presently working on the Smart Cities Initiative, following Secondary Research Methodology. For *primary research*, a questionnaire was devised questionnaire followed by quantitative analysis of it.

Smart City Initiatives in World's Leading Cities

A look at world's leading cities and their implementations of smart city initiatives can be an exempler for India.

Analysing the Smart Cities Model devised by the Government of *the United States of America*, the development is carried out on state-levels, by state governments and business-sector funded projects (*DOI, 2016*). The focus is on five broad aspects: improving transportation systems to enhance the internal and external mobility of a city, enhancing energy efficiency to foster the sustainability of the development of the city, revamping all kinds of information and communication infrastructure of the city, strengthening the monitoring and security of the public space of the city, reforming public governance and planning and adjusting city functions and services to adress challenges of urban management.

The major cities in the United States, including New York, Boston, Seattle, San Francisco, San Jose, etc. have been going through devisive changes to incorporate the aforementioned five aspects. *New York*, for instance, has been a pioneer in the smart city development. The government of New York City, along with Cisco IBSG (*Jeff Frazier, Tom Touchet, 2012)* have been working on the Smart Screen City 24/7 initiative, for the dissemination of consolidated information of the public and private sectors through mobile networks. Under this initiative, outdated payphones in the city are being converted into smart screens, incorporating touch, video, and audio capabilities, to enable public access of information

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anytime. The smart screens would also work as WiFi hotspots, to work into forming a city-wide wifi network, which is going to be a one-of-its-kind. The government has also launched the Hudson Yards Project to develop a commercial and residential area on the upper west side of Manhattan. Other initiatives include the installation of electronic sensors to digitally track the city's local traffic, energy consumption, etc., and the enhancement of the city's waste disposal system, to upgrade the waste removing through underground pneumatic tubes.

San Francisco, being the Silicon Valley, is home to a number of innovation and technology enterprises, and free wifi coverage is provided extending three whole miles along its main road. It is also excelling in the area of waste recovery and recycling programmes, and initiatives to provide citizens with more than 100 charging stations throughout the city, to promote the use of hybrid and electronic cars. *Boston*, has the availability of mobile applications with full ranges of functions for its citizens, including real-time traffic and on-street parking information, route suggestions, and the city's bike rental services.

Besides these major American cities, the European Union, and many other Asian countries such as South Korea, Singapore, etc. have been taking steps to truly change how cities function. *Singapore*, in particular, is a pioneer in smart city development, and is one of the fastest growing cities. It has adopted a top-down planning model for city-redevelopment, in respect to strategic positioning, masterplanning, and practical implementation. Given its dense population, small size, and tightly-packed facilities, Singapore adopts a strategy that aims at building a well-connected socity through developing and employing infocomm industry in various aspects of the development. In 2005, the iN2015 masterplan was drawn out as a blueprint for the development of the smart city in Singapore. The plan aims at enriching the citizen's lives by working on enhancing Singapore's economic competitiveneness, the quality of life of the citizens, and the growth of its infocomm industry.

The Government of Singapore has moved with a set of four strategies to take this initiative forward:

- To spearhead the transformation of and innovation in the government, society, and economic sectors
- To establish a high-speed, pervasive, and trusted infocomm infrastructure
- To develop a globally competetive infocomm industry
- To develop an infocomm-savvy population and workforce

A steering committee was set up by the Government of Singapore, led by the Chairman of IDA and comprising of government officials of several departments, including Ministry of Education, Information, Communications, Finance, and the Arts. The committee also includes many private sector institutions and enterprises, including Singapore Management Institute, and companies such as Raffles International Ltd. and Hewlett-Packar Asia Pacific Pvt. Ltd.

The benefits of the iN2015 masterplan has been manifold, including the outreach of ultra-highspeed broadband coverage in Singapore, which has cross 95%. 90% of households in the country use broadband and almost all households with school-going children own computers.

(*The difference in the economic and technological instillation in India, as compared to Singapore, is vast. In the capital city of India, i.e. Delhi, only about 27% of households have a penetration of computer systems*).

The Government of Singapore considered the following seven topics while working on the initiative.

Fig. 2: Strategies of the Government of Singapore

How smart cities would be impacted through Internet of Thing (IoT)?

The interconnection of computing devices embedded in everyday objects via the internet, enabling them to send and receive data is generally referred to as the Internet of Things (IoT). The main concept of the IoT is the universal presence of objects that can be measured, inferred, understood and that can change the environment. On this basis, IoT is enabled by the developments of various objects as well as communication technologies. Involved things in the IoT consist of smart devices including mobile phones and other objects like foodstuff, appliance, landmark, monument, work of art that can cooperate together to provide a common target. The impact of the IoT on the life of users can be considered as its key feature.

Some of the IoT-related technologies are (*DOI: 10.1109/EEEIC.2016.7555867, "IoT-based Smart Cities: a Survey" (2016)*:

A. Radio-Frequency Identification (RFID)

These systems consisting of readers and tags play an important role in IoT. By applying such technologies to any involved object, it is possible to carry out their automatic identification and assign a unique digital identity to each object, in order to be incorporated in the network and related to the digital information and service.

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B. Wireless Sensor Network (WSN)

WSNs can provide different suitable data and also may be used in many cases such as healthcare, government and environmental services and seismic sensing. WSNs could be integrated with RFID systems to gain some goals like obtaining information regarding the position, movement, temperature, etc.

C. Addressing

As well as the Internet can enable a remarkable interconnection of people, the existing trend in the IoT can similarly provide an interconnection of objects and things, in order to establish smart environments. To this end, the capability of uniquely identifying objects is crucial for favorable outcomes of the IoT. This is due to the fact that uniquely addressing the large-scale combination of objects is vital for controlling them via the Internet. In addition to the mentioned uniqueness concept, reliability, scalability as well as persistence denote the key requirements to develop a unique addressing scheme.

D. Middleware

As a result of some issues related to the heterogeneity of contributing things, to the restricted storage and processes capability, as well as to the enormous diversity of applications, the middleware plays a critical role in the interconnection of the objects to the application layer. The key objective of the middleware is, indeed, to concisely integrate the functionalities and communication capabilities of all involved devices.

The Internet of Things, thus providing current applications such as surveillance systems, smart cars, wearable-tech, etc. also has a number of *potential applications for the future*. This includes:

Smart Homes: Developing products including home appliances, ventilations, home-lighting, etc. that can be connected to the internet, to allow users to access them from anywhere, without actually being present there, along with connecting these devices to analysis systems, to help better the consumption of electricity and energy can be a big application to homes connected to the internet.

Smart Energy And Smart Grids: The utilization of the IoT can furnish intelligent management of energy distribution and consumption in heterogeneous circumstances. The IoT nodes have some abilities such as sensing and networking. This management can also be extended to emergency conditions. One of the most important results of this extension is *Fault Location, Isolating And Service Restoration (FLISR)*. Implementing this, the IoT provides an advanced tool, which determines the position of the defective parts, separates them, and applies switching task to recover the largest number of healthy part of the affected energy feeder. Also, at the advanced level, this function can be developed by using self-healing methods, that are able to activate the participation of the customers as well as of dispersed generation units.

However, the inclusion of devices, objects, homes, and in turn cities, cause for a number of *challenges* that need to be overcome before practically bringing these applications into implementation:

Security and privacy: When all the data are collected and analyzed in a common IoT platform, the system can be subjected to several attacks (e.g., cross-site scripting, and side-channel). Besides, such a system is exposed to important vulnerabilities. Furthermore, multi-tenancy of this system can also bring out the security issues and cause the leakage of data.

Heterogeneity: The IoT system has typically evolved with distinguished solutions in which every system component is knitted to the particular application context. Accordingly, the authorities must analyze their target scenarios, determine the required computing hardware and software and then integrate these heterogeneous subsystems. The existence of such infrastructures and the provision of a suitable collaborating scheme between them can be truly a big challenging task for the IoT system.

Reliability: There are some reliability issues that have arisen in the IoT-based systems. For instance, because of the vehicles' mobility, the communication with them is not reliable enough. Furthermore, the presence of numerous smart devices will cause some reliability challenges in terms of their failure.

Large scale: Some specified scenarios require the interactions between large numbers of embedded devices, which are possibly distributed over wide area environments. The IoT systems provide a suitable platform that can analyze and integrate data coming from different devices. However, such large scale of information requires suitable storage and computational capability collected at high-rate which makes typical challenges harder to overcome. On the other hand, the distribution of the IoT devices can affect the monitoring tasks because these devices must handle the delay related to dynamics and connectivity.

Legal and Social Aspects: The IoT system may be service based on the user-provided information. For such cases, the service provider has to be in accordance with different local and international laws. Also, the users should have enough incentives to participate in the defined scenarios and data collection. It will be more convenient if opportunities are given to the users to select and take part in submitting data, which denote a thing.

Big Data: Considering about 50 billion devices, it is certainly necessary to pay attention to transferring, storing and recalling and also analyzing such a huge amount of data produced by them. It is obvious that the IoT infrastructures will be some of the major resources of big data.

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Sensor Networks: Sensor networks can be considered as one of the most important technologies to enable the IoT. This technology is able to shape the world by providing the ability of measuring and inferring environmental indicators. Recent developments and improvements in technologies have provided devices with high efficiency and low-cost to employ remote sensing applications in large-scale. In addition, smartphones are associated with a diversity of sensors and consequently, they enable a variety of mobile applications in several areas of IoT. To this end, the major challenging task is to process the large-scale data of the sensors in terms of energy and network limits.

Conceptualizing India's 'Smart Cities Mission'
According to a Report by the Ministry of Urban Development, Government of India, the following are the prominent developments that are to be experienced in the future smart cities of the country:

- *Promoting mixed land use in area based developments*– Planning for 'unplanned areas' containing a range of compatible activities and land uses close to one another in order to make land use more efficient. The states will enable some flexibility in land use and building bye-laws to adapt to change.
- *Housing and inclusiveness* - Expand housing opportunities for all.
- *Creating walkable localities* –Reduce congestion, air pollution and resource depletion, boost local economy, promote interactions and ensure security. The road network is created or refurbished not only for vehicles and public transport, but also for pedestrians and cyclists, and necessary administrative services are offered within walking or cycling distance.
- *Preserving and developing open spaces* - Parks, playgrounds, and recreational spaces in order to enhance the quality of life of citizens, reduce the urban heat effects in areas and promote eco-balance.
- *Promoting a variety of transport options*- Transit Oriented Development (TOD), public transport and last mile para-transport connectivity.
- *Making governance citizen-friendly and cost effective*- Increasingly rely on online services to bring about accountability and transparency, especially using mobiles to reduce cost of services and availing services without going to the municipal offices. Forming e-groups to listen to people and obtain feedback and use online monitoring of programs and activities with the aid of cyber tour of worksites.
- *Giving an identity to the city* - Based on its main economic activity, such as local cuisine, health, education, arts and craft, culture, sports goods, furniture, hosiery, textile, dairy, etc.
- *Applying Smart Solutions to infrastructure and services*- In area-based development in order to make them better including making areas less vulnerable to disasters, using fewer resources, and providing cheaper services.

A few questions related to the above were administered and the respondents gave their views:

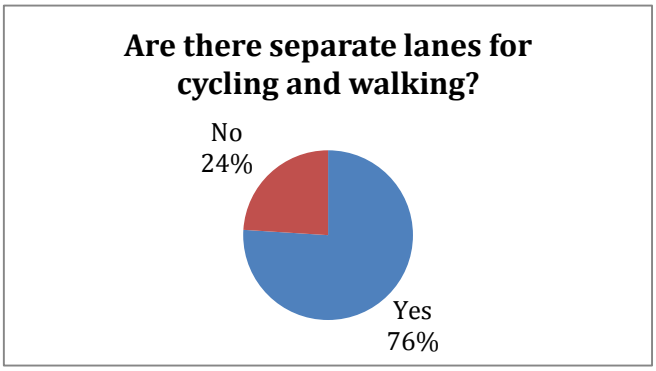

Fig. 3: In terms of walking spaces and cycling, a survey conducted suggested that just 76% people believed that there were separate lanes for cycling/walking in their cities.

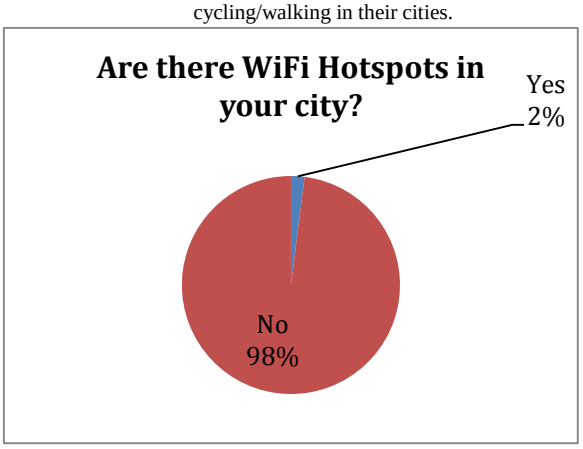

Fig. 4: The wifi spots were negligible.

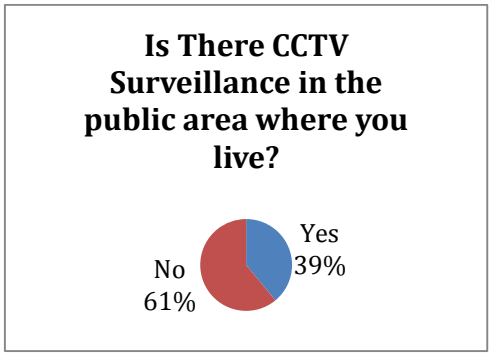

Fig. 5: The Public areas did not have CCTV Surveillance and the public security was in question and the city areas were still very vulnerable.

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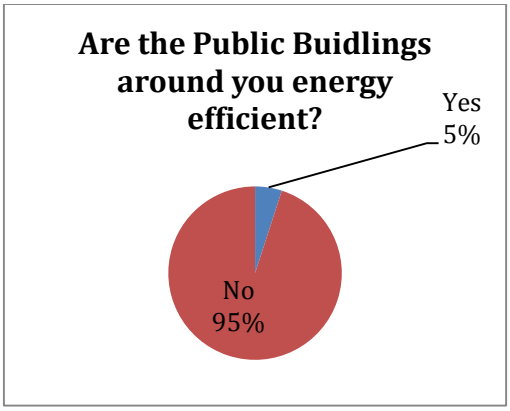

Fig. 6: The public buildings are not energy efficient

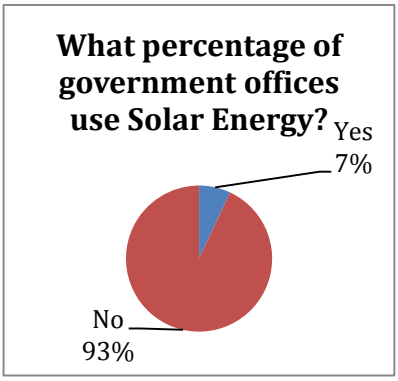

Fig. 7: Use of Solar Energy was conspicous by its absence in the government offices.

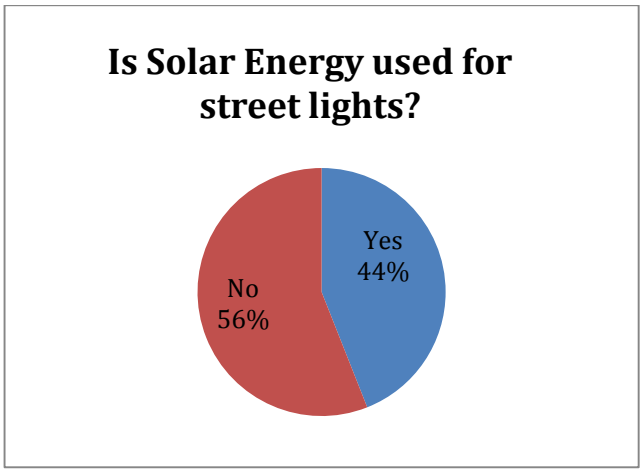

Fig. 8: Use of Solar Energy was being made partially in the street lighting

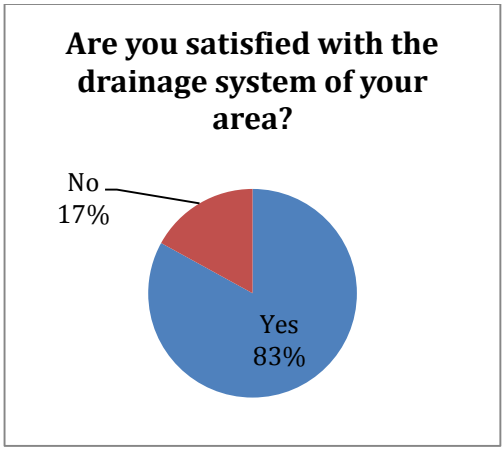

Fig. 9: The drainage system of the vicinity is a huge problem requiring urgent action.

STRATEGY OF THE MINISTRY OF URBAN DEVELOPMENT, GOVERNMENT OF INDIA

In light of above and many other problems and their solutions, the strategy that the Ministry is planning to use is a four-fold one, comprising of the following:

Retrofitting: It will introduce planning in an existing built-up area to achieve smart city objectives, along with other objectives, to make the existing area more efficient and livable. In retrofitting, an area consisting of more than 500 acres will be identified by the city in consultation with the citizens. Depending on the existing level of infrastructure services in the identified area and the vision of the residents, the cities will prepare a strategy to become smart. Since existing structures are largely to remain intact in this model, it is expected that more intensive infrastructure service levels and a large number of smart applications will be packed into the retrofitted smart city. This strategy may also be completed in a shorter time frame, leading to its replication in another part of the city.

Redevelopment: It will effect a replacement of the existing built-up environment and enable co-creation of a new layout with enhanced infrastructure using mixed land use and increased density. Redevelopment envisages an area of more than 50 acres, identified by Urban Local Bodies (ULBs) in consultation with the citizens. For instance, a new layout plan of the identified area will be prepared with mixed land-use, higher FSI and high ground coverage. Two examples of the redevelopment model are the *Saifee Burhani Upliftment Project in Mumbai* (also called the *Bhendi Bazaar Project*) and the redevelopment of *East Kidwai Nagar in New Delhi* being undertaken by the National Building Construction Corporation.

Greenfield Development: It will introduce most of the Smart Solutions in a previously vacant area (more than 250 acres) using innovative planning, plan financing and plan implementation tools (e.g., land pooling/ land reconstitution) with provision for affordable housing, especially for the poor. Greenfield developments are required around cities in order to address the needs of the expanding population. One well-known example is the

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GIFT City in Gujarat. Unlike retrofitting and redevelopment, green-field developments could be located either within the limits of the ULB or within the limits of the local Urban Development Authority (UDA).

Pan-city Development: It envisages application of selected Smart Solutions to the existing citywide infrastructure. Application of Smart Solutions will involve the use of technology, information and data to make infrastructure and services better. For example, applying Smart Solutions in the transport sector (intelligent traffic management system) and reducing average commute time or cost of citizens will have positive effects on productivity and quality of life of citizens. Another example can be wastewater recycling and smart metering which can make a huge contribution to better water management in the city.

Results and Challenges in the Smart Cities Mission
Based on the discussion above, we have tried to find out how are two main cities namely, New Delhi and Jaipur fair as far as the parameters of Smart City are concerned.

A number of challenges in faced by Indian cities in moving forward with the "Smart Cities Mission", keeping in perspective New Delhi and Jaipur are:

Population Density: The density of population in a city plays a vital role in providing perspective to the problems associated with development projects in the city. We compared the population densities of the major cities in the world, in comparison to Delhi and Jaipur, whose results were as follows:

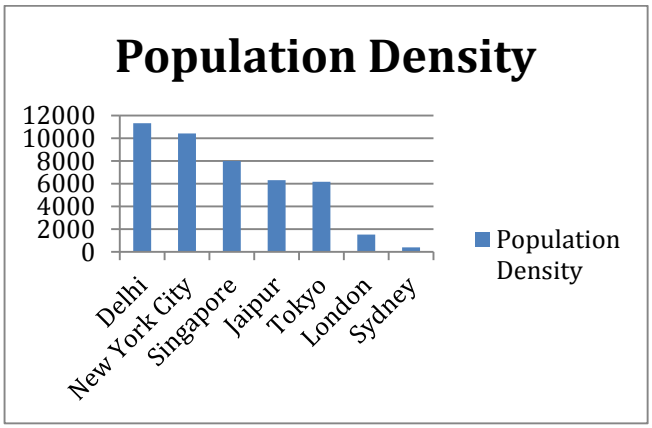

Fig. 10: Population Density of the select areas

Considering the high population density of New Delhi, leaving behind only a handful of the world's top cities, in a ranking of the world's most densely populated cities, the development of better infrastructure, facilities, public transportation systems, waste and water management systems, etc. becomes quite a difficult task.
This also leads to a problem of congested living, which directly is linked to the quality of life of a person in a city. About 36% of households in Delhi are living in congested houses (*Economic Times, 2014*). Jaipur, on a parallel node, has about 25% households living in congested houses *(HIS, 2014).*

Computer/Internet Access: The access to internet/mobile phones/computer systems signifies the ease of access to technology. Delhi has just about 62% households with access to mobile phones, about 27% households with access to computer systems/laptops with internet, and just about 16% households with access to computer systems/laptops without internet. Jaipur too has about 12% of households with access to internet-enabled computer systems, with just about 66% households with access to mobile phones.

Intelligent Parking Systems/Shared Parking and Transportation Management, and Smart Signalling: Smart management of transportation and parking systems is a key area in making a city smart. At present, cities including Delhi, Jaipur, Pune, Surat, Ahmedabad, Chennai, and a few others have proposed to helping develop smarter parking and transportation management systems.

Seamless Network and WiFi Connectivity/WiFi Hostpots: Providing undettered network availability throughout the city, with access to seamless wireless internet connectivity is a decisive factor in making a city smart. A report by the Economic Times (*http://economictimes.indiatimes.com/industry/telecom/call-drops-in-india-much-higher-than-global-average-survey/articleshow/51345585.cms)* stated that the average call drops rate in India stands at 4.73%, which is much higher than the standard 3% global rates, and the 2% standard set by TRAI.

Other challenges that the cities need to overcome include: Underground Wiring, Solar Street Lights and Plans, Renewable Energy Initiatives, Complete CCTV Suveillance, Bicycle Tracks, Slums Redevelopment, Disabled Friendly Pathway Designs, Business Incubation Centres, Travel Cards and Citizen Applications, Smart Waste Management Techniques, etc. among a few.

Based on the discussions above and the findings deduced by several sources, we are able to find a number of loopholes in the structuring and functioning of the Smart Cities Initiative developed by the Government of India. In comparison with smart cities from around the world, cities from India (especially Delhi and Jaipur) have a long way to go.

In terms of infrastructure, the lack of CCTV surveillance, WiFi hot-spots, pedestrian-sidewalks, solar-energy inclusion, and smart parking systems are some of the major hurdles that cause the difference between global smart cities and their Indian counterparts. Take the capital of India for instance. New Delhi, being a metropolitan city has just about 27% households with an access to computers/laptops with internet connectivity. Such statistics really create a strong case when it comes to moving forward with technological advancements. Secondly, the lack of a smart waste management and disposal system has caused an even bigger hurdle when it comes to improvising the conditions of our cities.

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A sincere and in-depth planning and implementation strategy is required from the Government to make the country's cities as developed and as smart as cities such as Singapore, San Francisco, Japan, etc. Better and easier access to good public facilities, including seamless network and wireless connectivity to the internet should be a top priority.

The Smart City project is at the prime of its age and its implementation is not an easy task and requires dedicated efforts. "Internet of Things" technology can be enabler for people to connect, and manage their homes and lives with the purpose to promote a healthy, happy, and vibrant lifestyle.

An model recetly implemnted by the Government of Delhi mentioned below can be an exempler.

Case Study of Waste Disposal in New Delhi

Under the Smart City Project, a new idea of dumping your waste and getting paid has been implemented in New Delhi where the New Delhi Municipal Corporation (NDMC) has installed smart vending machines for recyclable waste at Connaught Place and India Gate. The underlying idea is anyone who would dispose off waste like, glass bottles, plastic, paper etc. will get a monetary reward.

"The concept is to give people something in return to segregate the waste and this is the smart way of doing it. Anyone can dispose plastic bottles, glass bottles and papers, and will get Re. 1, Rs. 2 and Re. 1 respectively if return. For bigger bottles people will receive Rs. 3 and for plastic bags, they will get Re. 1 per bag" (*TOI, April 16, 2017*).

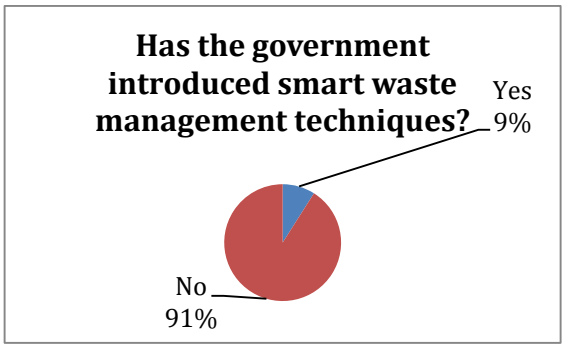

Fig. 11: The Smart Management Techniques are still at the prime

Another smart idea attached to it is that these machines are linked to e-wallets and the money to be paid is to be directly transferred to the beneficiary. A two minutes procedure before the disposal of waste will register the person to the e-wallets, which in turn is linked to many additional features. One could purchase movie tickets, DTC or Volvo tickets, mobile recharge, cabs payment etc. through it. "The machine has numerous features. It has free wifi, which allows people to book trains, platform tickets and book hotels too. Even NDMC 311 bills can be paid through MaxPay wallet". It is also lined to Aadhaar Card or thumb impression to open bank accounts or purchase sim cards, get doctor's appointment and pay school fee with the machine. However, the government is still testing its feasibility.

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