Developing Smart Cities using Internet of Things: An Empirical Study

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***Abstract* – IoT is an emerging technology that creates a massive network of things communicating with one another. It encompasses a broad set of technologies, hardware and software stacks. Data, humans, devices and communication are critical elements of an IoT ecosystem. For a developing country such as India, which has quite limited technology penetration at the national level, an efficient architecture for IoT needs to be based on present technology advances, capabilities that provide affordable and sustainable solution, and entrepreneurial and social value. Smart city is an important concept for the development of any nation. It is crucial for government of India to offer different services to its citizens and IoT helps significantly to achieve this purpose. It will be possible to communicate transparently and seamlessly with large number of homogeneous and heterogeneous systems, while having selected access to data for designing numerous digital services.**

The primary purpose of this research paper is to study the role of IoT in development of Indian smart cities, understand the India IoT policy, find out the key drives and advantages of IoT based smart city and identify the consumer preferences and demographics of Indian citizens who prefer IoT based smart city solutions.

Keywords – Digital India; Internet of Things; Smart Cities; Smart Healthcare; Smart Energy and Smart Infrastructure

I. INTRODUCTION

Our lives are now being impacted by a new buzzword, namely Internet of Things [IoT]. Globalization has been taken forward and the world is now becoming truly boundary less as not only are people connected by means of technology. The internet network is connecting things or electronic devices and creating innovative and advantageous new services. IoT is essentially a system where the Internet is connected to the physical world via a multitude of sensors. By 2011, the number of Internet-connected devices [12.5 billion] had surpassed the number of human beings [7 billion] on the planet. The number of Internet-connected devices are expected to number between 26 billion and 50 billion globally by the year 2020.

Countries such as USA, China, and South Korea have already begun preparations for taking advantage of IoT. India is not willing to lag behind. The IoT is poised to make rapid inroads in India as mission will be operated as centrally sponsored scheme and central government proposes financial support of INR 48,000 crores in 5 years and plans to setup 100 smart cities across the country.

II. LITERATURE REVIEW

A very simple explanation of the internet is that it is an intricately linked worldwide computer network. The network enables global communication by moving computerized information, known as data from one place to another. The connections between the computers are a mixture of old-fashioned copper cables, fiber-optic cables [which send messages in pulses of light], wireless radio connections [which transmit information by radio. waves], and satellite [Woodward, 2014]. Although it is not this paper's objective to discuss in detail the working of the internet, we do need to acknowledge the importance of the internet's addressing system or IP – a series of digits separated by dots or colons. The world is moving from people connectivity to machine connectivity. This is being possible as electronic devices each have a unique address or IP. We thus have devices which are being called 'smart'. What differentiates the internet from the internet of things is that connectivity is possible among devices which are not only computers, smartphones and tablets but also a variety of sensors and monitors. The end result of this connectivity is to make life easier for people by anticipating need and arranging to fulfil the same.

According to research conducted by Goldman Sachs Equity Research group [2014], personal lives, productivity in the workplace, patterns of consumption will all be impacted by IoT. The research group estimates that about a billion users were connected through internet in the 90s. With the increase in mobile usage by 2000, the figure rose to two billion. The IoT has the potential to connect nearly 28 billion 'things' by the year 2020.

The precursor to a smart city is the establishment of an effective IoT network. Zanella, Bui, Castellani, Vangelista, Zorzi [2014] rightly comment that the concept of IoT being relatively new and the demands of putting in place an effective system being fairly complex, there is a gap in the establishment of best practice. Zanella et al. suggest deployment of an urban IoT. They are of the view that once the citizens benefit from improvement in public services such as transportation, parking facilities, lighting, security, garbage collection etc., they may be motivated to participate actively and add to the success of the system.

The concept of IoT and smart cities being fairly new, a reasonably large body of literature the subject is yet to be developed. As research in the field progressed and new

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technologies developed and matured, a number of companies such as CISCO, IBM and others provided solutions making IoT a implementable option for modern cities aimed at improving quality of life, Boulos and Al Shobraji [2014].

III. Smart City

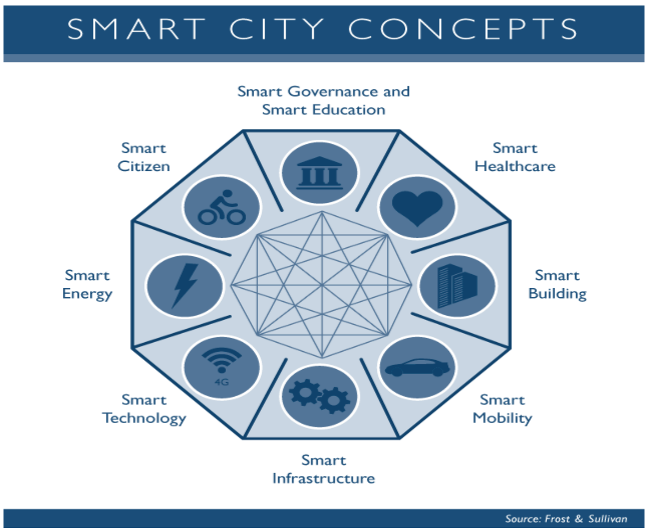

Fig.1. Smart City Concept

A. Traffic Congestion:

IoT has the service to monitor traffic congestion in an urban city. Camera-based traffic monitoring systems are already in place and used in many urban cities, a better source of information is low-power widespread communication. Monitoring is done using GPS installed on new age vehicles. City officials need to discipline the traffic, send officers where needed while city people plan in advance a shopping trip or a route to arrive at office.

B. Air Quality Management:

City air is polluted due to crowded areas, parks etc. IoT will provide ways to track the quality of air in urban cities. The health applications executing on runners devices will be connected to the ICT infrastructure. Citizens will be digitally connected to their preferred personal training application. They can figure out the healthiest path for outdoor activities. To achieve the same, air quality and pollution sensors needs to be installed across the city and sensor data should be made readily available to people.

C. Smart Health:

Monitor several critical parameters of patients such as changes in heart condition, temperature, pulse and respiration. Warning and alerts for life-threatening cases in hospitals and at remote patient locations including ambulance and old people's home. To support mentally unhealthy patients, infants and young children using relevant information from different digital sensors within IoT ecosystem.

D. Smart Energy:

A service hosted using IoT can help to monitor the energy consumption of the whole city, thereby empowering authorities and citizens to get a detailed view of the amount of energy consumed by heating/cooling of public buildings, traffic lights, public lighting, control cameras, transportation etc. This will aid in isolating the main energy consumption sources and to set priorities accordingly. The power draw monitoring devices must be integrated with the power grid in the area. It is also possible to improve these service with active functionalities to control local power production structures [e.g., photovoltaic panels].

E. Smart Infrastructure:

Regular monitoring of the real conditions of buildings and identification of areas with most effect by external agents is required for proper structural maintenance. IoT can use a distributed database that contains structural measurements, gathered using sensors in buildings. Examples: Atmospheric sensors to track pollution levels, temperature and humidity sensors, vibration and deformation sensors to study building stress. Possibility to add seismic readings and vibration to understand and study the effect of light earthquakes on city buildings. Installation of sensors in buildings, nearby areas and their connectivity to a control system is needed to create the essential infrastructure.

IV. INTERNET OF THINGS

A. Definition

The Internet of Things connects devices such as everyday consumer objects and industrial equipment onto the network, enabling information gathering and management of these devices via software to increase efficiency, enable new services, or achieve other health, safety or environmental benefits. The term was first proposed by Kevin Ashton, a British technologist, in 1999 when he was at MIT.

S-E-N-S-E	What the Internet of Things does	How it differs from the Internet
Sensing	Leverages sensors attached to things (e.g. temperature, pressure, acceleration)	More data is generated by things with sensors than by people
Efficient	Adds intelligence to manual processes (e.g. reduce power usage on hot days)	Extends the Internet's productivity gains to things, not just people
Networked	Connects objects to the network (e.g. thermostats, cars, watches)	Some of the intelligence shifts from the cloud to the network's edge ("fog" computing)
Specialized	Customizes technology and process to specific verticals (e.g. healthcare, retail, oil)	Unlike the broad horizontal reach of PCs and smartphones, the IoT is very fragmented
Everywhere	Deployed pervasively (e.g. on the human body, in cars, homes, cities, factories)	Ubiquitous presence, resulting in an order of magnitude more devices and even greater security concerns

Source: Goldman Sachs Global Investment Research.

Fig.2. S-E-N-S-E Framework

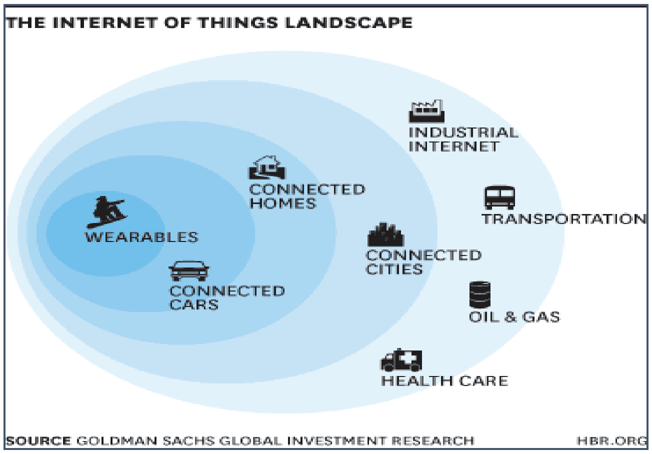

Fig.3. The internet of things landscape

V. INDIA AND IOT

IoT architecture for India is dependent on social and entrepreneurial value applications, current technology advances and competencies that make IoT sustainable and affordable. Communication systems, data, city people and devices play crucial roles in the IoT ecosystem. To drive a sustainable and practical IoT business architecture following points should be considered –

- IoT has unique value proposition due to the direct interaction between "Things" and "Humans".
- To generate actions, which are driven by intelligence, it is important to capture interactions between "Humans" and "Things" in the physical and virtual worlds.
- Meaningful analytics, based on "Big" and "Little" data, done on information from multiple sources within IoT architecture helps in data driven decision making.
- Instead of going for massive deployment of sensor networks it is more advantageous to utilize symbiotic infrastructure and rely on existing widely adopted standards.
- ICT solutions with latest capabilities for advanced economies are less preferred over reusable sensors and devices.
- IoT provides great opportunities for entrepreneurship and innovation. It is important to ensure transparency in sharing, usage and data ownership and sharing. Availability of better operating models using data brokering, which encourages open data sharing by users with businesses.
- Decision making should be probabilistic. Applications and systems should not fail when in imperfect condition and be conscious of what is "good enough".
- There are uncertainties in the system and humans beings so the decision making should be contextual within IoT infrastructure and applications.
- IoT business models are classified in 2 categories – Verticals that integrate technologies to provide value proposition to end user and Horizontals that enable technology and components.

A. *Government IoT Policy Objectives*

- Establish IoT industry worth 15 billion USD in India by 2020, leading to rise in connected devices from 200 million to 2.7 billion by 2020. As per the Gartner report, the total revenue generated from this industry globally will be 300 billion USD and the connected devices will be 27 billion by 2020. India will account for 5-6% of the global IoT industry.
- Develop IoT specific skills for both domestic and international markets.
- To undergo Research and Development for all the surrounding technology ecosystems.
- Design IoT related products to meet the needs of Indian consumers in multiple business domains such as water quality, health, natural disasters, agriculture, security, automobile, waste management, smart cities, transportation, automated metering and monitoring of utilities, supply chain management etc.

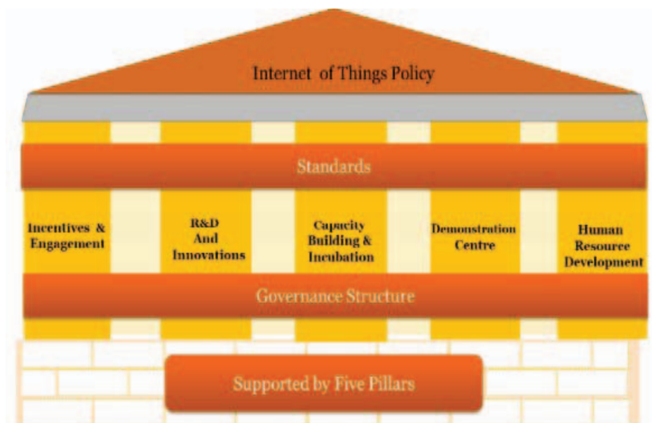

Fig.4. Source: Indian Government IoT Policy Document

VI. RESEARCH METHODOLOGY

A. *Methods of Data Collection*

A questionnaire was shared with 84 working Indian executives. These resources are the preferred segment of respondents for this kind of study since companies are positively moving towards IoT implementation and their employees are heavily involved in such transformation programs. Several in-depth research studies have confirmed time and again that IoT will be the next big technology revolution after the Internet era.

B. *Primary and Secondary Data:*

The questionnaire was designed and administered carefully to gather relevant information pertaining to our key research objectives in this research paper. The method of convenience sampling was used to collect the primary data. The secondary data was collected from multiple Research Papers, Journals and Books.

C. Data Analysis and Interpretation:

Tools IBM SPSS and MS Excel 2013 were used to analyze the primary data collected for this study. Following information was used in the study –

- Dependent Variable:

IoT based Smart City Solution Adoption Likelihood

- Independent Variables:

IoT Drivers: Government IoT Policy, Information Security and Device and Sensor Interoperability, IoT Revenue Model and Hardware Cost and Reliability

IoT Advantages: Parking and Traffic Management, Energy Management, Air Quality and Noise Management, Health Care and Citizen Safety Management and Information Accessibility

- Demographic Variables:

Age, Qualification, Gender and Income

- Alpha Value: 5% [0.05] **Confidence Level:** 95% [0.95]

VII. KEY RESEARCH OBJECTIVES

- Study the development of India smart cities using IoT
- Analyze the impact of Indian government IoT policy on adoption likelihood of IoT based smart cities
- Analyze the association between key factors that drive IoT based smart city adoption and its likelihood in India
- Analyze the impact of IoT advantages on adoption likelihood of IoT based smart cities in India
- Understand the perceived usefulness, perceived ease of use and preferences for IoT based smart cities of Indian corporates
- Find out the demographic details of Indian citizens who prefer IoT based smart cities

Hypothesis # 1: In India, government IoT policy plays an important role in the adoption of IoT based smart city solution

Hypothesis # 2: In India, strong revenue model affects adoption of IoT based smart city solution significantly

Hypothesis # 3: In India, information security affects adoption of IoT based smart city solution significantly

Hypothesis # 4: In India, hardware cost and reliability affects adoption of IoT based smart city solution significantly

Hypothesis # 5: In India, device and sensor interoperability affects adoption of IoT based smart city solution significantly

Hypothesis # 6: In India, strong relationship exists between key independent variables listed above and dependent variable

TABLE I.

		IoT_SmartCity_Adoption	Govt_IoT_Policy
IoT_SmartCity_Adoption	Pearson Correlation	1	**.571****
	Sig. [2-tailed]		.000
	N	84	84
Govt_IoT_Policy	Pearson Correlation	**.571****	1
	Sig. [2-tailed]	.000	
	N	84	84

TABLE II.

		IoT_SmartCity_Adoption	IoT_Revenue_Model
IoT_SmartCity_Adoption	Pearson Correlation	1	**.824****
	Sig. [2-tailed]		.000
	N	84	84
IoT_Revenue_Model	Pearson Correlation	**.824****	1
	Sig. [2-tailed]	.000	
	N	84	84

TABLE III.

		IoT_SmartCity_Adoption	Information_Security
IoT_SmartCity_Adoption	Pearson Correlation	1	**.761****
	Sig. [2-tailed]		.000
	N	84	84
Information_Security	Pearson Correlation	**.761****	1
	Sig. [2-tailed]	.000	
	N	84	84

TABLE IV.

		IoT_SmartCity_Adoption	Hardware_Cost_Reliability
IoT_SmartCity_Adoption	Pearson Correlation	1	.666**
	Sig. (2-tailed)		.000
	N	84	84
Hardware_Cost_Reliability	Pearson Correlation	.666**	1
	Sig. (2-tailed)	.000	
	N	84	84

TABLE V.

		IoT_SmartCit	Device_Sensor_In

		y_Adoption	teroperability
IoT_Smart City_Adoption	Pearson Correlation	1	.565**
	Sig. (2-tailed)		.000
	N	84	84
Device_Sensor_Interoperability	Pearson Correlation	.565**	1
	Sig. (2-tailed)	.000	
	N	84	84

TABLE VI.

Dependent Variable: IoT_SmartCity_Adoption					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9.949[a]	4	2.487	17.798	.000
Intercept	1497.178	1	1497.178	10713.986	.000
Parking_Traffic_Management	9.949	4	2.487	17.798	.000
Error	11.039	79	.140		
Total	1713.000	84			
Corrected Total	20.988	83			
a. R Squared = .474 (Adjusted R Squared = .447)					

TABLE VII.

Dependent Variable: IoT_SmartCity_Adoption					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11.480[a]	4	2.870	23.845	.000
Intercept	1552.832	1	1552.832	12901.593	.000
Energy_Management	11.480	4	2.870	23.845	.000
Error	9.508	79	.120		
Total	1713.000	84			
Corrected Total	20.988	83			
a. R Squared = .547 [Adjusted R Squared = .524]					

Dependent Variable: IoT_SmartCity_Adoption					
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	8.094[a]	4	2.024	12.398	.000
Intercept	1191.722	1	1191.722	7301.572	.000
AirQuality_Noise_Management	8.094	4	2.024	12.398	.000
Error	12.894	79	.163		
Total	1713.000	84			
Corrected Total	20.988	83			
a. R Squared = .386 [Adjusted R Squared = .355]					

TABLE VIII.

Dependent Variable: IoT_SmartCity_Adoption					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	13.534[a]	4	3.383	35.856	.000
Intercept	1438.410	1	1438.410	15243.633	.000
HealthCare_Safety_Management	13.534	4	3.383	35.856	.000
Error	7.455	79	.094		
Total	1713.000	84			
Corrected Total	20.988	83			
a. R Squared = .645 [Adjusted R Squared = .627]					

TABLE IX.

Dependent Variable: IoT_SmartCity_Adoption					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11.530[a]	4	2.882	24.076	.000
Intercept	899.215	1	899.215	7510.737	.000
Information_Accessibility	11.530	4	2.882	24.076	.000
Error	9.458	79	.120		
Total	1713.000	84			
Corrected Total	20.988	83			
a. R Squared = .549 [Adjusted R Squared = .527]					

VIII. CONCLUSION AND FUTURE SCOPE

By analyzing the results of correlations, we conclude that independent variables: “IoT Revenue Model [Pearson Correlation = 0.824]”, “Information Security [Pearson Correlation = 0.761]” and “Hardware Cost and Its Reliability [Pearson Correlation = 0.666]” have high positive correlations with the dependent variable Adoption likelihood of IoT based smart city solution. While variables “Indian Government IoT Policy [Pearson Correlation = 0.571]” and “Device and Sensor Interoperability [Pearson Correlation = 0.565]” have moderate positive correlations with the dependent variable Adoption Likelihood of IoT based Smart City Solution. The p values that are displayed by the sig fields in the correlation tables are less than the alpha value of 5% with confidence level of 95%. This means that null hypothesis are rejected, leading to acceptance of alternate hypothesis.

By analyzing the results of ANOVAs, we conclude that independent variables: "Health Care Safety Management [R square = 0.627]", "Information Accessibility [R square = 0.527]", "Energy Management [R square = 0.524]", "Parking and Traffic Management [R square = 0.447]" and "Air Quality and Noise Management [R square = 0.355]" explain 62.7%, 52.7%, 52.4%, 44.7% and 33.5% of variability respectively in dependent variable "Adoption Likelihood of IoT based Smart City Solution". When we combine the 5 independent variables: "Health Care Safety Management", "Information Accessibility", "Energy Management", "Parking and Traffic Management" and "Air Quality and Noise Management" to see the impact on dependent variable "Adoption Likelihood of IoT based Smart City Solution" we get R square = 0.865, which means 86.5% of the variability in dependent variable is explained by these 5 independent variables.

To take advantage of the IoT based smart city solution, the citizens of India need to carry positive mindset and understand the impact of this emerging technology. Moreover, as per the Technology Adoption Model [TAM], the perceived ease of use and perceived usefulness are key decision parameters to adopt a particular technology. What India needs is strong IoT revenue model, high information security, positive government attitude, affordable hardware and decent reliability, up-to-date infrastructure, increased device and sensor interoperability. Better health care safety management, better information accessibility for the Indian citizens and better energy management are the prime advantages perceived by Indian corporates surveyed. Big companies are investing several millions to setup IoT infrastructure and develop different applications. Indian government and companies should study the IoT implementations outside India in detail and customize as per the needs of its citizens. Digital India program, which aims at setting up e-infrastructure in the nation will strengthen the establishment of the IoT industry. India with strong focus on technology development is well positioned to grow further economically in the new and exciting era of the IoT.

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