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Developing Smart Environmental solutions using Internet of Things for Smart City Infrastructure: A Survey

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ABSTRACT

A smart city is an advanced platform that uses information and communication technologies (ICTs) and other means to advance quality of life, effectiveness of urban process and facilities, and affordability, while confirming that it meets the requirements of current and forthcoming generations with respect to financial, social and environmental aspects." Cities around the world are under immense pressure to accommodate growing populations and focus on environmental challenges. Constructing a smart city is not happening on the spot, it demands creative governance to lead the developing of the smart city and its architecture platform. The conceptualization of Smart city, differs from one nation to another, varying on many characteristics involving the level of development of the country. This survey paper aims to explore the fundamental principles of designing a smart city by understanding the IoT architecture of the creation of smart cities, research with an analysis is to identify the principles of smart cities with importance on the IoT Architecture.

***Keywords*:** Smart Cities, Smart Environment, Internet of Thongs (IoT), Application Architecture

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1. INTRODUCTION

Smart Environment for Smart Cities uncovers the model and protocol of environment and social system of cities that advance every city to smart city through smart environment. Smart cities could improve on existing services, Smart cities manage many critical infrastructures such as transportation, waste management, water resource management, and building services that are ripe for enhancement in a smart city context. There are various world-wide or international cities that inspire and encourage peoples from outside the nation, or even from all over the world. Most of the time, these cities compete for resources. An option analytic description says that the "city is an urban society falling under a specific administrative limit". The overall intention of smart cities is to promote the use of IoTs to advance efficiency in urban planning and facilitate interactive opportunities among citizens, government and other actors in cities to enrich urban living. The early research on the subject focused on a view that by embracing IoT devices at the core of their operations, cities will be able to advance their efficiency levels and benefit from improvements in the market economy.

2. SMART CITY EVALUATION

Figure 1. Smart City Timeline

Transformation of legacy cities into smart cities demands consequent transformation of conventional unidirectional non-smart objects into bi-directional smart objects of e-applications for different domains. The word "Smart City" was invented in the initial 1990s to demonstrate the use of technology and revolution in urban development. More precisely, it can be specified that in the 1990s, researchers analysed cities and their ongoing information technology projects from diverse ideas, and using slightly different terms, described IT and communication-based project initiation in urban spaces (Fig. 1). The smart city developed into a digital city in 1994 in Amsterdam. In 1997, it was declared that there existed 2000 virtual urban areas across the globe. Later the introduction of the virtual city, the virtual community came into reality in 1998. In 1999, the first smart city concept was considered in Dubai [6]. A New well-known digital city system was Kyoto [7], which was developed in 1998, and developed in 3D and 2D spaces, where citizen communications were accumulated with sensors, and their behaviour was animated. The preceding smart city types evolved progressively into a more complicated environment, which was able to present more services and enable scientific embeddedness [8]. The new age of smart cities, from the view of the internet of things.

Evolution of smart cities with eight smart features, including smart Economy Smart building, smart mobility, smart energy, smart information communication and technology, smart planning, smart citizen and smart governance [4, 12].

3. SMART CITY MODEL

Smart cities were also called first, wired cities but the term wired lost meaning in an era of wireless communication technology. Other names are Intelligent City, Digital City, Hybrid city, Ubiquitous city, and Information city. Citizens oriented smart cities are called the Knowledge city, Learning City, Humane city and Innovative city. The difficulty of describing these conditions generated a situation that these conditions became unpopular. All these words which may be considered as an earlier model were subsequently substituted by the "Smart city". Urban Planners consider "smart model" as strategic development of a city emerging out of SWOT (Strength, Weakness, Opportunities and Threats) analysis which also forms part of smart city model approach.

Smart city model is a combination of digital city in cyberspace, Internet of Things, cloud computing, bigdata and artificial intelligence. Using radio frequency identification (RFID), infrared sensors, global positioning systems (GPS), laser scanners, and other information-sensing devices, the Internet of Things connects real objects in the city based on protocols that conduct information exchange and communication to achieve intelligent identification, positioning, tracking, monitoring, and management. Cloud computing is an Internet-based processing model for public participation. Bigdata provides an efficient and effective data storage and retrieval for all smart devices. Sometime smart environments can decide on their own with no human intervention using artificial intelligence.

4. COMPONENTS OF SMART CITY

A smart city is described by six components such as Smart Government, Smart Environment, Smart Economy, Smart Living, Smart Mobility, and Smart People [1-3].

Figure 2. Components of Smart City [1-3].

Smart city system comprises of six key building blocks: (i) smart governance, (ii) smart environment, (iii) smart mobility, (iv) smart people, (v) smart living, and (vi) smart city economy, Each are moving towards one other with a common goal of providing better services for modern cities [24]. These six building blocks are directly interconnected and support to the 'Smart City System'. Some authors treat the six elements of a Smart City System equally [4, 5], we give prominence to 'smart people' because without their active participation and involvement a Smart City System would not function in the first place. A Smart City System will risk its efficient functioning without Smart People.

4. 1. Smart Governance

Social media can be effectively used by government to encourage value co-creation and citizen involvement within smart cities. [35] Santander City brain managed by the city council of Santander in Spain. The study determined that social media is an effective tool for civil society, but accomplishment is reliant on government involvement, clear communication, security, privacy and ease of use. Innovative planning approaches are needed for successful smart cities [36, 31] and in the case of Barcelona and its evolution toward becoming a smart city [37].

The study highlighted the criticality of citizen partnership when designing, implementing, and evaluating potential smart cities related projects [37, 38] examined barriers that affect development of smart cities from an Indian context. The study found that governance is the most significant category of barrier and recommend policymakers promote e-governance services to bring accountability and transparency to the decision making process in the development of smart cities. Open data is a mechanism designed to help smart government enhance their communication with stakeholder data and make it more accessible [39]. Citizens and government should be able to decide how, where and when to use any collected data [40, 41] and discussed how open data can be used to provide new and updated services to citizens within smart cities.

The study found that open data initiatives can enhance the delivery of public value in terms of economics, strategy, politics, stewardship and quality of life [42]. The challenges connected to open data by using two smart cities cases (traffic dashboard and public transport dashboard) [43]. The study highlighted the key challenges: insufficient data quality, deficiency in understanding of data, poor analysis, improper interpretation, confusion about the results and imposing a pre-defined view. These challenges can lead to misconnects, incorrect decision making and less trust in government.

4. 2. Smart Environment

Smart Environment initiatives include the use of technology to improve essential aspects of city living such as waste disposal, food growth, pollution control, smart electric grids, housing quality, and facility management. This session presents a few state-of-the-art examples of how the Internet of Data and the Internet of Things can help reduce the ecological footprint of smart cities. The widespread use of IoT sensors (such as Radio Frequency Identification chips, proximity detectors, pressure sensors, optical sensors) can drastically change the way we manage the smart city environment [33]. City councils may optimize garbage collection, sorting and recycling by deploying low-cost smart sensors in garbage cans, trucks and recycling plants that share real-time data about the quantity and the quality of urban waste in each neighbourhood. This intelligence may not only facilitate decision making in terms of logistics and urban strategy but can also inform educational campaigns to improve recycling behaviour. In agriculture, sensors can monitor plant growth under different conditions, pest control and soil conditions, allowing bio-scientists and microbiologists to develop customized treatments to minimize the use of toxic pesticides and fertilizers. Pollution control is another main field of IoT application. Sensors can support to detect and prevent wildfires, automatically inform against the level of microparticles and other air pollutants, improve prediction, visualization and simulation of city pollution. Wireless Sensor Networks can be deployed in buses, bus stations, metro wagons and private vehicles to monitor emissions while also learning about how to make them more energy efficient [34].

4. 3. Smart Economy

Smart cities can develop more competitive business environments. Thus, Smart Environment, Mobility and People are the foundation for the advanced business models of the Smart Economy. Smart cities frequently generate technology hubs to enable the sharing of knowledge in the forms of research centers, start-up incubators, and accelerators, as well as invention parks. According to the Triple Helix perspective [44], the physical proximity of talented individuals, innovative companies and government agencies can lead to a knowledge economy environment based on social networks of trust, sharing and learning.

Innovative cities and technology parks are pure magnets for open innovation projects. when advanced IT infrastructures are developed locally by public-private partnerships, communities of lead users emerge both in companies and university labs [45]. They cite the example of Nice in France, where a “living lab” was designed around a green mobility project. This initiative involved the regional institution for air measurement quality, the local research institute dealing with the Internet of Things solutions (INRIA), the Internet Foundation for the New Generation, which empowered workshops among local users, as well as a small company which offered access to electric cars, environmental data, and sensors. People could take part

in the project through the internet, developing Arduino-assembled kits to perform experiments and by building their own sensors. In this co-creation process, operators become "prosumers" and support directly to the development of the project. Such an initiative would not have been possible without the social and human capital surrounding the Technopole of Sophia Antipolis near Nice, where several of the participants were physically located. This type of open innovation is facilitated by the synergy and creativity that emerge from open co-operation in the knowledge economy.

4. 4. Smart living

Smart living comprises areas such as city: public safety, healthcare, education, tourism and smart buildings all of which enhance the quality of living for its citizens. Public safety is a big area of concern in growing urbanisation especially in developing countries. Studies investigated how to enhance public safety by using ICT tools [50]. Proposed and tested a crowdsourcing model based on voluntary participants of citizens in South Africa. Examined the usability of an Interactive Voice Response (IVR) system, concluding that it can be an effective channel for people to report any safety issues. The study highlighted that usability was dependent on the system being: effective, safe to use, easy to learn and be efficient. The study by [50] also discussed the factors affecting usability of an IVR system. By collecting data from 361 citizens of East London (South Africa), they found that efficiency, effectiveness and perceived satisfaction significantly influenced the intention to interact with the IVR system.

4. 5. Smart mobility

Cities are facing ongoing challenges on how to manage levels of vehicle capacity, a situation exacerbated by increasing levels of urban congestion. Researchers have discussed this issue in the context of intelligent transportation systems (ITS) and how these can benefit smart cities [46]. The term Internet of Vehicles (IoV) has been referenced in some studies were the concept is described as playing a crucial role within an ITS, by providing a number of applications aiming to improve road safety and traffic efficiency. By using IoV,(47) proposed a Hybrid Emergency Message Transmission (HEMT) system that has better network compatibility and scalability making network management easier. Several studies on smart cities focused on traffic management [46].

4. 6. Smart People

One of the main aims for smart cities is to provide citizens with an improved living environment and increase their overall quality of life [48]. Citizens are users of smart services, thus it is crucial when planning and designing services, that the citizen perspective is considered to ensure full adoption of new changes and services [49]. The study attempted to predict factors that can influence citizen usage within smart cities highlighting the critical aspects of perceived information and system quality [49]. Citizen privacy and security concerns were discussed where the study investigated the factors affecting the intention to use smartcard services for public facilities and public transport, arguing that complexity is a barrier to smart card adoption. A privacy framework was developed to identify citizen concerns when interacting with smart technologies. The study identified areas of concern relating to: impersonal data and personal data used for surveillance purposes. A study by [49] found that acceptance of ICT based smart cities services is affected by innovation concept, service quality and perceived privacy. From

these studies it can be concluded that privacy plays a crucial role in acceptance and usage of service and technologies in smart cities. Thus, citizens should be educated about the laws and policies which are used in the environment of information processing. Also, social networking services can help to educate citizens about smart cities services, providing the information regarding the benefits of these services, its improvements and how they can satisfy needs of society [49]. It is important to pay attention to these factors as they directly impact the adoption of smart services, all of which have influence on the quality of life of citizens.

5. IOT FRAMEWORK FOR SMART ARCHITECTURES

The IoT applications architecture can vary significantly depending on the use case. the significant characteristic of a city IoT infrastructure is its ability of participating with different technologies with the current communication structures to support a advanced evolution of the IoT, with the interconnection of other devices and the understanding of novel functionalities and services. One More basic feature is the essential to make (part of) the data gathered by the urban IoT easily accessible by organizations and citizens, to boost the responsiveness of organizations to city problems, and to stimulate the awareness and the participation of citizens in public matter [10]. For better management, planning, decision and support, a environment needs to be smart to operate IoT based smart city. Smart environment is about improving the way of delivery, smart administration and democratic process. In order to coordinate with different agencies departments and sectors, our bureaucrats, government officials and leaders need smart tools and systems. To bring transparency in the system, it is important to have a unified system that should be accessible by segments of society to monitor real-time performance.

The smart city architecture focus on the following components:

a) Smart city meta-architecture
b) Smart city multilayer communication architecture
c) Smart city modular architecture

The smart city multi-tier, meta-architecture consists of Natural Environment layer, Hard Infrastructure (Non ICT-based) layer, Hard Infrastructure (ICT-based) layer, Smart Services and Soft Infrastructure layer. The communications view of the architecture is also multi-tiered, and consists of Infrastructure layer, Sensing Layer, Network Layer, Data and Support layer and Application Layer [9].

The seamless integration of technology and architecture facilitating cross cultural communication is critical to the operational effectiveness of smart cities and key to its economic growth [13-15]. This requires the processing of large amounts of data as well as accommodating the range of interaction technologies and associated information security issues [16].

The increase in connected devices within smart cities results in significant levels in growth of data. This data needs to be communicated, processed, stored in adherence with data protection guidelines and in compliance with government laws regulations. Studies have reviewed the impact of these areas on the operational effectiveness of smart cities highlighting the day to day issues of use of digital signatures, encryption and privacy within location based services [17-19]. There is a huge demand for better quality of services with ease of use approaches [20] especially in developing countries like India.

For the interoperability and effective integration of advanced techniques such as artificial intelligence in smart services, internet of things (IoT) based platforms are necessary [21]. The IoT is a network of connected devices which are uniquely addressable that communicate in the real time through the standard IP based communication protocols [22]. IoT is a convergence of sensors, actuators, telecommunication, cloud computing and big data, interconnecting them through the Internet to provide goal-oriented services [22], monitoring and control applications as shown in Figure 3.

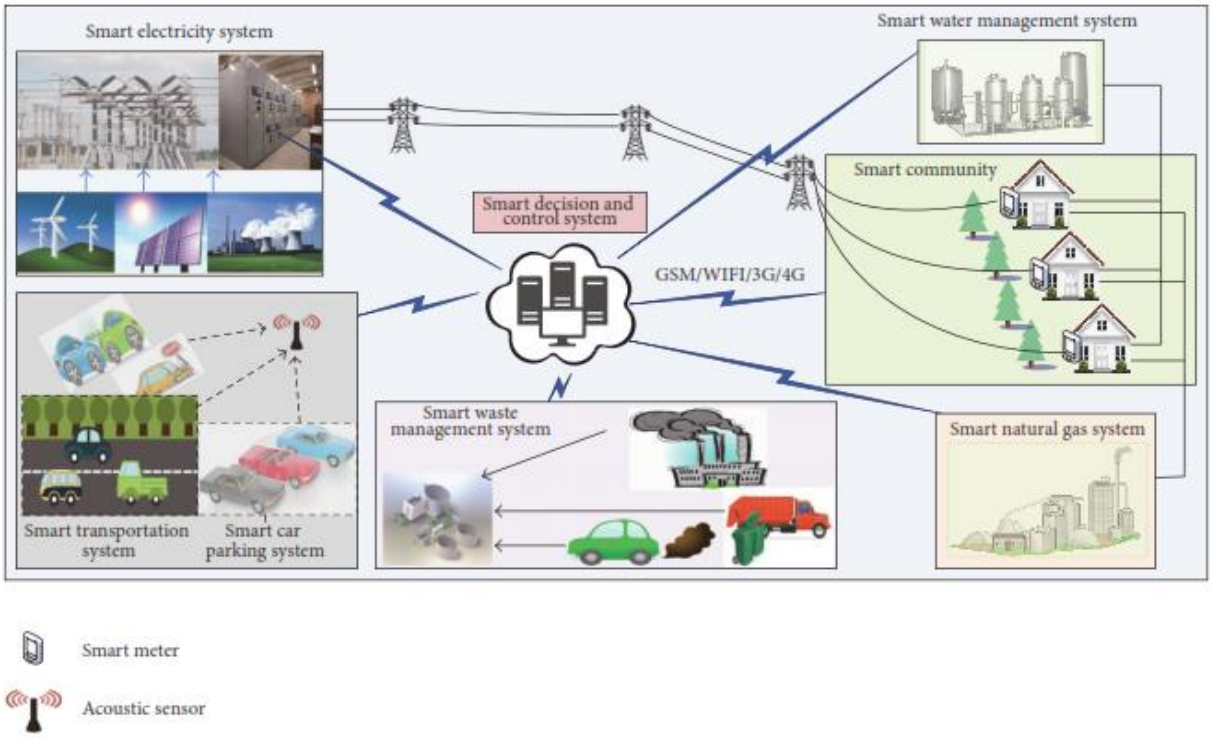

Figure 3. Typical Smart City Architecture

A four layered IoT architecture that can be deployed to facilitate different services and applications in smart cities [21]. This architecture encompasses (i) Technologies layer which is comprise of wireless sensor networks, wired sensors, gateways, etc. to capture the data generated by multiple channels; (ii) Middleware layer where all input data from various sources are expressed as it is collected; (iii) Management layer which is in-charge of determining decisions based on advanced analytics to target services provided in smart cities; and (iv) Services layer which can be enforced to provide smart applications in various city domains such as environmental monitoring, traffic control, energy efficiency, multimodal transport, education, location based services, tourisms responses in emergencies, and other civic services.

6. SMART APPLICATION ARCHITECTURE

Smart cities are expected to provide an array of applications like Intelligent Transportation System (ITS), smart healthcare, smart grids, HVAC (heating, ventilation, AC), smart buildings, environmental monitoring etc. [1].

Smart Things ubiquitously present in a smart city sense sufficient to understand dynamics of smart city. Data from sensors that span a large geographic region is necessary to provide insight for offering intelligent smart city services. In order to make well informed decisions about welfare of smart city, relevant sensor data needs to be uploaded on the cloud for city-wide data analytics e.g. electricity usage pattern over a large number of houses is needed to optimise power consumption of the city. The simplified smart city application architecture is shown in Figure 4.

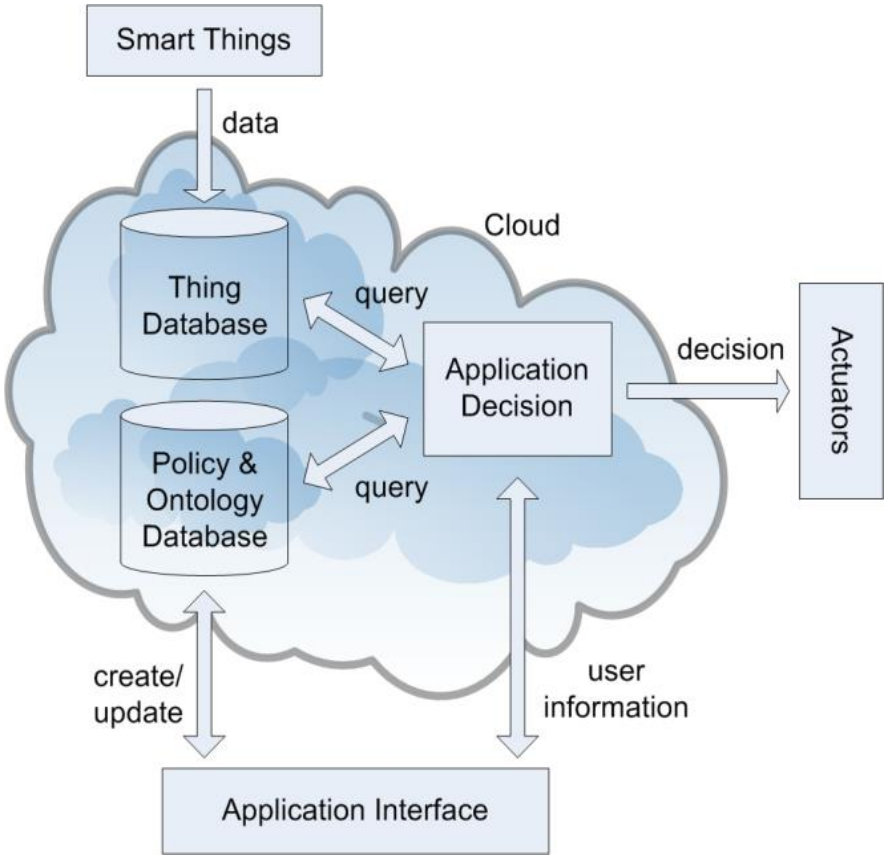

Figure 4. Application Architecture

Smart things upload data to Thing Database (TD) that resides in the cloud, serving as a repository of smart city data. Semantic computing offers feasible methods to indicate Thing Database in a manner compatible among different IoT devices to facilitate interoperability and data aggregation. Smart city applications function in a variety of contexts that may need to be handled differently. Security and decision policies applicable to an ontology are specified in Policy and Ontology Database (POD). The context in which smart thing operates is depicted via the mechanism of ontologies and policies applicable using Web Ontology Language (OWL). The definition of context and the policies applicable are indicated by an authorized user by means of Application Interface (AI). It enables a user to create, query, update and delete the profiles as per requirement. Application Decision (AD) uses necessary cloud infrastructure for processing smart city big data to provide advanced user services. Whenever a decision needs

to be made by an application, Application Decision queries relevant data from Thing Database and obtains context and policy information from Policy and Ontology Database. After a decision is made, relevant user information is conveyed to the Application Interface.

IoT applications are applicable to a massive number of areas ranging from personal to 'big' business. [31] support this notion, stating that the IoT facilitates the development of a myriad of industry oriented and user-specific IoT applications. Whereas devices and networks provide physical connectivity, IoT applications support device-to-device and human-to-device communications in a consistent and robust manner. [32] grouped IoT applications into four broad domains: Transportation and logistics, healthcare, smart environment (home, office, plant), and personal and social domain. [31] listed the leading four industries in terms of IoT value according to their re-search as manufacturing, retail trade, information services, finance, and insurance. In a study of 500 senior executives worldwide who were leading IoT initiatives, results revealed the extent of the importance of IoT applications within areas of their organizations.

7. IOT ENABLED SMART CITIES

The enormous implementation of Internet of Things (IoT) is enabling Smart City projects and initiatives all over the world. The IoT is a flexible method to combine several sensors with all the ICT solutions. In Conjunction With over 50 billion things will be linked and deployed in smart cities in 2020. The heart of smart cities processes is the IoT communications. IoT is intended to support Smart City concept. Growing ubiquity of smart devices throughout society, digital technologies and artificial intelligence offers a new trend of opportunities to turn information into actionable insights, establishing a stability between social, environmental, and economic expectations. These expectations, in turn, can then be delivered through smart city planning, design, and construction.

A smart city can be defined as a modern city that is functionalized in an intelligent and sustainable way to ensure sustainability and efficiency. This goal can be achieved by integrating varied infrastructures and services into cohesive units such that they can be monitored and controlled by intelligent devices. Smart cities mainly aim to address both critical and everyday issues such as crime management, education, energy, environment, healthcare, public transportation, employment, waste management, and the strategic and shared use of buildings and other city spaces, vehicles, and even pets. Utilizing IoT-centred data management and cloud technologies, various urban information systems can be developed to incorporate sensory level data and networking help structures [25]. The benefits and major challenges of the IoT technologies in smart cities have been examined by many researchers [26-29].

8. SMART CITY CHALLENGES

There are numerous aspects and challenges that are to be brought into consideration before moving ahead. The reasons behind why a city may want to change can determine how quickly it will take. Sometimes, cities want to direct their resources to improve the city for higher quality of life and other times cities may be reconstructing itself after a natural calamity or disaster. Following are some main challenges that require to be considered for smart cities.

8. 1. Planning

Cities are shaped by the inhabitants and understanding the human behaviour is critical. For better decision-making, it is essential to investigate urban dynamics, open data, and residents participation. A common issue with many cities is that they are often in a rush to become a smart city. As a result, projects are often insular, creating an information island that wastes funds because of repeated and redundant construction. Several cities do not have a master plan or city development plan. It is essential to plan a smart city and act based on a city's needs in order to improve and provide better facilities to residents. Retrofitting current legacy city infrastructure to make it smarter is another common concern that cities face. There are several challenges when evaluating smart city strategies. One of them is being able to define the areas that need improvements. Also, combining isolated legacy systems into the city is very difficult.

8. 2. Security and Privacy

Various smart solutions require the use of ICTs which increases a concern for information security. The technology range is so large in smart cities that even a small deficiency can cause significant damage. Measures to improve this concern include imposing regulations and laws about information safety, implementing information security levels and risk evaluation systems, increasing the network monitoring capabilities, and strengthening network management. Data that is produced from sensors are used to create effective models. However, the data can be intrusive to some residents making them uncomfortable. As a result, placing sensors on everything may be impractical.

8. 3. Risks

There are numerous possible risks that arise with smart cities. There are policy risks, technology risks, construction risks, operational risks and market risks. Each type of risk is summarized in Table 1.

Table 1. Types of risks

Type	Description
Policy risk	Risk that governing framework changes, heading to a fall in the profitability of the project.
Technology risk	Risk that new technology does not operate as expected in real-life deployment.
Construction risk	Risk of unexpected delays or difficulties that can arise during construction.
Operational risk	Risk that an operation may not operate to its fullest potential because of the lack of skilled operators.
Market risk	Risk that the market demand for a new service or product is below expectation, leading to a loss-making operation.

8. 4. Costs and Quality

Choosing between low costs versus high quality has always been a tough decision. Spending in low-cost materials and resources for smart city projects will result in decreased performance and/or quality. On the other hand, superior quality materials and resources often perform better; however, it is only available at a higher cost. An ideal example of costs versus quality can be deciding which sensors to use. Sensors are one of the most important devices used in smart cities. They are used for smart water management and electricity meters, global positioning system (GPS) devices, traffic sensors, parking meters, weather sensors, crowdsourcing, etc. Low-cost ubiquitous sensors can be utilized in large numbers; however, they produce a low-quality signal and may often require recalibration. In contrast, expensive sensors are more accurate and can be self-calibrated. However, the cost of the costly sensors will be too high to install for significant area coverage.

9. FEATURE VISION OF SMART CITIES

Feature of the Smart cities will allow IoT systems to transform the approach we live and conduct business, with sensors attached to virtually every vehicle, device, or piece of equipment that a city uses on a daily basis. The possibilities are almost endless, as IoT produces invaluable data for a multitude of business intelligence systems, therefore Smart cities research leaves further scope and a need for future research. This research is not free from limitations. Most of the IoT start ups studied as part of smart environment research have a successful background. Using an Artificial intelligence in the smart environment is likely to have a significant and widespread impact on the nature of jobs. Engineering innovation in this area can significantly improve productivity and profitability, and will confidently ensure future food, transportation, water, and energy provision.

The utilization of Smart City IoT technologies results in cost effectiveness, strong infrastructure, and an enhanced urban experience. Smart cities is the modern concept when it comes to constructing the cities of the future. Smart cities are believed to be the key to integrating a sustainable future with continued economic growth and job creation to add a new identity and unique significance to the lifestyle. The new innovations being put forth and built around the Smart city framework now includes eco-city, eco-town, eco-village.

10. CONCLUSIONS

Since the implementation of the IoT infrastructures could facilitate numerous and massive opportunities, initially the utmost research motivations are described and then some useful applications summarized. The Smart Cities Mission is a bold new worldwide initiative to drive economic development and enhance the quality of life of people by empowering local advancement and utilizing technology. The objective of this survey was to offer an insight into new research attempts in the intelligent Smart Environment. We looked at different elements of the smart city system and explained thoroughly with different aspects of this smart application.

There are several factors and challenges that are taken into consideration before moving forward and we have discussed some of them in the paper. Smart city initiatives often require

detailed coordination, funding, and continuous support, as a future work, we plan to survey various solutions and recommendations to address several of the challenges of IoT and smart architectures for smart cities.

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