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Analyzing the Role of the Intenet-of-Things in Business and Technologically-Smart Cities

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Abstract This research analyzes and theorizes on the role that the Internet-of-Things will play in the expansion of business and technologically-smart cities. This study examines: a) the underlying technology, referred to as the Internet of Things that forms the foundation for smart cities; b) what businesses and government must do to successfully transition to a technologically-smart city; and c) how the proliferation of the Internet of Things through the emerging cities will affect local citizens. As machine-to-machine communication becomes increasingly common, new use cases are continually created, as is the case with the use of the Internet of Things in technologically-smart cities. Technology businesses are keeping a close pulse on end-users' needs in order to identify and create technologies and systems to cater to new use cases. A number of the international smart city-specific use cases will be discussed in this paper along with the technology that aligns to those use cases.

Keywords Internet of things, Smart cities, Machine-to-machine communication, Analytics, Open data, Technology, International use cases, Business technology

1. Introduction

Since early humans settled to cultivate the land and trade with neighbours, forming larger and denser populations, it has been mutually advantageous to organize in cities that provided community services and utilities. Initially, cities were created to provide military protection but later for attaining economies of scale and efficient management of resources and services (i.e., utilities, healthcare and communications, among many others.)

Emerging business and technologically-smart cities are complex human settlements and associated information systems deployed for collaborative governance and services (i.e., commerce, sanitation, utilities, land-usage, housing, and transportation). Through machine-to-machine communication, the Internet-of-Things (IoT) has become increasingly prevalent in the day-to-day activities of people across the world. In addition to changing the way that technology consumers live their lives through elements such as wearable technologies, including the Fitbit which tracks one's sleep and physical activity, governments around the world are realizing the benefits that IoT can have when integrated throughout their cities' physical infrastructure. The traditional method of city design dates back to the 1800s in which centralized networks were designed to deliver energy and water and facilitate transportation; however, "modern cities designed around the private automobile, with single-function zoning, are becoming more congested, polluted, and unsafe" [1].

Angelidou expands upon the need for change by outlining four additional forces driving the need for modernization of cities [2]. Those four forces are:

- Increased urbanization driving the need for higher efficiency.
- Climate change and natural resource scarcity becoming a growing concern for cities.
- Diminishing financial resources.
- Competition among cities to attract investors, tourists, and skilled workers [2].

For these reasons, cities across the globe are beginning to integrate the IoT technologies throughout their current infrastructure and processes. The purpose of integrating the technologies is to capture and analyze data in order to identify and implement methods to run city operations in a more effective, efficient manner. Such cities are referred to as smart cities. This paper examines the role that the IoT plays in the proliferation of smart cities; specifically, it examines the underlying technologies that make up smart cities, what a city must do in order to transition to a smart city, and how the implementation of smart cities will affect its citizens.

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2. Smart City

Several studies in the academic field attempted to define “smart city” by reviewing existing definitions [3-6]. Those found “smart city” is referred as many different names such as intelligent city, knowledge (based) city, wired city, digital city, virtual city, and information city, and concluded the there is no clear definition of smart city. However, Cocchia found that the use of the term smart city became the overwhelming majority since 2011 [4]. Cocchia also summarized the most cited definition of smart city and digital city. The words shared in those definitions are information and communication technologies (ICT), people or citizens, and quality of life in city with less emphasis on environment, while Anthopoulos, and Vakali, claims that smart city involves ecological aspects [4, 6]. Anthopoulos created a smart city conceptual framework using the five domains: resources (including environment), transportation, urban infrastructure, living, government, economy and coherency [5].

Nine areas were identified as smart growth areas: transportation, government, safety, society, health care, education, buildings and urban planning, environment, energy, and water [7]. IoT-related technologies can be implemented in physical infrastructures in those areas such as roads, bridges, and traffic lights. From a high-level perspective, the necessary technologies for a fully integrated smart city can fall into the categories of mobile, social, cloud, and big data. On a more granular level, there are various technologies necessary in order to enable and connect the elements listed above. Some of the necessary technologies include wireless networking, fiber optic cables and/or long-lasting batteries for power, data gathering-sensors, imbedded processors and operating systems, as well as storage devices.

Smart cities have three information technology (IT) challenges: IT infrastructure, security and privacy, and operational cost [3]. In order to operate and perform their functions, these technologies must be supported by back-end infrastructure, such as virtual machines, high-speed networking, storage and backup. The data gathered by the operating-system enabled sensors is sent through the network where it reaches the data center and is stored on the virtual machines. From there, the data is put into usable form through a business intelligence platform that takes the data from its raw form and organizes it in way that is valuable to the end-user. Another important piece of the smart city puzzle are mobile devices enabled with the appropriate platforms so that the data can be accessed and used in real time to make decisions. Furthermore, an integral aspect of the IoT and its use in smart cities is the installation of sufficient security solutions in order to protect the data being gathered and analyzed through the network of systems and sensors implemented throughout smart cities. As this data includes information about citizens, infrastructure, utilities, and other local information, it is imperative that this information be protected. Finally, cost of IT professionals and consultants as well as cost of installation, training, operations and maintenance must be justified by benefits smart city citizens receive.

3. IoT and Smart City Technologies

The various sensors, networks, storage, and other elements are put together to form a number of technologies that create the foundation for smart cities. Examples of smart city technologies include the smart grid that uses smart meters, smart water management systems, transportation monitoring systems, and lighting management systems. Together, these technologies enable better monitoring and operational readiness and increased efficiencies. Companies infiltrating the smart city market include Schneider Electric, Cisco, City Protocol, Bigbelly, Metropia and others, which help governments achieve their goals of increased efficiency, monitoring, and operational readiness. Tables 1a, 1b, 1c and 1d shows examples of a variety of smart city technology solutions with emphasis on IoT and the functions they accomplish and each of them will be further discussed in this section.

Table 1a. Examples of smart city technologies and functions accomplished

Goal to be achieved	Potential Smart City Technologies	
	Company/Product	Role of IoT
Increase Energy Efficiency	Schneider Electric Geospacial Intelligence – ArcFM.	Collect real-time data about weather, traffic, vibration on machinery, and power consumption on all branches of the power system and more. Specific Function: Enterprise geographic information system with network intelligence.
Increase Energy Efficiency	Siemens Microgrid	Collect data from weather forecasting system, local building automation systems, and metering systems and more. Specific Function: Generates, distributes, and regulates the flow of electricity in an efficient manner by integrating distributed energy resources.
Increase Energy Efficiency	Cisco Smart+Connected City Lighting	Gather data such as levels of humidity, CO2/O2, UVA/UVB, particulate matter, motion and earthquake-related activity, video, sound and more and perform real-time video and sound analysis. Specific Function: Light-sensory network that provides data to support city services across a common infrastructure.

Table 1b. Examples of smart city technologies and functions accomplished

Goal to be achieved	Potential Smart City Technologies	
	Company/Product	Role of IoT
Smart Transportation	Gogoro Smartscooter.	Collect data of electronic scooter performance for analyzing each driver's riding patterns and generating a smoother, more energy efficient ride. Specific Function: Zero emission, two-wheel vehicle.
Smart Transportation	Metropia Metropia Mobile	Collect real-time traffic condition from traffic cameras. Specific Function: Traffic portal that provides navigation and route information during both peak and non-peak times.
Smart Transportation	Veniam NetRider.	Turn any vehicle into a mobile Wi-Fi hotspot and collect on-board data, GPS positions, footage from surveillance cameras, passenger counts, and ticketing information. Specific Functions: Equips vehicles with networking to facilitate vehicle-to-vehicle and vehicle-to-infrastructure communications across a common infrastructure.

Table 1c. Examples of smart city technologies and functions accomplished

Goal to be achieved	Potential Smart City Technologies	
	Company/Product	Role of IoT
Smart Waste Management	Bigbelly Connect.	Host a Wi-Fi spot and report when a waste container is full. Specific Function: Smart waste management and recycling.
Smart Waste Management	Enevo One	Monitor the fill-level, temperature and movement of solid or recycle waste bins. Specific Function: Measures and forecasts the fill levels of waste containers.
Smart Waste Management	MIT SENSEable City Lab.	Track the movement of each recyclable waste. Specific Function: Visualize the movement of each recyclable waste to achieve 100% recycle.

Table 1d. Examples of smart city technologies and functions accomplished

Goal to be achieved	Potential Smart City Technologies	
	Company/Product	Role of IoT
Data Analysis	NTT Data. BRIMOS.	Collect real time streaming data such as changes in position, slant, stress and more. Specific Function: Bridge monitoring and data analysis.
Data Analysis	IBM. Watson Analytics, Smarter City Operations Center and Intelligent Operations Center.	Monitor weather, traffic, water flow, events, crimes and emergency situations. Specific Functions: Predictive, prescriptive analytics, data visualization and collaboration.
Data Analysis	Apical. Spirit ART.	Process raw pixel data from a camera lens, identify a person without actual video pictures and predict his/her behaviors and detect abnormality in behavior. Specific Function: Real-time analytics for visual information.

The state of Vermont in the United States utilizes a smart city product called ArcFM, developed by Schneider Electric. It is an enterprise Geographic Information System with network intelligence that provides information such as pipe water direction flows, the number of customers attached to a gas meter, and what devices are downstream of a particular fuse on a map [8]. IoT sensors in the system collect real-time data about weather, traffic, vibration on machinery, and power consumption on all branches of the power system [9]. Then, the system uses predictive analytics and geospatial visualization to provide intelligence as a cloud based service for governments to make a better decision about utilities, water, transportation, health care, oil and gas management.

An island of Hawaii in the United States uses Siemens' Microgrid, which integrates distributed energy resources such as solar photovoltaic, backup generators, behind-the-meter batteries and other grid-edge technologies into a power grid [10]. It works as a scaled down version of the centralized power system that generates, distributes, and regulates the flow of electricity for smaller power operators such as university campuses, industrial and commercial sites, and municipalities [11]. It collects the data from IoT used in a variety of systems including weather forecasting system, local building automation systems, and metering systems to forecast demands and provides seven-days generation forecasting from a variety of resources such as solar, wind, diesel, thermal, and so on [12, 13].

Cisco's Smart+Connected City Lighting and

Smart+Connected City Multi-Sensor Node create a Light Sensory Network by transforming LED light fixtures into smart devices. City Multi-Sensor Nodes are embedded in lighting infrastructures to gather data such as levels of humidity, CO2/O2, UVA/UVB, particulate matter, motion and earthquake-related activity, video, sound, and more (Cisco, 2015). The uniqueness of IoT used by Cisco is that the data captured at each fixture can be analyzed at the capture point. They are equipped with capability that can perform real-time video and sound analysis, as well as license plate and facial recognition. The system can gather real-time parking availability data, which helps drivers to find a parking spot and allows parking facility owners to dynamically price the spot [14]. The system can also count traffic, the number of visitors and the duration of visits, allowing more effective management of airports, malls, and business districts [14]. Those data and analytics results are transmitted via the Light Sensory Network to support many city services and programs for security improvement, environmental improvement, transportation monitoring, and earthquake preparedness [14]. The city of Kansa City in the United States is one of the users of Cisco's Smart+Connected City.

Gogoro established a battery-swapping network for its electronic scooters. The scooters can be locked and unlocked by iOS and Android smartphones as well as by Apple Watch. They contain eighty sensors to collect data and the "smart mode" analyzes each driver's riding patterns and generates a smoother, more energy efficient ride by optimizing the power, tuning the torque, and dimming the light. A unique feature of Gogoro's system created is a network of kiosks called GoStation, where the drivers can swap the scooter's two lithium-ion batteries. The Gogoro App locates GoStation and reserves batteries. Gogoro App also monitors the status of the scooter, alerts the driver if any maintenance issues are detected, and reserves an appointment [15]. Gogoro provides two years of free battery swapping and uses a subscription model for the swapping after the two years [16]. Gogoro has established the network in Taipei and is trying to establish another in Amsterdam [16].

Metropia is a traffic app that predicts better routes and times by analyzing the city's mobility pattern. Metropia uses traffic cameras as IoT and cloud-sourced information from social media to collect the data and pushes real-time traffic condition information to the users [17]. The driver can reserve a trip ahead and can receive an alert about changes on the route such as an accident, detour, or closures before and during the drive [18]. The system also provides incentives such as gift cards or free event entries to the users to drive during off-peak hours or take a less congested route [18]. Los Angeles, Austin, and mountain ski resort areas around Denver are examples of Metropia users.

Veniam NetRider is a box that can turn any vehicle into a mobile Wi-Fi hotspot and it also includes 3G or 4G cellular interface. Veniam's system can seamlessly cover the entire city with a single login Wi-Fi by using a meshed network created by the combination of stationary routers attached to the city's existing Internet infrastructure and mobile Wi-Fi spots created by fleet of vehicles such as buses, cabs, waste trucks and police cars, filling in the gap between the stationary routers [19]. Each vehicle is connected to the stationary router, but if it becomes too far from the router, the vehicle can piggyback on the connection of another vehicle within a range to connect to a stationary router. The system also collects the urban data such as on-board data, GPS positions, on-board diagnostics, footage from surveillance cameras, passenger counts, and ticketing information in the network and the data is used to control the vehicle network to enhance the fleet operations and improve security [20]. The system can also be used to collect data about air quality, noise, or a garbage container from sensors all over the city as the vehicles go around [21]. The system has already been used in Porto, Portugal.

Connect by Bigbelly is a smart cloud-connected waste and recycling system that delivers an integrated, cloud-connected platform as a service [22]. The system uses solar-powered, self-compacting waste and recycle containers that can not only handle five times the amount of trash but also host Wi-Fi hotspot service to the public and display custom-advertisements. The containers have sensors that report when the cans are full. The data collected are sent via a cloud system and enable cities to optimize pickup routes and save money [23]. The real-time data allows scheduling only necessary pickups instead of driving trucks around. The system was created to solve the waste collection problem in which "cities were either collecting too often and wasting fuel and labor while creating CO2 emissions, or they were not able to keep up with the demands and overflowing trash cans created litter, health and safety issues" [24]. The city of Philadelphia estimated the saving in the operating costs from the system is 70% [25]. The Connect by Bigbelly has been used in New York, Chicago, Boston and many other cities.

Enevo Plus system uses a self-powered wireless sensor to monitor the fill-level, temperature and movement of solid or recycle waste bins. The sensor uses standard wireless cellular network technology to transfer the data to Enevo servers. Using the data, the Enevo system can display predicative fill level forecasts, fill level trends and history, urgent needs of collections, collected weights and volumes on a dashboard [26]. The Enevo Operate system automates the process of collection scheduling and optimizes collection routes [26]. The system provides tailored views for operations managers, dispatchers, and drivers with navigation guidance. The city of Rotterdam, Netherland is one of the users of Enevo.

MIT SENSEable City Lab worked in 2009 on Trash Track to achieve 100% recycle of trash and tested in New York and Seattle when only about 30% of the waste was diverted from landfills for recycling in the city of New York [27, 28]. Trash Track uses a tag attached to different types of recyclable trash. The tag is a smart and location aware micro-electromechanical system called smart dust. Using this IoT technology, it becomes possible to follow the movement of everyday recyclable objects through the waste management system in real time. One the tag is attached, TrashTrack can visualize where a recyclable waste item is heading in real time.

A bridge monitoring system, called BRIMOS, developed by NTT Data, uses sensors installed on a bridge to collect real time streaming data such as changes in position, slant, and stress. Then, the data are sent to its data center and immediately analyzed using Complex Event Processing (CEP) for real-time anomaly detection. CEP is a relatively new type of event processing that filters and summarizes incoming event streaming data as they arrive and detect patterns and an occurrence of more significant events in the future within seconds or minutes [29]. CEP software vendors include IBM, SAP, Software AG, Tibco, Oracle, SAS, Microsoft, LG, Hitachi, and others. CEP was applied in fraud detection, financial trading, dynamic pricing, and other areas that require real-time data analysis and immediate decision making and responses. NTT Data accumulated the data from multiple bridges for mining and developed a CEP software that processes the data in-memory, detecting abnormalities in the data combined from multiple sensors, estimating the degradation of the bridge over time, the weather conditions, the state of the bridge after a natural disaster such as an earthquake, the weight of passing vehicles and the number of vehicles, and suggesting a repair and maintenance in real time to avoid a catastrophic event such as a collapse of the bridge [30]. BRIMOS was placed on the Cau Can Tho bridge in Vietnam.

IBM Watson Analytics is a cloud-based predictive and visual analytics service with natural language-based cognitive capability. Watson Analytics Professional provides an additional feature that allows multiple people to work simultaneously in a single Watson Analytics dataset for collaboration [31]. Watson Analytics helps to identify what is happening, why it is happening, insights hidden in the data and communicate the insights with others [32]. Three main features of Watson Analytics are exploration of the data, predictive analytics, and dashboards. Based on IBM, unique features of IBM Watson is its natural language processing capability and dashboards, which are useful for decision makers of city governments and businesses because many of those decision makers lack the technical skills to perform the analytics [33]. Watson has a feature to help the user construct a question using a natural language and also allow the user to create a starting point for the data exploration by changing the data presented in the visualization charts [32].

IBM has several products that use IoT technology, dashboards, analytical tools such as Watson, and collaboration tools. Those include Smarter City Operations Center and Intelligent Operations Center and others. For example, Smarter City Operations Center and Intelligent Operations Center monitor weather, traffic, water flow, events, crimes and other data, display them on a map, detect abnormality, initiate a collaborative work flow, and send notifications to relevant agencies in near real time [34]. Intelligent Operations Center for Emergency Management can recognize an emergency situation as it arises and send the best available equipment and emergency personnel [34].

Apical Spirit ART system receives raw pixel data from a device that contains a camera lens and transforms them to digital representation of important features found in the scenes [35]. Its uniqueness is a capability to analyze visual data without video, decipher the scene, and use visual sensing to create digital computer-usable avatars of individuals in the scene [36]. Actual videos that may contain a person in underwear are not captured. Spirit ART system can differentiate adults from kids, people from pets, residents from strangers [37]. This can be used to monitor the behavior of people and what's going on at home based on their identity, pose, gesture, movement as well as any change in the Internet-connected devices at home that monitor lighting, smoke and temperature. It could be used to detect abnormalities and even predict what people want to do next as their behavioral pattern. A smart home can know anticipate a user's wants and/or needs [38].

As shown in the examples (see Tables 1a, 1,b, 1c and 1d, IoT plays a significant role in information systems for smart cities. However, it is obvious that the necessary technologies such as IoT, mobile devices, social media, cloud computing, and all different types of analytical tools must be fully integrated as a smart city solution.

4. Transition to Smart City

There are several approaches to transform a traditional city to a smart city. For example, Zygiaris developed a seven-layer holistic conceptual reference model and claims that the balance between the top-down approach and bottom-up approach [39]. Bouton at McKinsey & Company summarized the managerial practices synthesizing more than 80 cases [40]. Letaifa, states that "a city is 'smart' when that city can integrate and synchronize formal leadership and endogenous democratic participation in the IT-based urban ecosystem [41]." Letaifa also claims that smart cities need hybrid models of the top-down and bottom up approaches to combine community-based and private section initiatives and the government's long-term vision, coordination, support and monitoring and developed the SMART model (Strategy, Multidisciplinary, Appropriation, Roadmap, and Technology) [41]. Finally, Schneider Electric developed its 5-step approach that also combines bottom-up and top-down approaches: vision, solution, integration, innovation and collaboration [42]. A city's government must decide what it wants its end goal to be; from there, it must acquire the technologies and training necessary to achieve that goal. Next, it must integrate the new technologies with the city's current infrastructure and do so in a way that meets the unique business model of that city. Finally, it must create collaboration between global players and local stakeholders. The main common theme found in these approaches is the combination of top-down and bottom-up approaches are necessary.

Most smart city implementations are done with at least one of the following three goals: increased energy savings, decreased water loss, and increased safety and efficiency on roads. However, as a first step, it is important to identify a city's competitive advantages to strengthen existing advantages or incubate a new advantage [40]. By doing this, the city can not only use a top-down approach to identify a smart city opportunity but also a bottom-up approach to coordinate efforts created by the community and private initiatives into the city's formal smart city plan. Another aspect to be considered during this stage is the use of a broader regional perspective. City leaders need to think about regional growth and seek for the cooperation of near-by municipalities and service providers to avoid unnecessary local competition and conflicts [40]. Depending on what a city's end goal is, there are a number of different ways to achieve each goal. For example, if a city's goal was to reduce energy expenditures, it could do so by installing smart grids, and leave it at that, or it could implement a number of different energy-saving technologies such as a light management system and geospatial intelligence solutions. First, a city must decide specifically what its end goal is, for example by how much it would like to reduce its energy expenditures. From there, it should work with stakeholders such as regional authorities, community and private sectors, as well as an IT consulting or advisory firm to determine the optimal plan of action considering the city's current infrastructure, budget, and overall needs.

Once a city decides its end goal, it then has to choose which technology solutions it will implement in order to achieve those goals. It is important to inventory the existing ICT infrastructure as integration of smart technologies to the existing infrastructure is a key to succeed. Then, a city can choose one from the two main options. The first one is to choose from a number of off-the-shelf solutions offered by large vendors, such as IBM or Cisco. The portfolio of their products provides solutions across a wide variety of purposes. For example, Cisco's Smart+Connected Communities includes Cisco's Smart+Connected City Safety and Security Solution that aims to reduce a city's crime rate by providing location monitoring, incident detection and management, administration, and analytics, its Smart+Connected City Lighting that aims to reduce energy through a powerful light-sensory network and others such as Operations Center, Connected Parking, Traffic, and Wi-Fi. IBM has a variety of Smarter Cities solutions for three major categories: public safety, government and agency administration, and smarter buildings and urban planning.

As the second option, a city could also choose to piece together solutions from smaller, niche vendors such as Metropia and Bigbelly. Although a city's IT department may experience integration issues when implementing solutions from various vendors due to the varying platforms and operating systems on which they run, the challenge may be worthwhile if the individual solutions are the best fit for the goal and strategy that the city has decided to achieve. As the amount of smart city technologies increase on almost a daily basis, cities have a plethora of options to begin their transition to smart city. The technologies often require large capital investments and strenuous work to implement, therefore, it is imperative that a city's IT department seek counsel when creating their strategy for transitioning to a smart city.

After a city has decided upon a strategy and chosen the appropriate vendors and technologies, it is then tasked with deploying the technologies into its current physical infrastructure. A city can either get its IT department the training it needs to install the technology itself or it may choose to partner with a professional services team who specializes in the installation of the specific technologies. In some cases, such as installing the BRIMOS technology on a bridge, it may be necessary that a city partner with a team that specializes in the installation of each smart city technology. Once the technology is installed and connected with the necessary back-end technologies, a city can then begin using technology for its desired purpose.

One of the issues with IoT used in smart city technologies is security. Many IoT devices may not have enough security, or the users of IoT devices tend to ignore securing them. This was proven in a massive Internet outage which happened on the East Coast of the US in 2016. IoT devices were used for a distributed denial of service attack (DDoS) [43, 44]. After the outage, a Chinese company recalled millions of web-connected cameras and digital recorders to enhance the security because the users failed to change the default password, and the devices were compromised [44]. It is critical to ensure that IoT devices are secured at as a high level as other traditional computing resources.

Another issue is privacy. An article in Harvard Business Review shows that 46% of the companies surveyed believe "ensuring privacy and regulatory compliance" is an obstacle in deploying IoT technologies, while 28% of them expressed "securing IoT sensors and their data" is an obstacle [45]. There is no privacy regulation specific for IoT, complying with guidelines and regulations, such as Fair Information Practice Principles (FIPPs), Privacy by Design, and, for European citizens, General Data Protection Regulation (GDPR), helps to understand the privacy risks associated with IoT devices [46].

5. Effect of a Technologically-Smart City

The type of benefits that a city can receive by implementing smart city technologies can be endless. Of course, a city must first make the initial investment in the smart city technologies, but if the solution has been correctly chosen and architected, the return on investment can be exponential from a number of perspectives including monetarily, operationally, and socially. One of the largest potential benefits that a city can receive through the transition to a smart city is that "many different services and infrastructure systems can be managed from one central hub, keeping oversight on many divergent aspects of life in the city" [47]. The ability to monitor a city and thus track elements such as traffic conditions, emergencies, and crime can be invaluable to a city's government as the data provides the opportunity to better understand and potentially prevent future negative incidences. As mentioned before, the city of Philadelphia estimated the saving in the operating costs in waste management from the Bigbelly system is 70% [25]. A study from Electric Power Research Institute says smart grid technology could save $1.3 trillion to $2 trillion in benefits over that period over twenty years [48].

Other benefits are not as easy to quantify. For example, Charlie Catlett, the Director of the Urban Center for Computation and Data in Chicago, is leading an effort called The Array of Things, a project in which 500 sensor-packed boxes are distributed throughout the city to gather data on air quality. The Array of Things will feature boxes that "will likely measure temperature, precipitation, humidity, air quality, and pedestrian flow," and "microphones, for instance, could detect noise pollution or trucks idling in one spot for too long" [49]. The data from these boxes would be made available to atmospheric scientists, social scientists, and city planners, thus giving them information on areas such as air quality, temperature, traffic patterns, and pedestrian counts in order to equip them with reliable data to make more informed decisions such as knowing where to place new bus stops [49]. This data could also be made available to citizens, such as runners, to help them make decisions on routes to take to avoid more highly polluted areas.

The variety of purposes that can be accomplished through IoT continues to grow at a rapid pace as companies consistently innovate and provide new offerings. As of right now, some of the most consumer-friendly technologies include parking applications that show drivers where available parking spots are; open-data initiatives that make city-wide data such as restaurant sanitation scores available to citizens; city guide applications that make real-time data on traffic, museums, and other local landmarks available to citizens and tourists; social media-based alert and response systems; and smart climate control systems [50].

A number of cities, such as New York, Glasgow, Vienna, Nice, and Tokyo have implemented various elements of smart city technologies, but few have executed the concept as completely as Barcelona has. According to Juniper Research's Smart City Ranking, Barcelona is ranked as the top smart city in 2015, followed by New York, London, Nice and Singapore [51, 52]. As part of effort between 2011 and 2015 led by the major, Xavier Trias, the city of Barcelona initiated over eighty distinct projects in twenty-two programs in twelve areas including transportation, water, energy, waste, and open government [53]. The city now uses its fire optic cable network to utilize several IoT systems such as smart meters for monitoring energy consumption, smart bins for managing household wastes, and a smart lighting system for reducing energy consumption, monitoring air quality, and creating Wi-Fi spots, digital bus stops that provide updates of bus locations, USB charging stations, free WiFi, a smart parking system that shows available parking spaces, guides drivers to open spaces, and notifies if the vehicle has been parked in a given space location, and the telemanaging irrigation system at parks for monitoring humidity, temperature, wind velocity, sunlight, and atmospheric pressure and controlling park irrigation and water levels in public fountains [53]. The government of Barcelona had its citizens at the forefront when it created its smart city strategy. This citizen-focus is evident throughout a number of Barcelona's smart city projects such as its Telecare Service which provides free emergency response service to elderly and disabled residents. Another popular aspect of Barcelona's smart city efforts is its Apps4BCN portal that brings together a number of different mobile applications that provide information on current local activities, places to see, restaurants to visit, and local news. More projects include those such as smart traffic lights that emit sounds designed to help blind people navigate pedestrian crossings. With these IoT smart city systems, Barcelona estimated $58 million saving on water, $37 million saving from the smart lighting system, $50 million increase in parking revenues, and 47,000 new jobs [53].

Another popular aspect of smart cities that a number of governments are implementing is that of open data initiatives in which governments make city data available to everyone. Barcelona made its platform open, sharing the data not only across the city departments but also with private companies that develop sensors and analytics software in the future, and it has been working with an international organization called City Protocol to share the data with other cities [54]. The government of Vienna has been working with Open Data Institute co-founded in 2012 by the inventor of the web Sir Tim Berners-Lee and AI expert Sir Nigel Shadbolt and has implemented the open data initiative to make makes the city data available to the public for their further use [55]. Similarly, London has been working with Open Data Institute and instituted the London Data Store which provides citizens with information on statistics such as population, crime rates, household waste, and unemployment [56].

Through projects such as Barcelona's Telecare Service, London's Data Store, and Vietnam's Cau Can Tho bridge, one can see how both citizens and governments can benefit from the implementation of smart city technologies. Whether the technologies are implemented to provide convenience to citizens and tourists, reduce energy expenditures and water loss, ensure timely maintenance of city infrastructure, or any number of the other purposes that IoT can accomplish, the benefits are undeniable. As cities experience the benefits of transitioning to a smart city, technology vendors will continue to innovate and create more offerings to meet more needs.

6. Conclusions

According to Gregory Mone, "More than half of the world's population currently lives in or around a city. By the year 2050, the United Nations projects another 2.5 billion people could be moving to metropolises [49]." As cities continue to grow, the need for better monitoring and operational efficiency becomes increasingly important. The traditional method of designing cities has become outdated, which is easily observable by anyone that has experienced a large city during rush-hour traffic, had to modify his/her route due to unforeseen construction, or simply dealt with an unnecessarily high utilities bill. For that reason, it is imperative that governments around the world begin evaluating the idea of making the transition to a smart city. As shown in this paper, there are a number of different ways that a city could leverage smart city and IoT technologies. The city could start off with a technology that meets the greatest area of need, such as Cisco's Smart+Connected City Safety and Security Solution in an area with high crime rates or Schneider Electric's Smart Grid technology in an area that experiences excessive utility expenses. From there, the city could implement a series of connected technologies that meet other needs to not only improve operations but also improve the lives of its citizens. Making the transition to a smart city requires much planning, large investments of capital and human resources, and a period of adaptation, but the benefits can far outweigh the costs.

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