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Smart City Technologies and Implications for Global Sustainability and Social Development

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Abstract

The purpose of this paper is to introduce the problems posed for the cities of the future, and then to present the technologies that can, and will be developed around the world to create smart cities to combat these problems. There are many opportunities for organizations to develop, implement, and take a role in developing the cities of the future by adapting many technologies that are already being used in private industry to cities. These technologies impact on business will also be presented. Numerous journal articles, reports, white papers, news sources and industry resources were used to research the concept of smart cities in an attempt to create a full, holistic view of the impact they are expected to have and the technologies they will utilize in the future. These resources were also used to gain a clearer picture of the extreme population growth and the problems and unique opportunities it poses for society and business. Smart cities are able to create more efficient and sustainable living areas by leveraging technologies to improve infrastructure and services to the increasing number of residents that dwell in urban environments. Some however are not so sure, and the concerns and limitations related to smart technologies therefore will be addressed before the paper concludes.

Keywords: Smart Cities, Population, Technology, Sustainability, Social Development

Introduction

Once one begins to understand the magnitude of the population that resides in our cities, as well as the size of our cities, one can begin to see the need for an idea such as smart cities. A pair of quick statistics can quickly put this into perspective. Cities currently only cover 2% of the planets livable land, and 50% of the planets population lives in cities (United Nations, 2014). This trend is expected to grow, and in the next fifteen years the amount of people that live in cities is expected to increase by 39% to 5 billion people and the United Nations believes that "Managing urban areas has become one of the most important development challenges of the 21st century" (United Nations, 2014). Furthermore, cities have tremendous economic ramifications as McKinsey expects an estimated $30 trillion dollars will be added into the world economy by 2025 from growing cities (McKinsey Global Institute, 2012). Let the magnitude of those numbers sink in for a moment. The extreme pressure and needs to develop modern power sources, city services, transportation, buildings, etc. become abundantly clear.

Realizing these increases in population and the associated costs are coming, and knowing the impact cities have on the environment and economy, at both micro and macro levels, leaders are beginning to plan and adapt their cities to the future. This is done with the idea of making their cities more attractive and sustainable places to live, as well as more affordable to run. Therefore, to achieve what one report refers to as 'healthy growth', many are turning to data driven solutions and information and communication technologies to cut operational costs and create new efficiencies to improve the quality of life and economy within their cities (Bouton, Toes, & Woetzel).

What is a Smart City?

The idea of a Smart City is still one that is very much evolving, and is one that is used around the globe to mean a variety of different things. The term itself is not even yet fully agreed upon as some use 'urban intelligence', 'City 2.0' or 'real-time city' (Roche, 2014). This lack of conformity and agreement surrounding this term is understandable. This is because every city is different and the subsequent technology solutions and scale are unique and different as a result. Many definitions involve connecting existing city infrastructure to new IT infrastructure such as this definition which defines a smart city as "a city in which information and communication technologies are merged with traditional infrastructure, coordinated, and integrated using new digital technologies" (Batty, Axhausen, & Fosca, 2012). One encompassing definition which perhaps best summarizes the overall theme of many smart city definitions, that of using technology to improve and enhance economic conditions and quality of life within urban areas is that proposed by Robert Hall (2000). "Smart Cities is the urban center of the future, made safe, secure, environmentally green, and efficient because all structures - whether for power, water, transportation, etc. are designed, constructed, and maintained making use of advanced, integrated materials, sensors, electronics, and networks, which are interfaced with computerized systems ..." (Hall, 2000).

Regardless of the terminology used or the definition applied, leaders adopting the ideas and technologies associated with smart cities are invariably taking a long view of their city and its goals and "trying to figure out how technology can be in service of that vision." (Townsend). The idea here is the evolution of the way we as humans work and reside in cities as both the world around us and the technology within it change at a rapid pace. Cities and industry are realizing that adapting technologies and cost saving approaches such as data collection and mining to improve decision making and RFID to track assets, can improve the way a city is run, benefitting all those who work and reside there. Having a smart city will allow cities to better collect, store and analyze data and make that information more easily accessible to the right parties. This will help lead to "efficient, effective implementation and management of smart solutions for economic, social, and environmental gain." (Falconer & Shane, 2012).

Implications for Business

As cities look to integrate new technologies with their existing and planned infrastructure they will need a variety of knowledge and vendors to help them choose and implement the proper solutions for their unique cities. Therefore the opportunity for companies to capitalize on the emerging market of smart cities is great. A recent Forbes article puts the estimated market potential related to smart cities at over 1 trillion dollars, a dollar total larger than many countries GDP (Singh, 2014). There will be and are many market participants including those that offer a smart product, one that has intelligent sensing technology and connects and transmit information through the internet. In this way the product is able to sense and interact with its changing surrounding environment and can provide optimal performance and efficiencies as a result (Perevezentsev, 2012). Although there are numerous ways for all companies, not just tech companies to capitalize on this market opportunity, there are 4 generally agreed roles that companies may adopt for this market (Reddy, 2015).

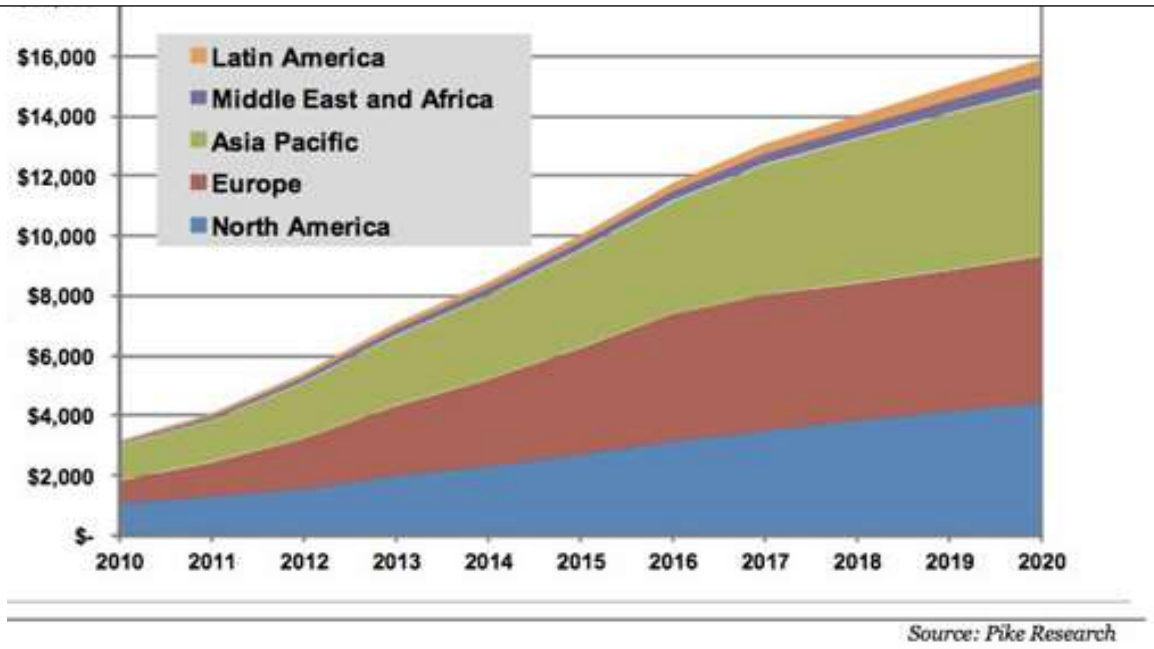
- *Consolidators (Integrator)* - Using pre-packaged platforms, these companies provide end to end service between the many areas of the smart city, creating and enabling a unified system.
  Ex: IBM provides end to end services to many cities and provides solutions for integrating disparate city systems, helping to improve the efficiency and functionality of city services. (IBM, 2014)
- *Contractor* - These companies will offer data analytic services, enterprise working solutions, and network services. They will function as network operators and service providers and will likely be able to use their pre-existing capabilities to do so.
  Ex: Cisco leverages its pre-existing networking abilities used in private industry to offer intelligent networking capabilities to cities.
- *Concessionaire* - These product vendors will provide the hardware and devices that are used as the main connectivity points within the smart city. Some cities are willing to partner with vendors to try new products. In this way the city receives the service for a discount and the vendor receives valuable feedback before attempting to scale the product (Department for Business, 2013).
  Ex: Eaton provides smart electricity meters that communicate both to the consumer and the city utility

- *Caterer*- These companies provide onsite consulting, monitoring and other managed services.
  Ex: Infosys provides third party support to cities

Smart cities benefit businesses both large and small across many industries including construction, manufacturing, trade and utilities, professional services etc. in addition to the technology industry. There is a strong demand for companies that can provide adaptable and sustainable solutions to the various problems that cities face both now and in the future and those that offer affordable and adaptable solutions are posed to capitalize.

The concept and implementation of a smart city can benefit the cities inhabitants' quality of life but also can help create a more diverse and healthy economic environment. These cities offer additional employment opportunities as companies expand, create projects and invest. Investment in smart technologies and cities is a global trend that is expected to grow substantially over the next few years.

Figure 1. Smart-city and smart infrastructure investment by region, world markets, 2010-2020



Expected Areas of Growth

Within this growth there are certain areas that are expected to see the most investment and business activity. These areas are often both beneficial to the city in terms of increasing livability and reducing costs. These areas are also conducive to pre-existing and available technologies. However, every city is unique, and there is certainly not a one size fits all technological solution for the variety of problems one might face. As mentioned, there are however a variety of common problem areas faced by cities where technologies are driving the solution. Some of the common problem areas and the related technologies being applied in smart cities to address them are presented next.

Transportation

Traffic is an unfortunate part of everyday life for many around the world. Infrastructure is often underfunded and overcrowded; long commutes and frustrated consumers and workers are a result. This time in traffic is not efficient or safe, consumes natural resources and is time taken away from other economically viable activities.

The IoT, or internet of things, is one technological approach smart cities are applying to fight back against rising traffic and its associated costs. IoT will equip otherwise typical objects with "sensing digital parts, microprocessors and suitable communication protocols enabling them to be part of digital communication with one another and with the city" (Sofronijević & Milićević, 2014). With this technology in place, cities are able to connect and utilize different and new smart technologies.

These include combing video cameras and motion sensors along with existing aspects of the transportation system such traffic lights, and public transportation infrastructure to transmit real-time data such as traffic flow, speed and volume. This data is used to reduce operating costs by improving and facilitating real-time decision making by officials and helps citizens by providing better services and less congestion (Cisco, 2015).

Another technology being used to combat traffic and improve transportation in cities is predictive analytics. By utilizing historical and real-time traffic data, smart traffic solutions are able to forecast future traffic conditions. According to IBM their intelligent transportation solution can predict traffic conditions up to an hour in advance (IBM). This technology can be used to improve public transportation, increasing ridership and revenues as well as reducing the overall level of traffic in a city.

Buildings

Buildings are of course the fundamental pieces of a city. Unfortunately buildings are also huge consumers of energy and carbon emissions, which are both hurtful to companies as operating costs and to the environment and inhabitants of the city. The amount of energy consumed and paid for to maintain and run security systems, lighting and HVAC systems to cool IT systems and people, is robust and in the US, buildings account for about 70% of energy use (Bélissent, 2010).

Smart cities leverage technologies in their buildings such as advanced monitoring devices that can help control and monitor consumption as well as capture valuable usage data (Hernández-Muñoz, Bernat Vercher, & Muñoz, 2011). These meters that monitor consumption and the related data they capture everyday are used to more efficiently manage buildings electricity and resource consumption and their associated costs. Here we have big data and analytics at play in addition to sensory and monitoring technology. Data capture and the associated information provided by mining algorithms assist in decision making by efficiently analyzing large amounts of energy data overtime to help identify trends, set efficiency benchmarks and reveal actionable opportunities for significant energy and operation savings (IBM, 2015). Integrating this type of data across large areas and spaces like airports, universities and cities provides great opportunities for cost and energy savings. Recently Carnegie Mellon University partnered with IBM to have the company provide them a cloud-based analytics system that monitors and analyzes thousands of data points. This system uses powerful sensors and analytics systems and will cover HVAC, lighting, water and other utilities across the universities 36 buildings. This initiative is expected to reduce utility costs by 10% and save the university close to $10 million annually. (Simmons & Haswell, 2015)

Water Grids

As noted before, the increase in population is very much a driving factor behind the increasing relevance of applying technologies to and creating smart cities. This is because the rate at which the population is growing will create very real and difficult to meet demands on the cities in which these populations reside. It is with this in mind that a need exists for increased efficiency around this valuable and necessary natural resource.

Smart water meters or ‘Advanced Metering Infrastructure’ are the most efficient and scalable way to leverage the benefits of communication networks, IT and intelligent devices in this area. These technologies enable real time data to be made available to both the utility provider and the consumer, allowing both to make more informed decisions that drive conservation and keep prices down. Smart meters utilize advanced sensing technology and are thus provide more encompassing and accurate results than traditional meters. These meters provide useful information on the average daily usage characteristics of each end use which is useful in developing water demand patterns (Gurung, 2015).

The market for smart devices that are part of smart water networks and allow cities to begin to conserve water using real-time information and data is expected to grow to more than $3.3 billion dollars as forecasted by Navigant Research (Navigant Research, 2015).

Energy Grids

Similar to the delivery and measurement of water, energy companies are embracing smart meters and the associated technologies. Smart meters are able to communicate with the utility company in real-time, delivering a myriad of relevant data such electricity theft, power outages, and usage. Contrast this to the traditional system of sending out an employee to read a meter 12 times a year and it is easy to see there a number of ways both companies and cities will benefit from this large increase in data.

The utility can use this data in a number of ways from simple applications, like when a customer's usage is trending high they send an alert, to more advanced applications such as being able to locate outage locations more accurately. Utility companies are increasingly modernizing with communications networks, analytics and digital sensors, helping smart cities conserve and reduce costs. A report by the Edison Institute reveals that about 46 million smart meters have been installed in the United States, a trend that has seen increased growth. (The Edison Foundation, 2013)

Smart Cities

Leaders around the world are looking for ideas and technologies to make their cities more attractive and sustainable, allowing them to attract the educated citizens and businesses that will put them in a competitive position within the global economy. A recent report by IHS estimates that the number of smart cities will rise from 21 in 2013 to 88 by 2025 (IHS, 2014).Some cities have already embraced a new mindset and new technologies to begin their transformation into a smart, sustainable city.

Barcelona

Barcelona Spain is one of the most connected and digital communities in the world. It is currently regarded as the example of what a city that embraces smart technologies can be and the benefits it can realize. It is currently looked at by many for best practices in this area. This city has done a tremendous job using technologies to address the needs of its people and has done so in a cost effective manner. This city provides real application of technologies in many of the areas touched upon earlier including transportation and energy efficiency.

Areas and initiatives in this city that are being improved and facilitated by the IoT, information and communication technologies and other various soft and hard technology assets and solutions include:

- Smart Parking: Both city employees and residents are benefitting from wireless sensors placed in parking locations across the city. Residents are able to view open spaces and reserve them via smartphones reducing the traffic and energy consumption caused by driving around the city looking for a spot. City workers are able to view meters that have expired and as a result, as noted by Barcelona Deputy Mayor Antoni Vivesthe, the city has increased revenues related to parking citations by $50 million annually by implementing and utilizing smart parking technology (Cisco, 2014). This data is not only used for citations however, it also provides valuable insight into travel and usage patterns of the city's residents.
- Smart Meters: "We can now control the system directly from an iPad." Said a Barcelona official in regards to their new water efficiency technology that is expected to reduce costs by 25% after sensors are installed (Scott, 2014).
- Smart Lighting: Street lamps account for a healthy portion of a cities power bill and often times they are shining on an empty stretch of sidewalk or road. Barcelona has now installed LED streetlamps that are operated via timers, motion sensors and information and communication technologies. These lights which are also available to be controlled via a network by city employees, will reduce wasted energy in the city as well as lower maintenance costs as this type of bulb needs to be replaced less frequently.

New York

New York is one of the most densely populated cities in the world and realized the need to start using big data and technology to begin creating a more livable and sustainable city. The city has funded an Office of Policy and Strategic Planning that uses Big Data and mining algorithms to make sense of the vast amounts of data, over a terabyte a day, the city collects. The city can then use this information to launch strategic initiatives aiming to reduce costs, inform citizens and allow the city to function more efficiently. The director of this office, Doug Flowers said of big data and analytics "It opens the door to a unique partnership between the city and its residents so that people can come up with innovative ways of using information". (Feurer, 2013)

Further harnessing the power of data analysis, the city partnered with Accenture to create a centralized call center for complaints to the city. Upon calling, the citizen provides information that is captured by the system, and then the system transfers the caller to the appropriate department that captures more information while addressing the issue. The city eventually collected extremely large amounts of data on and around these complaints and decided to create a mining project called DataBridge. This system utilizes data sets and algorithms to both classify and make predictions about complaints. By using data mining the city put together classification criteria regarding building complaints that posed the highest risks for fires.

These criterions were formed using information captured during the as well as by using data available in their city records such as age of building, past electrical issues and average income of the neighborhood. The city then put this information to good use, and was able to dispatch fire inspection officials to the highest risk areas, potentially saving lives. Prior to this technology the city was only able to check priority areas such as schools and public buildings, now they are able to be more accurately dispatched, saving money, time and increasing the level of safety provided to the public.

Concerns and Limitations

Although many of the new and existing technologies that will be utilized in smart cities present great benefit, they also present areas of concern. Many concerns cities and their citizens have about becoming and adopting a smart city approach concern the limitations of IT solutions. A report on smart cities groups these IT challenges into three dimensions, IT infrastructure, security and privacy, and operational costs (H.Chourabi, T.Nam, & Walker, 2012).

IT Infrastructure

The current technological capabilities and preexisting infrastructure of a city are a limiting factor for initial adoption and one that may be a costly area to address. One infrastructure element that will be common to all smart cities and that may be an initial barrier to entry is high-speed internet. This high-speed internet will be "the essential connectivity backbone for all IoT traffic and services" (M. Boulos & A.Tsouros, 2015).Consequently, cities will have the associated costs of a good bandwidth management system as well as the costs of ensuring high-speed internet services throughout their city and public spaces. Many do not yet have this capability or the means to finance such an initiative.

Legacy systems are plentiful and another IT infrastructure issue. These incompatible and antiquated systems may be a hurdle for many cities looking to be able to realize the benefits of having all of its systems communicate and integrated. Therefore costs are very much a related problem to that of problematic IT infrastructure, as new systems and IT assets would need to be purchased. Barcelona for example would be further along in their adoption of smart technologies if their economy was healthier, as is the case currently the economy of Spain is struggling greatly, limiting its ability to invest.

Security and Privacy

As smart cities and the associated technologies expand, it is important that appropriate security measures and best practices are in place and followed. These days it seems all too common to hear of data breaches, even occurring within advanced branches of our government such as the NSA. Data collection and mining techniques, such as those used in smart city applications in New York, come with related security risks that cities must consider when they begin this type of activity. The type of data that is being collected and stored in large data warehouses these days is becoming increasingly personal and is certainly of interest and vulnerable to hackers. Cities will need to ensure adequate safeguards are in place to keep their citizens and its private data protected. The threat of personal information being stored and potentially put at risk by third parties and the government may lessen the public's acceptance of otherwise potentially beneficial smart city technologies.

Device and data privacy and the threat of hacks are a main concern along with system availability. Most of us have experienced system downtime at work or at school, however having failures and downtime in IT that monitors and controls important city functions such as traffic lights and utilities is a major and potentially catastrophic risk. "Availability needs to be guaranteed because services delays and DoS attacks don't have to affect daily life of citizens" (Bartoli & Hernandez-Serrano, 2013). Proper security for smart cities will mean protecting against physical disruptions in the cities smart services as well as ensuring proper privacy protection systems keep citizens private information secure. In order to gain acceptance and trust of its citizens, cities will have to invest heavily in keeping these vulnerable networks running and safe.

Operational Costs

The biggest initial barrier for many when starting smart city initiatives will be implementation and operational costs. Initial costs will invariably be high and include extensive consulting and planning costs, hard and software expenses, installation of systems as well as training for many city employees and citizens.

Furthermore, a very real and often overlooked cost will be the operational costs of running smart technologies over an extended period of time. IT professionals will need to be employed to maintain and derive real benefit from these systems once installed. It will be important for cities to create long term business plans and ensure the necessary ROI on smart city costs.

Conclusion

Cities are incredibly complicated places and the task of implementing effective and affordable technology throughout one is certainly not one to be taken lightly. Numerous parties and stakeholders will be involved and affected and taxpayer, likely along with private money, will be at risk when potentially making, maintaining and operating these investments. Furthermore many cities do not have experience making these types of IT investments, furthering the risk of a costly and failed implementation. Often times many will avoid the risk that comes with such an involved and complex project altogether.

On top of the financial constraints and concerns, security and privacy are a major issue when instituting technology on such a large and public scale. It seems many large corporations struggle to protect consumer data and citizens are valid in having concerns over their cities beginning to collect and store similarly sensitive data. Therefore if undertaking smart city initiatives it will be important for cities to invest heavily in privacy preserving mechanisms and properly educate the public to ensure buy in.

Although the barriers to implementing many of the technologies and approaches to changing and better managing urban living are costly, that does not mean that they are impossible, should not be explored or invested in. It would be extremely shortsighted to not acknowledge the global trends and forecasts of larger populations and constrained resources in urban areas and to consider the benefits that smart city technologies may bring. These benefits can be both, physical and economic, and the two are not necessarily unrelated.

It is clear that the world continues to evolve, and often times not in ways that make it easier to inhabit. It is also clear however that cities, which are expected to be incredibly populated in the future and will continue play an extremely vital economic role can evolve and improve by leveraging many technologies that already exist and are being using in private industry. It is with the realities of a constantly changing world and available technologies in mind that leads me to conclude that cities around the world should begin to explore how investments of any size in smart technologies could benefit their cities environment, economy and quality of life.

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