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Smart cities utilize both technology and social coordination to improve a variety of municipal functions. Current research surrounding the success of smart cities and smart city project implementations have produced sets of factors that determine a city's potential for success. In this case study, these factors are compared to the unique case of the Town of Cary, NC's implementation of a smart water metering system. By conducting interviews with municipal employees, this research determined that some of these success factors defined in the literature may be over-generalized. Further, this research suggests that more research may be needed on the subject of managing and sustaining the data collected by smart cities in order to maximize the potential data use. This study hopes to lay a foundation for future research in defining smart city success factors and properly managing smart city data use.

Headings:

Smart City

Data Analysis

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SMART CITY PROJECT IMPLEMENTATIONS: A CASE STUDY OF A SMART WATER METERING SYSTEM IN CARY, NC

by
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Table of Contents

INTRODUCTION

Smart cities use a combination of technology and social coordination in order to improve city planning, resource sustainability and general livelihood (Batty et al., 2012). Many cities around the world have already implemented various information and communication technologies in order to assist with urban issues unique to each city. Common smart city implementations include traffic management and transportation planning, electric and energy infrastructure, flood planning and mitigation, sewer services, and water and wastewater management and sustainability among others (Albino et al., 2015). There are a number of factors that lead to the success of a smart city including access to technologies, a strong economy, community engagement, and a relationship with businesses (Albino et al., 2015, Nam & Pardo, 2011).

The Town of Cary, NC provides examples of smart city initiatives local to the Research Triangle region. Cary is a town located west of Raleigh and south of Durham with a population of over 160,000 citizens (Town of Cary, nd.). Many recent developments in Cary's social and physical infrastructure align with goals researchers have identified that work to define smart cities. Efforts have been made to improve community engagement, sustainability, resource management, and transparency with citizens (Town of Cary, nd.). This includes the Town of Cary's open data policy, business and economic development, the Cary 311 community information initiative and numerous sustainability efforts (Town of Cary, nd.). This case study will focus on Cary's use of technology, community engagement, and relationship with business and industry to improve its sustainability and resource management. Specifically, this will consist of an in-depth look into Aquastar—Cary’s smart water metering system.

While there have been previous case studies on smart city applications similar to this in other parts of the world, there are no case studies that focus particularly on applications within the Research Triangle region—an area primed for smart city applications due to its network of research universities and diverse business and industry ecosystem. Therefore, this case study provides significant findings by analyzing one of the first, large-scale implementations of a smart city project in the Research Triangle region. Further, these findings can lead the way to additional smart city applications in Cary and other municipalities in the region by identifying lessons learned and promoting future collaboration by drawing attention to this project.

LITERATURE REVIEW

The term “smart city” has been used ambiguously since the late 1990’s and incorporates many synonymous terms identifying similar concepts (Cocchia, 2014; Lee & Lee, 2014). A time-analysis performed on literature surrounding the term “smart city” suggests that the first research study regarding this topic was carried out in 1994, however other literature that mentions this term does exist that predates 1994 (Cocchia, 2014). A smart city is often characteristic of having information communication technology (ICT) and Internet of Things (IoT) capabilities that allows for close monitoring of environmental factors, especially energy and resource usage, among other urban planning goals (Dameri, 2012; Albino et al., 2015; Nam & Pardo, 2011).

One resource in particular that can be efficiently monitored with today’s technology is water usage (Cocchia, 2014; Albino et al., 2015; Nam & Pardo, 2011; Lee & Lee, 2014). This literature review will synthesize the various definitions and intents of a smart city in order to provide an acceptable scope for the purposes of this case study. Since the context of this study is focused on the use of ICT—and smart meters in particular—I will then review the current purposes of ICT and IoT technology, especially applied to municipal water metering.

Smart Cities

Many different definitions have been used to describe a “smart city” and several common alternative terms are used to highlight similar goals for a municipality in the context of improving urban life (Cocchia, 2014; Dameri, 2012, 4). A systematic literature review performed on the terms used to describe smart cities found that the most common recurring terms are “smart city” itself, as well as “digital city” (Cocchia, 2014). Some of the other persistent terms used throughout similar literature include: “virtual city”, “ubiquitous city”, and “intelligent city”, among many others. Each of these terms has slightly differing characteristics that have since been organized into three major dimensions by researchers: the technology dimension, the human dimension, and the institutional dimension (Cocchia, 2014; Nam & Pardo, 2011).

The wide range of terms used to describe similar urban planning goals is due primarily to the explosion of research and literature on the topic. A time analysis performed on the literature surrounding smart city research found that there are five key dates characterized by events that likely explain the upward trend in the research (Cocchia, 2014). These landmark events include the Kyoto Protocol on two occasions, the widespread use of the Internet and ICT infrastructure development, IBM’s notion of a “Smart Planet”, and the commencement of the Europe 2020 Strategy by the EU (Cocchia, 2014; Schaffers et al., 2012; IBM, 2015; Europe, 2018). Many of these events involved increases in technology and environmental awareness, leading to an increasing interest in research within this area. It is likely that the sudden increase in research on smart cities has led to the ambiguity among definitions and the broad spectrum of synonymous terms, as there was little agreement on the foundation of the concept (Albino et al., 2015).

Aside from the variety in terminology, there seems to be some consensus among the factors that define the purposes of a smart city. Among the recent literature surrounding smart city concepts, there are identifiable factors that build a framework for what smart city initiatives should accomplish to improve urban life. These factors fall under the more general technology, human, and institutional dimensions previously discussed.

The first factor focuses on sustainability and environment. The primary goals involve appropriate management of natural resources and associated infrastructure (Chourabi et al., 2012; Albino et al., 2015). In the scope of a smart city, this includes using technology and ICT infrastructure to assess and meet these goals. Additionally, there is the anthropological factor that addresses human interactions with the environment and natural resources, as well as human rights and equal access to such resources (Albino et al., 2015; Alawdah, 2017).

Another factor regards the collaboration between government and citizens, and citizen interaction. Recently, more attention has been paid to this factor than the majority of the other smart city factors, as it has become more apparent that the quality of life of citizens is affected by their education and participation within the city (Chourabi et al., 2012; Batty et al., 2012; Nam & Pardo, 2011). With increased connectivity, citizens can communicate among each other and with governing bodies almost instantaneously, allowing for citizens to be much more engaged in expressing communal needs and assisting with future urban planning opportunities (Chourabi et al., 2012; Batty et al., 2012). In fact, this has also led to the overall growth of the communal experience, developing a deeper sense of community among citizens (Albino et al., 2015; Nam &

Pardo, 2011). Nam and Pardo also explain the importance of social and human infrastructure, such as how culture, education, and commerce are essential to the holistic development of smart city dimensions.

The next factor concerns the economy of the city. A common factor among the various properties described in the literature, urban economy is easily quantifiable and often used as a smart city measurement (Chourabi et al., 2012; Albino et al., 2015). In a smart city context, the economic dimension is generally described as business development, especially businesses that use, create, or develop ICT systems and infrastructure (Chourabi et al., 2012; Albino et al., 2015). It is important for smart cities to foster the development of industry, businesses and the associated workforce (Albino et al., 2015; Nam & Pardo, 2011).

A conglomerate factor important to any smart city is the policy, governance, and management of urban planning and activity. This factor is often closely tied with the economy of a smart city, as the business and industry provide the necessary ICT and IoT technologies, whereas government and policies dictate how these technologies can be used and can facilitate the community engagement (Batty et al., 2012). Most smart city initiatives and implementations cannot occur without the development of policies and the cooperation of governing agencies, as is the case with most urban initiatives. There are several properties aligned with successful governance, especially in the scope of smart cities, which are: collaboration, leadership, participation and partnership, communication, data exchange, service and application integration, accountability, and transparency (Chourabi et al., 2012). It is important to highlight the policy, governance, and management aspects of a smart city because it is often overshadowed by the technology and sustainability factors generally found in literature defining smart cities (Batty et al., 2012).

Finally, the remaining smart city factor is in fact the information and communication technologies themselves, especially with the continued growth in emerging technology applications for smart cities. The main goal of this factor is to develop interoperability among ICT and IoT technology in order to not have siloed data and communications (Zanella et al., 2014). This is where the use of the Internet of Things can play a key role, as it is primarily based on the idea that everyday items can collect and receive data via internet connectivity (Internet of Things, nd.). Additionally, a key goal in the use of IoT technology involves the ability to compose data from multiple sources in a variety of formats to useful and meaningful information, from which intelligent decisions can be made (Haskins, 2019).

These 5 factors have a symbiotic effect on the success of smart city initiatives and mark the agreement across the literature for general definitions of a smart city. It is important to note that the term “smart city” does not just identify the use of technology, but involves institutional, human and technological factors in order to be successful (Chourabi et al., 2012; Albino et al., 2015; Nam & Pardo, 2011).

Smart Sensors and ICT

Information and communication technology, especially in the form of smart sensors, are the backbone of enabling data collection and communication for devices in smart cities. These technologies have the capability of allowing both governing bodies and citizens within the community to promote sustainable lifestyles, improve quality of urban life, and participate in the responsible management of natural resources (Segrouchni et al., 2016). The use of sensing devices is often referred to as the third phase of automation, with the first two described as mechanization followed by informationization (Meiher, 2014).

There are several different types of sensors, and not all sensors can be classified as “smart”. From an engineering perspective, sensors are devices that can convert different forms of energy such as thermal, mechanical, or chemical into electrical signals that can be collected and processed (Meiher, 2014). When a sensor can convert analog to digital signals and is embedded with a microprocessor designed to analyze or communicate information, the sensor can then be classified as “smart” (Meiher, 2014; Atkins & Escudier, 2013). Further, an integrated smart sensor system consists of a smart sensor with sensing and computing components on the same chip, capable of wireless communication (Meiher, 2014; Segrouchni et al., 2016). This type of system allows for virtually real-time data collection and analysis from a variety of sources, such as cars or homes (Meiher, 2014). Such technology leads to applications like smart water metering from both the utility and end-user levels.

There are numerous examples of smart sensor applications to improve urban living and city planning. A common example is the smart grid, where sensors are used to improve the quality of electricity distribution grids. In this application, sensors can be used to monitor several factors such as overhead transmission lines and blackout occurrences (Hancke et al., 2012). Similarly, these sensors can also be utilized to gather environmental data in order to make more accurate predictions of future energy demands (Hancke et al., 2012). Sensors are also often used within homes and buildings to monitor energy usage. Because HVAC systems account for roughly 46% of home energy usage, these sensors will track this energy usage and attempt to use collected data to reduce overall energy consumption (Hancke et al., 2012; Energy Use, 2013).

A relevant application to this case study involves water distribution monitoring via smart sensors. In this case, the sensors are used to collect and gauge water usage data, quickly identify leaks, and monitor the water quality throughout the system (Hancke et al., 2012). This use of smart sensors to monitor water usage and quality is often referred to as smart water metering (Marais et al., 2016).

Smart Water Metering

Collecting and analyzing data is an important step in responsibly and intelligently monitoring natural resources, including water resources. Access to fresh water is necessary for sustaining human life, especially in urban settings where there are high concentrations of people and processes that require water resources. Sensors can be used to collect data in urban settings for both potable water and wastewater services (Ingildsen & Olsson, 2016). Sensors enabled throughout a water system can help create a smart metering system. Smart meters provide real-time water use information via two-way communications, allowing both the consumer and utility to access the collected information (Roby, nd.).

The primary purpose of utilizing smart water metering systems is to lower electricity and water usage and boost the efficiency and efficacy of the water distribution system (Lloyd Owen, 2018). The management of smart water systems is often employed in several stages with regards to the data and information. Generally, this involves data collection, transmission, interpretation, manipulation and presentation (Lloyd Owen, 2018).

Smart water metering and the associated information produced provide benefits to both the consumer and utility in the form of more accurate meter readings, which manifest as more precise billing for the consumer (Roby). Because the metering system transmits information wirelessly, the utility does not have to use resources to manage fleets sent out to manually read meters and thus provides the opportunity for detecting leaks and losses within the system much more quickly and effectively (Britton et al., 2013; Mdumbe & Abu-Mahfouz, 2015; Lloyd Owen, 2018). Additionally, consumers can view their water usage data with a higher granularity and make personal water use decisions based on this information (Mdumbe & Abu-Mahfouz, 2015). There are many other potential outcomes of smart water metering, all of which are motivated by the primary objective of sustaining resources, improving efficiency, and improving quality of life (Lloyd Owen, 2018)

METHODS

This research will be conducted in the form of a case study and attempt to answer two main questions: (1) What factors do smart city project personnel feel influence successful project implementation, and (2) How has the information or data from this project been used to improve both end-user and utility water functions. As this research was designed to be a case study, naturally the methods associated with this research are largely qualitative (Benbasat et al., 1987; Yin, 2014; Westat, 2002). However qualitative research only describes the nature of the research evidence, not the design of the research itself (Yin, 2014).

Often, case studies fall under the umbrella of idiographic research: research that focuses on the study of unique entities or individuals, usually outside the scope of generalized theories (Coleman, 2015). Case studies are intended to be descriptive examinations of a particular entity in its natural setting and context, where the principal investigator provides an analysis of certain experiences determined from the case compared against other similar cases (Westat, 2002; Shanks et al., 1998).

For this case study research in particular, there was an in-depth review of a single case. This suggests that beyond the general methods of the case research methods, this research follows an embedded single case design as described by Robert K. Yin, where the study focuses on subunits of the case (Yin, 2014). For this study, two subunits of the smart water metering system were identified: the utility—the provider of the service—

and the end-user citizens—the consumer of the service. Further, this case study is rationalized by the common single case design (Yin, 2014). This rationale of single case studies focuses on studying one particular case in an effort to provide additional insight into a greater relationship or experience. This case study is intended to provide such insights into successfully implementing a smart city system, primarily in the form of smart water metering.

Further, some methods of qualitative research—especially case studies—follow a realist form of inquiry. This is described as intending to discover new relationships and build up the understandings of experiences as opposed to verifying previously produced hypotheses and theories (Hunt, 1990; Perry et al., 1994). Similarly, case studies are intended to focus on in-depth understandings and explanations of experiences, so design tests can often hinder such exploration (Riege, 2003). This case study follows both of these methods of qualitative research.

Case studies often require a lot of time and resources (Westat, 2002; Yin, 2014). As a result, interviews were conducted to develop a deeper understanding in place of long-term observation. This was done for the sake of the timeframe of this research, as there was not enough time to become fully immersed in the case and exclusively make contextual observations.

Data Collection

The initial contact of participants began by emailing the primary contact associated with the Aquastar system as listed on the Aquastar information page on the Town of Cary website. This email was intended to gauge interest in participating and to then determine the viability of attempting a case study on this system. From here, “snowball sampling” occurred, as the initial contact then led to the discovery of additional contacts within the Town of Cary municipality.

I followed up with all contacts via email to provide information about the study and the expected time commitment. After the participants agreed and meeting times were set, I conducted semi-structured interviews, with guiding questions that could lead to further follow-up questions dependent upon the responses. Interviews lasted between 30 and 45 minutes and were all conducted in person. Interviewees were informed that the conversation was recorded purely for the purposes of transcription for accurate reporting. Participants that agreed to participate in an interview signed a consent form agreeing to participate and answer questions with which they were comfortable and agreeing to be audio recorded during the interview.

Ideally the interviews were to be conducted over a period of about a month with a sample size of 5-10 total participants from both the Town of Cary utilities department and from one of the subcontracted companies in order to obtain multiple perspectives in the responses. Unfortunately, due to time constraints, only 3 interviews were conducted and only with employees from the Town of Cary utilities department. The questions asked were broken into two parts in order to gain insight on both of the main research questions as stated at the beginning of the “Methods” section. The first round of questions pertained to the project management and implementation, while the second round focused on the data collection and use throughout the system.

Semi structured interviews were chosen as the method of data collection due to the nature of inquiring qualitative responses such as “why?” rather than quantitative responses. This methodology falls in parallel with the goal of case studies which focus on "how" and "why" questions (Yin, 2014; Fylan, 2005).

However, there are some concerns with this form of data collection. Diefenbach summarized these concerns into five areas of semi structure interview data collection: (1) before collecting data and during the whole research process, (2) the process of collecting data, (3) internal validity and making sense of data, (4) external validity of the data and findings, and (5) relation between the findings and social sciences as well as social practice (Diefenbach, 2009). While these are valid concerns that should be considered with the reported results, using semi structured interviews to collect data for an embedded single case study in the required time frame of research was the most efficient and effective methodology.

The semi structured interviews were developed and conducted following the stages as outlined by Rabionet, which include the following: (1) establishing ethical guidelines, (2) crafting the interview process, (3) conducting and recording the interview, and (4) reporting the findings (Rabionet, 2011). As such, consent was required for interviews to be audio recorded and no personally identifying information was collected in order to maintain an ethical interview process.

In addition to the semi structured interview process, additional research was conducted by collecting demographic information about the Town of Cary through publicly available information sources located on websites hosted and updated by the municipality. This included population and economic reports along with published communication plans.

Data Analysis

The recorded audio interviews were transcribed and reviewed by hand in order to identify common themes related to the research questions. Therefore, the identification of themes was based on the implementation of the smart city project and the use of the collected data.

Due to the qualitative nature of the data collected for this case study and the fact that this is a single case study and is unique against other similar cases, the evidence was analyzed using an explanation-building strategy in order to identify casual links and build a narrative explanation about the case (Yin, 2014). Because this case is generally considered to be a success by both the providers and the users, the goal of analyzing the data is to identify the factors that led to this conclusion and compare this to factors discussed in the literature review.

Ultimately there is a concern with biases in the data collected due to the sample population's relation to the subject of the case study. However, this research and its findings are meant to act as a basis for future research by establishing groundwork. There is further work that can be done that will be thoroughly discussed in both the "Discussion" and "Future Directions" sections of this research report.

RESULTS

Cary was selected for this case study because of its location within the Research Triangle region, providing unique opportunities for smart city project development, and because this municipality was one of the first in the area to implement a large-scale smart city application. At the time this research was conducted, the smart city project observed for this case study had existed for about 10 years, allowing for enough time to pass for the municipality to experience both successes and hindrances with the system and be able to report on the state of the system over this period.

This case study focuses on the implementation and lifecycle of the Aquastar smart water metering system. This system consists of multiple parts and affects both the municipal functions as well as the citizens' interaction with water utilities. The physical infrastructure of the Aquastar system is made up of the water pipes that move water throughout the municipality, the smart meters at each household within the system, the radio towers that receive transmissions from the smart meters, and the information technology hardware that stores the collected data. In addition, there is a web-based dashboard that provides water utility information to both the municipality and the citizens that make up the data and software infrastructure.

The following results describe information collected via semi-structured interviews and publicly available information as described in the methodology section. While the information collected through the interviews was reported by public officials and employees of the Town of Cary, they have chosen to stay anonymous and their positions within the municipality will not be reported.

City Demographics

The Town of Cary, NC is located in the Research Triangle region of North Carolina with a population of over 160,000 citizens, making it the third largest municipality in the region behind Raleigh and Durham (Town of Cary, nd). The median household income sits around $105,000 with a median age of about 38 years old (Cary Economic Development, 2019). It is one of the four primary municipalities that make up the Research Triangle region, connecting it to the network of research universities in the area—most notably Duke University, North Carolina State University, and The University of North Carolina at Chapel Hill.

Another key feature of Cary and the Research Triangle region is the diverse ecosystem of businesses which include large companies such as IBM, Cisco Systems, and SAS Institute, which have established strong industries in the area such as manufacturing, technology and life sciences. In Cary alone, the largest employer is SAS Institute and the largest industries are clean technology, information technology, and life sciences.

Motivations for Smart City Development

In the case of the Aquastar system, there were a number of common themes identified in the interview responses that reveal many of the motivations behind implementing a smart city application in Cary. While these themes were discussed by multiple interview subjects, there were two major themes that were addressed first in each of the interviews.

The prospect of long-term financial savings was discussed as the first topic in all of the interviews that addressed motivations, suggesting that it has a very high significance in motivating the project implementation. In particular, one respondent highlighted that the ability to point to the monetary savings was a major influence in getting approval from the town council.

In addition to the financial aspect, the desire to improve upon the existing system arose as the second major theme in the form of maximizing both system efficiency and customer service. The goal was often described as attempting to modernize the existing system by reducing the need for manual meter readings and collecting and providing more accurate data. However, one respondent also noted that an additional supporting factor in the initial decision to begin this project relied on the availability of appropriate and affordable technology that could support the implementation of the water metering system.

The nature of the responses and the consistency of the themes that describe the motivation for this smart city project suggest that there is no single variable that indicates an appropriate timing. In fact, it seems that the implementation of such a project requires a combination of certain factors in order to effectively begin the implementation, most notably financial savings, improved services, and technological infrastructure.

System Evaluation

To evaluate the Aquastar smart water metering system after deployment, certain metrics needed to be defined and quantified to determine where the system succeeded and failed. A primary method of evaluating the project success was monitoring the ability of the project team to adhere to the initial schedule and budget. The entire implementation of the project consisted of phases for each part of the physical and software infrastructures as discussed previously.

There were additional individual budgets and timelines for each phase. These were used as major indicators of initial success while the project was actively implemented. Each of the phases had additional metrics related to their unique goals and objectives that were monitored as well. The budget and timeline metrics were chosen to indicate success because of the ability to quantify each one and actively compare this to the intended progress.

The number of complaints received by customers and the read rate of the meters were used as additional quantifiable metrics for determining the success of the system after the system was set up. These metrics evaluated the success of the customer service improvement and manual meter reading minimization goals of the project.

Additional measurements of success were also discussed, coming from a qualitative and subjective perspective. One such indicator is the ability of the municipality to become a primary innovator in the smart utility space within the Research Triangle region. The other indicator is the increased capability of communicating with citizens regarding their water use to provide more complete answers and suggestions that are backed by data. More granular data is available to both the municipality and the users, allowing for more informed and accurate decisions to be made regarding the management and consumption of water resources. These factors are related to the improved read rate success metric.

Risks and unforeseen circumstances were also observed and reported with the implementation of the Aquastar smart water metering system. The major risks were associated with the scale of the project and communication with the citizens.

There was a potential for a mass disruption to the water system because the smart meters were installed on almost every home within the municipality. A risk of miscommunication and improper installation during the project implementation was amplified because there were two subcontractors working on installing the system, which made the management of the project more complex.

Communication with the citizens became a risk to the project as well. Some citizens were worried that the rollout of the new system meant that there were issues with the existing system, leading to concerns of proper utility billing in the past. In order to mitigate these risks, the town developed a communication plan that attempted to provide citizens with details of the project including why it was being implemented, how long implementation would take, and other relevant information.

Further, with the switch to a more technologically reliant system, there was a heavier reliance on the technological infrastructure to be up and running. There was also a learning curve for the employees who were then required to learn and interact with a new system.

In addition to risks with the project implementation, there were issues and unforeseen circumstances that arose throughout the project development and during the lifecycle. With the new system, more data is available to users at a higher frequency and quality which users considered to be an improvement from the old system. However, this led to higher expectations from the user for data availability and system uptime.

Similarly, the user portal was developed to allow users to view their water usage with high data granularity which is intended to help users consume less water by monitoring their use. After the deployment of the system, there was a low adoption rate reported for the user portal. This was attributed to the fact that if users notice regular water bills and usage, they are less likely to use the portal to monitor their usage until users notice some type of change. This results in a less effective method of preventing water waste, because it largely goes unnoticed until after water waste has been occurring for some time.

Another unforeseen issue identified was the volume of data. It was apparent throughout all the responses that there was not a clear understanding of the amount of data that would be produce from this system. An additional issue stems from this misunderstanding. With the availability of more data to provide more answers, more complex questions arise. After the deployment of the system, the municipality noticed increased call times and reported more complex inquiries from customers.

This led to another issue: a shift of workload as opposed to an assumed decreased workload. The deployment of the system was successful in decreasing the required number of manual reads of the meters, but the workload then shifted to the office-based employees. The increase in data collection increased the time employees spent analyzing the data and interacting with customers as previously discussed.

Also associated with the unanticipated volume of data is the narrow use of the data. The Town of Cary does not have a dedicated data analyst or data scientist that is managing the massive amounts of data and improving on how it is being used. There is also a lack of canonical data sources. The format of the data collected from the Aquastar water metering system does not match the format of the data from the water plants, and therefore is not being compared.

DISCUSSION

The results of this case study show that there are a variety of important factors that can lead to a successful smart city project implementation. It is also apparent that these factors fall in line with existing literature that outlines both characteristics of a smart city and characteristics needed for a city to begin smart city project development. However, there are some findings from this case study that might indicate a need to expand these existing definitions and point out potential flaws or over-generalizations. Additionally, the results suggest that while data collection from a smart water metering system can directly improve both municipal and end-user water resource functions, there are many ways to consider how else the data can be used for further improvements.

Smart City Characteristics

When comparing the demographics of Cary, NC and the results of the interviews to necessary smart city factors commonly discussed in the literature, there are a many identifiable overlaps. The first common factor is community engagement. It is apparent that the city government of Cary makes an effort to inform citizens of the various endeavors and activities occurring within the municipality. The existence of the Cary 311 initiative, which provides citizens with accurate information about various aspects of the town, is a prime example of the use of technology to increase community engagement and knowledge.

This example, along with the findings from this case study, reinforces the idea that community engagement and connectivity are highly important when implementing smart city projects. While using technology to provide opportunities to allow citizens to access information and become more engaged, it is apparent that communication between the community and the government is a key element to the success of this endeavor. In fact, the Aquastar system was successful in many ways due exclusively to the communication efforts of the city as indicated by some responses to the interview questions.

Two additional overlaps include the availability of technology and collaboration with businesses. Cary, as well as the rest of the Research Triangle region, house many businesses in the technology industry, especially clean technology and information technology, as described in the city demographics section of the results. This case study highlights just one example of collaboration between industry and municipality. What makes this case unique when considering these two factors, is that they exist in tandem.

The collaboration of the municipality with business and industry is what provided the city with the available technology to pursue this smart city project. Further, the quality of the economic state of the Cary is also due to the relationship and existence of businesses within these major industries. Perhaps Cary and the rest of the Research Triangle is in a particularly beneficial position to undergo smart city projects because of the existence of thriving businesses in these industries, as information technology and clean technology are the two driving technologies that create smart city opportunities. An additional aspect to these factors is the proximity of research universities, which is another key characteristic of the Research Triangle region.

The literature that discusses the factors that allow for smart city development rarely include the impact of universities as an enabler for smart city development. Education of the citizens is discussed, but the proximity of universities to the area—especially research universities—is not highlighted. While the relationship between the municipality and university would likely be similar to that of the municipality and businesses, further exploration into this relationship might yield interesting results regarding the success of smart city development.

While the literature does make note of the economy of the municipality as an important factor in the success of smart city development as well, again the existing literature falls short of taking into account the state of the existing infrastructure. While a strong economy might be conducive of well-maintained municipal infrastructure, this may not always be the case. Further, a strong economy—or any of the other factors presented by the existing literature—does not necessarily indicate the age of the municipality. The results of this case study suggest that Cary's existing physical infrastructure made some of the transitions to a new system more feasible. One response to the interview highlighted this feature while discussing the potential of reproducing this project in another municipality:

> "Cary's infrastructure is not as old as some other infrastructures around […]. If you take the City of New York: very old, have a lot of pipes […] they have an againg infrastructure. So some of the concerns that they might have might even be completely different."

A similar conclusion could be made of the information infrastructure of the city. In the case of Cary, their information infrastructure was not originally set up to easily integrate a smart water metering data flow. The responses indicated that the data sources from the water plant and the smart metering system do not have canonical data sources and are not currently analyzed side-by-side. This makes it difficult or near impossible to integrate the two data sources and analyze them against each other.

Reproducibility and Collaboration

The results of the case study signify unique and highly beneficial circumstances within the Research Triangle region for smart city development. As a result, the successes and failures discovered during this study could be considered by other municipalities in the Research Triangle region to implement smart city projects of their own.

At this point, there are a variety of smart city projects that exist throughout the region. However, due to the already collaborative environment that exists between municipalities, universities, and businesses, reporting these factors would be highly beneficial to the whole region. The responses in the interview suggest that this already occurs, but not at the rate and scale it has the potential to be shared. By sharing the shortcomings and methods of other smart city projects, other municipalities in the region could avoid pitfalls and maximize the benefits of public projects.

Additionally, continuing to collaborate with industry even after the deployment of the project could benefit services provided by the municipalities. This would the benefit the businesses in return, as they would be provided these improved serviced. For example, the results of this case study showed that the data collected was not being used to its full potential. Collaboration with businesses in the area could lead to better data storage, management, and analysis, leading to further improvement in services and decision-making.

Apart from inter-municipal collaboration on future projects, the results discovered from this case study could also be applied to future projects within Cary. With the information available between the results of the Aquastar implementation and existing literature, Cary has the opportunity to develop future smart city projects that can avoid some of the unforeseen issues discussed in this study. However, this study does suggest that even with planning and support, there is ample opportunity for unforeseen results to appear throughout the project lifecycle.

Data use

Apart from expanding smart city characteristics definitions and exploring the potential for continued collaboration in the Research Triangle region, another important topic of discussion is the use of the data itself. This case study showed that, without proper planning and understanding of smart city projects, the data produced from such a project can be overwhelming and not utilized to the full potential.

Even now, after the system has been deployed for 10 years, the data is still barely being used beyond its basic potential. This finding was highlighted by the responses of the interviews from all of the respondents. Each respondent had multiple different ideas of how the data could be used to further improve the water metering system. One example from the responses suggested attempting to compare the differing data type collected in order to develop a water lifecycle analysis:

> "… at our water plants we keep data in a certain format […] and then we have the AMI data that's in a different format. And what we haven't done is build something that takes both of those formats and puts them together and start discussing the lifecycle of water."

Another example suggested that the data could be further analyzed to improve current system maintenance, alerts, and meter events. Other examples involved maximizing the use of reclaimed water or enforcing alternate water days.

Regardless of the nature of using the data, it is apparent that more can be done. Again, this is an unforeseen result that is not directly addressed by the existing literature on the subject of smart cities. In fact, there seems to be a lack of research or publications around the subject of smart city management in general. Much of the current research focuses on how smart cities can be developed and what is required, but less can easily be found on how smart cities can be effectively sustained.

FUTURE DIRECTIONS

This case study was designed as an embedded single case study. While the study provided some interesting results, it is far from comprehensive. The results of this study can certainly provide groundwork for smart city development research, but there is much more than can be explored to further qualify the results and provide useful insights.

The most direct improvement to this study would be to include more cases to produce a multiple case study. This would help qualify these results and provide more accurate conclusions for smart city development in a region similar to the Research Triangle region.

First, analyzing more cases would likely rule out one-off success measures as discovered in this study. If cases were added that included smart city project failures, this would help rule out some of the success measures reported and would identify factors that lead to failures. Additionally, studying more cases would be able to provide further comparison of municipal demographics to the success factors reported in literature on the subject. Finally, the explanation building methodology used for analysis in this study could be improved, as it is intended to be an iterative process (Yin, 2014).

With the addition of more cases, other important comparisons could be made. Rather than analyzing more cases from the same Research Triangle region, cases sampled from regions with a different combination of positive and negative smart city characteristics might further validate what is suggested by the sources in the literature review.

CONCLUSION

Smart cities can often have a variety of characteristics, but there are key factors which indicate the potential success of implementing initial smart city projects within a city. The Town of Cary provides insight into how factors described in literature surrounding smart cities can be applied when implementing the first smart city project within a municipality. Additionally, further questions are raised on the topic of smart city management apart from the factors that suggest a city has the potential to become a smart city.

This case study showed that the smart city project success measures extracted from the interview and research results are closely aligned with the factors described in existing literature. Some of the findings that suggest a few of the factors and definitions could be expanded but were largely the consistent. The most direct of the success factors discovered appear to be the communication and engagement between citizens and the government. However, the proximity of universities and businesses especially in the technology industry and the collaboration between the municipality and these entities provide an important foundation for the success of a smart water metering project implementation.

The results also showed that data collected from a smart water metering project has a great potential to improve municipal services from both the municipal and citizen perspective, however the data was not used to its maximum potential. These findings lead to the further questions of how a smart city projects can be sustained and properly managed, especially from a data perspective. Further, as technology continues to improve and smart city projects likely become more commonplace, this research aims to lay a foundation for future research into smart city projects and to provide useful information to municipalities attempting to implement smart city projects.

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APPENDIX A

Interview Questionnaire

Questions pertaining to research question 1 - What factors do smart city project personnel feel influence successful project implementation?:

1. How would you describe the scope and goal of this project?
2. What challenges or risks did you encounter with this project?
3. How did you attempt to mitigate these challenges or risks?
4. What metrics were/are used to rank the success of this project?
    a. Why were these metrics chosen to rank success?
    b. How have improvements & successes been measured (method of measurement)?
5. What successes and/or failures do you perceive from this project?
    a. How do you think these values been considered for further improvement on this project or others like it?
6. How would you describe characteristics of a smart city project as opposed to a traditional (municipal) project?
    a. How were these characteristics taken into consideration when implementing the project?
7. Why do you think this project was chosen to carry out?
8. Why do you think stakeholders agreed to implement a smart city project

9. How do you think this project has improved utility functions?
10. How do you think this project has framed future smart city applications within the municipality?
11. How easily do you think this type of project could be reproduced in other municipalities and why?
12. Do you think some aspect of this project should have been implemented differently?
    a. Why or why not?

Questions pertaining to research question 2 - How has the information or data from this project been used to improve both end-user and utility water functions:

1. What is your opinion on how the data or information gathered from this project has affected utility functions?
2. How effectively do you think the data or information gathered from this project has been used for utility functions?
3. How else do you think the data or information gathered from this project could be used for utility functions?
4. What is your opinion on how the data or information gathered from this project has affected end-users?
5. How effectively do you think the data or information gathered from this project has been used to change end-user experience?

6. How else do you think the data or information gathered from this project could be used for end-user experience?
7. What additional data or information do you think could improve the current state of the system?
8. Do you have any concerns regarding data privacy with this project?
9. Do you think there are data privacy concerns with smart city projects in general?
10. How do you think the municipality might benefit from additional smart city projects?
11. Do you have any concerns with more smart city projects within this municipality?