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A proposal and potential use-case for the transition from Gig City to Smart City

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ABSTRACT

Over the past decade, smart city concepts have been gaining attention from scholars, practitioners, and policy-makers in both developed and developing nations. A recent proliferation of publications has involved a multitude of disciplines, but have focused almost entirely on the potential for smart cities to change the way cities are managed, operated, and planned. However, there has been little published on the tangible benefits of a specific smart city initiative, nor many use-case studies following smart city initiatives. This paper aims to propose a transition from Gig City to smart city via technological advancement in the form of ICT to monitor, assess, and improve one of Chattanooga's most inefficient urban systems – the city curbside garbage and recycling services. The findings and projections produce implications for city planners and managers, as well as, academics and policy-makers focused on improving urban functions and systems and making urban lifestyles more sustainable.

Keywords: ICT; Smart city; smart sustainable city

INTRODUCTION

It is the century of cities. In 1950, the world's urban population was 751 million people. Today, that number has grown to 4.2 billion (United Nations, 2018). The United Nations (2018) reports 55 percent of humans reside in cities and that by 2050, 68 percent of the world's population will live in cities. By 2030, the world is estimated to have forty-three megacities with populations above 10,000,000. North America has the highest percentage of population residing in cities at 82 percent (United Nations, 2018).

Academics and environmentalists have estimated that although cities only take up 2 percent of Earth's land mass, cities are responsible for nearly 80 percent of all greenhouse gas emissions (Satterthwaite, 2008). Satterthwaite emphasizes stats from the Fourth Assessment by the Intergovernmental Panel on Climate Change to show that this number understates the contributions from agriculture, deforestation, non-renewable power stations, and various heavy industries (Satterthwaite, 2008). It is likely that less than half of total worldwide greenhouse gas emissions occur within city boundaries. If emissions were assigned to the consumer, rather than to the location of production, then cities would account for a higher percentage. By this calculation, Satterwaite (2008) estimates cities comprise between 60 - 70 percent of total emissions worldwide. Importantly, this method draws attention to the disproportionality of emissions assigned to higher income nations, which may play a significant role in allocating responsibility for emissions reduction initiatives. As one of the highest per capita carbon dioxide emitters and leaders of the global economy, the US has the opportunity to rapidly change and set a precedent for the world to follow.

The current urban environment is associated with unsustainable energy usage, accompanying greenhouse gas emissions, increased pollution of air and water, and environmental degradation. Rapid urbanization is giving rise to additional challenges, including endemic congestion, solid waste management, and accelerated resource depletion. Additionally, the outdated infrastructures within cities pose both technical and physical problems (Calldohl et al., 2013). For example, cities all over the world are experiencing severe water shortages. Most notably, Cape Town, South Africa was recently just days from “Day Zero” - the term describing the day in which public water systems would be shut off indefinitely. Urban systems are under increasing pressure due to the enormous challenge of sustainability coupled with the greatest wave of urbanization in human history (Bibri & Krogstie 2017a). There is an urgent need to ideate and develop innovative solutions to city planning and management to battle urbanization. In an urban environment with a growing demand for efficiency, sustainable development, quality of life, and effective management of resources, public authorities must consider an evolution in the way cities are planned, monitored, and managed.

The well-documented waste management woes of the 18th and 19th centuries American cities are examples of the early challenges of urban planning and development. American cities lacked organized public works well into the 19th century. After recurrent epidemics plagued many cities, efforts were made regarding water treatment and sewage infrastructure (Louis, 2004). It was not until the 1880s that attention was placed on solid waste management. At this time, funding was unavailable for capital intensive projects at a regional level (Louis, 2004). As a result, waste management became a local responsibility. There was no extensive legislation regarding municipal solid waste before the 1976 Resource Conservation & Recovery Act (RCRA). The RCRA forced the closure of open dumps nationwide causing a "garbage crisis" in the late '80s and early '90s. The private firms that expanded to fill the market need became regional players and created a flow of solid waste across state borders (Louis, 2004). Thus, today municipal waste management is primarily managed by cities, and operated by a handful of private organizations.

The concept of sustainable development was not proposed until 1987. The UN-Sponsored World Commission of Environment and Development in "Our Common Future (1987)" defined sustainable development as, "Development that meets the needs of the present without compromising the ability of future generations to meet theirs". The challenges of efficient energy consumption, congestion, pollution, and resource conservation require a paradigm shift to untangle and overcome - i.e., new ways of urban thinking founded upon a holistic approach with a long-term perspective (Bibri & Krogstie, 2017b). This shift is regarding the design and development of the current infrastructural, operational, and functional forms of cities. Sustainability and sustainable development have been applied to urban structural planning and design since the early 1990s. The concept of sustainable development has shifted questioning towards cities regarding how to lower energy consumption and pollution (Jabareen, 2006). Scholars and practitioners have sought a variety of sustainable city models and approaches that can contribute to sustainability and its improvement.

The distinguishing factor between smart city approaches and sustainable city models is the utilization of information and communication technologies (ICT). ICT offers unprecedented potential for monitoring, understanding, assessing, and planning cities (Bibri & Krogstie, 2017a). The data collected and insights drawn can be leveraged to improve urban sustainability. Despite the apparent potential of such initiatives in supporting cities in their transition towards sustainability, there has been a lack of connection between sustainable cities and smart cities regarding the operation, management, and planning of urban systems (Batty et al., 2012; Kramers et al., 2014).

There have been a great number of advanced technologies developed in response to the urgent need for dealing with the complexity of knowledge necessary for harnessing, enhancing, and integrating urban systems in sustainable planning and development (Bibri & Krogstie, 2017c). Moreover, many cities are partnering and working with private firms on smart city initiatives. In recent years, private firms have begun targeting municipal garbage and recycling operations as a means for cities to adopt ICT with sustainable development goals. One private firm based in Atlanta has implemented ICT in over twenty city public works departments, yet there has been little written about specific smart city use-cases and their impacts regarding sustainable development. Bibri & Krogstie (2017b) highlight the need for ICT development and innovation to be fundamentally connected to sustainable development. The aim of such a connection is that future investments be justified by environmental concerns and socio-economic needs, rather than technological advancement and industrial competitiveness.

This thesis proposes an advancement that establishes a clear connection of smart city technologies with sustainable city initiatives - i.e., the hardware, software, and continuous data collection from smart city concepts implemented with the goals and desired outcomes of sustainable development. This paper aims to propose an investment into one of Chattanooga's most inefficient urban systems. Chattanooga and the Chattanooga Public Works Department (CPWD) provide fertile ground for an impactful smart sustainable city initiative and a rare use-case detailing the estimated value of impact.

LITERATURE REVIEW

This literature review will take the following form: First, the concept of sustainable development and its impact on the urban form will be detailed. Next, the definition and scope of ICT in regards to smart city will be presented. Following ICT will be background on the development of smart cities and the difficulty academics and environmentalists have had connecting the two parallel developments of smart and sustainable cities. Lastly, the less explored and newly integrated smart sustainable city will be defined.

Sustainable City Models

The development of more robust sustainable city models has been one of the most significant intellectual challenges and research endeavors for more than twenty years (Bibri & Krogstie, 2017a). Jabreen (2006) notes it has been challenging to translate sustainability into the built form of cities and evaluate whether and the extent to which alleged sustainable urban forms contribute to the goals of sustainable development. The underlying argument is that urban systems in terms of operation, management, assessment, and planning have in themselves been complex with the vision of sustainability (Bibri & Krogstie 2017a). Cities, as dense clusters of urban populations, buildings, infrastructures, and resources, put immense strain on urban systems. For this reason, debates in urban and academic circles continue to focus on the role of sustainability in terms of responding to the sizeable challenges presented by rapid urbanization and the currently unsustainable urban form. Bibri & Krogstie (2017b) define sustainable urban development as promoting sustainability in terms of replenishing resources, lowering energy usage, and lessening pollution and waste levels.

Jabreen (2006) classifies sustainable city models into four categories: 1. Compact city; 2. Eco-city; 3. New Urbanism; and 4. Urban Containment. This paper will focus on the first three models. Not only have the first three been the most prevalent in literature, but Jabreen (2006) ranked these concepts first, second, and third most sustainable urban forms. Dantzig and Saaty introduced the compact city in 1973 with the vision to, "enhance the quality of life, but not at the expense of the next generation" (Ellis, 1975). The compact city concept is favored by many for the following reasons: efficient modes of transport, compactness and mixed-use buildings garner diversity and cultural development, and compact cities are economically viable from an infrastructure per capita standpoint (Jabareen, 2006). The eco-city is more of an umbrella metaphor than a detailed definition. The eco-city approach encompasses a wide range of ecological, societal, and institutional policies aimed at achieving sustainability (Jabareen, 2006). The eco-city model prioritizes not the urban shape a city takes, but rather how the residing society organizes and manages itself (Jabareen, 2006). Eco-cities have been attractive due to its emphasis on green and urban landscapes, cultural and ecological diversity, and the seamless integration of renewable energy generation into the city structures (Jabareen, 2006). Neotraditional development, or new urbanism, is focused on design-based strategies aimed at reimagining the current built environment to help rein in urban sprawling and rebuild inner-city neighborhoods (Jabareen, 2006). Charles Bohl (2000) argues that new urbanism is an approach of blending historical precedents with new-age planning and design to create new combinations of mixed structures. A primary focus of neotraditional development is to create (or rebuild) neighborhoods, rather than superblocks, suburbs, and projects (Jabareen, 2006). The more innovative and sophisticated the approaches to overcome challenges presented by urbanization become, the more reliant cities will be on technology and data collection. The three urban forms discussed so far do not leverage basic ICT in pursuit of sustainable development.

ICT

Data sensing software and hardware are being quickly woven into the fabric of today's cities. Simultaneously, wireless networks advancements, such as the Gig or the forthcoming 5G network, are proliferating at unparalleled rates. This change is underpinned by the recognition that cities, as evolving systems striving for sustainability, necessitate smart technology (Bibri & Krogstie, 2017a). ICT refers to technologies that provide access to information via telecommunications. It is similar to information technology but differs in the structures utilized. In the scope of smart cities, ICT refers to a set of urban infrastructures, architectures, applications, systems, and data analytics capabilities — i.e. constellations of hardware and software instruments across several scales connected through wireless, mobile, and ad hoc networks which provide continuous data regarding the physical, spatiotemporal, infrastructural, operational, functional, and socio-economic forms of the city (Bibri & Krogstie, 2017b). It is the seamless integration of ICT and its data sensing and reporting capabilities that differentiate smart city from compact city, eco-city, or neotraditional development.

ICT is a new wave of computing that functions unobtrusively and invisibly in the background of urban life to improve urban functions, understand urban phenomena, and plan and foresee the future of cities (Bibri & Krogstie, 2017a). There are hundreds of examples regarding how ICT has been and is being implemented yielding new data sets for grasping urban problems, facilitating improved urban functioning, and creating better solutions to improve quality of life (Batty et al., 2012). The central reason why attention is placed upon ICT as an answer to urban development struggles has been the success of many cities addressing complex problems using ICT (Jabareen, 2006). Batty et al. (2012) identify a number current of use-cases including real-time sensing of people for crowd control from social media interactions in the United Kingdom; coordinating and integrating multiple networks - i.e., the London Oyster Card analytics; and models for mobility behavior discovery on public roadways in Berlin (Batty et al., 2012). Many have written about smart cities as innovators that with the power of ICT can harness both social and physical infrastructures (Neirotti et al., 2014; Batty et al., 2012). To be most impactful, cities must strive for economic regeneration, environmental efficiency, and public service enhancement. It is clear ICT has great potential for supporting the transition to more sustainable cities, both in the management of urban systems and increasing utility of urban lifestyles (Kramers et al., 2014).

Smart City

In the past decade, the development of smart city has come to the fore as a promising response to the challenges presented by hyper-urbanization (Batty et al., 2012). Smart City answers the call for sustainable development by optimizing efficiency in urban systems, assessing their performance, and eliminating redundancy in operations (Batty et al., 2012; Bibri & Krogstie, 2017a). Kramers et al. (2014) describe the great potential the holistic approach of smart city has in supporting a transition towards sustainability regarding both the management of urban systems and offering more support for sustainable urban lifestyles. Smart city concepts have been gaining relevance and importance not only in urban research but also in city planning and politics. This has led to intense academic debate and has generated global attention for smart city as a framework for sustainable development (Höjer & Wangel, 2015).

The genesis of the smart city concept is debated due to different approaches and views of it. Gabrys (2014) traces the roots to the 1960s and the cybernetically planned cities, while Batty et al. (2012) determine it was not until the late 1990s when the smart growth movement penetrated city planning. The emergence of smart city initiatives supported by the European Union since 2010 has rapidly generated numerous publications and writings on smart city topics (Ahvenniemi at al., 2017). Due to its interdisciplinary nature, the topics are wide-ranging but difficult to create trends of. Despite widespread use, there is still inconsistent and speculative understanding of the meaning of smart city (Neirotti et al., 2014).

A smart city is emblematic of efficiency, which is achieved through intelligent management of systems utilizing ICT. There is a wide-ranging list of definitions for smart city across the different domains involved in its recent proliferation. Bibri & Krogstie (2017a) indicate that smart city and its definition are often context-dependent - i.e., the available resources, objectives, political and regulatory frameworks, etc. (Bibri & Krogstie, 2017b). The general definition involves the implementation and deployment of information and communication technology (ICT) infrastructures to support social and urban growth through improving the economy, citizens' involvement and government efficiency (Yeh, 2017). For the context of this paper, the following definition of smart city is sufficient: a smart city is "a city in which ICT is merged with traditional infrastructures, coordinated and integrated using new digital technologies" (Batty et al., 2012). In view of this, academics, ICT experts, and policymakers unanimously agree on the use of ICT across all domains of smart cities and believe it to be an inseparable facet thereof (Bibri & Krogstie, 2017a).

There are two conventional approaches to smart cities: the technology-focused approach, and the people-oriented approach (Bibri & Krogstie, 2017a). Kitchin (2014) pictures a real-time city - one that has all critical infrastructures integrated, uses data to make informed decisions, and maximizes resources and services for citizens. This technologically-oriented approach focuses on efficiency by optimizing the physical infrastructure via integrating sensors and software into the existing environment. The people-oriented approach focuses on human capital gains in the form of participation, transfer of information, social equity, and so on (Angelidou, 2015). Knowledge and participation are essential for people-oriented smart city approaches. Many variations of smart city have been adapted based on how integrated ICT has become within a city. Despite the potential, Kramers et al. (2014) note a lack of connection between ICT development and innovation and sustainable development goals currently. The gap between smart city and sustainable city frameworks suggest a need for developing smart city frameworks further or re-defining smart city concepts (Ahvenniemi at al., 2017). Assessment of smart city performance should not only use output indicators that measure the efficiency of deployment of smart solutions but also impact indicators that measure the contribution towards ultimate goals, such as environmental, economic, or social sustainability (Ahvenniemi at al., 2017). Against the backdrop of unprecedented rates of urbanization, alternative and new ways of conceiving cities are materializing. The recent simultaneous development of increased sustainability awareness, technological advancement, and rapid urbanization have converged to create a new field of study labeled ‘smart sustainable cities' (Höjer & Wangel, 2015).

Smart Sustainable City

Smart sustainable city is a new phenomenon, and the term has only been circulating since the mid-2010s (Höjer & Wangel, 2015; Bibri & Krogstie, 2017b). The smart sustainable city has emerged from five separate, but similar developments: 1. Sustainable city; 2. Smart city; 3. Urban ICT; 4. Sustainable urban development; and 5. Urban growth (Höjer & Wangel, 2015). In this context, ICT can be directed towards collecting, analyzing, and synthesizing data in order to develop intelligent urban functions, as well as create urban models to obtain deep and even predictive insights for sustainable strategic decision-making (Bibri & Krogstie, 2017a). Ringenson et al. (2017) describe two functional areas for ICT in a smart sustainable city model: 1. As a part of the city's infrastructure for monitoring, efficiency and process automation; and 2. As an enabler for sharing both information and goods among citizens with the expectation of it leading to more sustainable urban lifestyles. Similar to smart city, smart sustainable city has no universally agreed upon definition. In 2014, the International Telecommunications Union (ITU) published a definition based on analyzing around 120 definitions, "A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects". The combination between sustainable city and smart city has been less explored, in part because it has been conceptually problematic due to the multiplicity and domain diversity of the existing definitions of both city models (Bibri & Krogstie, 2017a). The literature on the topic lacks detailed use-cases of specific smart sustainable city initiatives. This paper aims to fill the gap by detailing the implementation of ICT in Atlanta and extrapolating the impacts achieved to Chattanooga.

CASE DESCRIPTION

Prior to December 2016, the Atlanta Public Works Department (APWD) faced many problems regarding its curbside garbage and recycling operations, including inefficient and redundant routes, lack of data collection on service confirmations and participation rates, and inaccurate human inputted data entries. Starting January 2017, the APWD began a partnership with a private firm on a smart city initiative involving implementing basic ICT sensors and proprietary software to collect continuous data regarding its curbside services. The city has since been able to achieve significant improvements in fleet efficiency. Also, the city has utilized the data to create targeted material campaigns that have notably increased citizens' recycling efforts. This thesis proposes the same, if not better, results are achievable in Chattanooga and estimates the economic impact for the city of Chattanooga.

Chattanooga

In 1969, Walter Cronkite called Chattanooga "the dirtiest city in America" on national television. At that time, Chattanoogans were known for driving with their headlights on all day in order to navigate the heavy pollution (Micheli, 2013). In the decades since the national embarrassment, Chattanooga has made great strides in cleaning up the city and transitioning towards a more sustainable urban form. Today, Chattanooga boasts the world's only automotive factory to be certified LEED Platinum, the EPA's highest green-building rating (Micheli, 2013). A major recent development for the city has been the implementation of fiber optic infrastructure. In 2010, Chattanooga became the first city in the US to offer gigabit internet speeds to all residents. The investment in technology and a focus on innovation has attracted more than $4 billion in foreign investment in recent years (Micheli, 2013). These trends along with a relatively low cost of living led to Outside Magazine calling Chattanooga "the best town ever" in 2015. Chattanooga's rapid turnaround has been nothing short of extraordinary. Statistically speaking, the city of Chattanooga has been able to avoid many of the problems presented by urbanization - i.e., mean travel time to work has not changed with statistical significance for the period 2009 - 2017 (2017 ACS); the city follows a nationwide trend of low unemployment; residents enjoy relatively low pollution rates (American Lung Association, 2018).

These trends and accolades suggest Chattanooga is seemingly moving towards a sustainable urban form if not one already. Moreover, recent progress would suggest that Chattanooga proficiently performs the most basic sustainable functions - solid waste and recycling. However, the Chattanooga recycling data suggests otherwise. For the period 1/1/2017 – 12/31/2017, Chattanooga's recycling recovery rate (RRR) was calculated to be 11.72 percent. For comparison, the national average for the same period was 34.7 percent, and some similarly-sized cities such as Oceanside, CA, have achieved rates as high as 80-plus percent. The RRR is the leading metric used by the EPA and other government agencies to measure recycling efforts and initiatives. By definition, it is merely the total amount of municipal solid waste recycled divided by the total municipal solid waste for a given period. At the onset of this thesis development, the CPWD not only was not measuring RRR, but managers had never heard of the metric.

Chattanooga Public Works Department

This thesis developed while completing an internship with the Chattanooga Public Works Department during the first five months of 2018. The position was under the recycling coordinator, and the focus was on municipal solid waste and recycling facilities and functions. During this time, many seemingly alarming aspects of current operations were uncovered. These include, but are not limited to: route inefficiencies and redundancies; lack of consistent data collection and use of outdated, unintegrated collection software; and the department does not formally measure and monitor critical metrics regarding recycling efforts. Due to the rigid hierarchical structure of public sector organizations, the decision making and change processes are inherently long. As of April 5, 2019, the Chattanooga Public Works Department (CPWD) has but does not use basic forms of ICT. The garbage and recycling routes are navigated using paper maps, rather than harnessing the power of the onboard computer and digital tablet. The data collection methodologies are minimal and highly inconsistent due to human input error. Various software and tools are used throughout the department for differing employees, but these systems are not well integrated. Data from one system is not easily imported into the others, creating imperfect knowledge within the organization. The city does not have an exact count of garbage and recycling participants, and therefore cannot make significant changes to routes or current operations. The city does pay for a route optimization software, but it has not been utilized since 2015. Meaning all new housing units built within the public works' coverage area since 2015 have been manually added to the routes by hand. This has created considerable inefficiencies and redundancies in both garbage and recycling routes. Despite not possessing an exact count, the CPWD estimates an additional 5,000 garbage and 3,500 recycling participants have been added since the routes were last optimized.

By not utilizing basic sensors and software, the CPWD lacks vital data on participation rates and service confirmations. These two data sets are particularly essential for improving operational efficiency and creating campaigns to improve citizen effort. Without this crucial data collection and subsequent metric calculations, the department is unable to make informed decisions about operational changes or new process implementation. This is visible when weighing the current recycling efforts of the city against the recycling improvement initiatives last year. The only effort made on behalf of the CPWD towards improving the recycling efforts was a packet of materials visually explaining what can and cannot be recycled curbside was sent to all known recycling participants in June 2018. The CPWD noted anecdotal evidence of positive public reaction to the campaign but were unable to detail any improvements to recycling efforts. The type of highly targeted material campaigns used in Atlanta are unavailable to Chattanooga so long as it does not utilize ICT. Currently, the Chattanooga Public Works Department does very little to initiate any transfer of knowledge from department to public. Without knowledge detailing the extent of the problem, citizens have no reason to change behavior. The current recycling efforts and state of the CPWD create an incredible opportunity to link the agendas of urban ICT development (smart city) and sustainable development quickly and inexpensively.

CASE STUDY

In January 2017, the city of Atlanta announced its first smart city initiative in conjunction with a private firm. After embedding sensors and implementing accompanying software, the APWD performed their routes for a month. The private firm's system was able to optimize the routes by gathering data on route inefficiencies and redundancies. Pierre Johnson, of the APWD, reported the city was able to reduce its average daily mileage by 7.8 percent with the private firm's software. This not only makes an immediate economic impact but a long-lasting environmental change as well. The more impressive feat achieved by the APWD was regarding the city’s RRR. During the period 4/1/17 - 3/31/18, the APWD utilized data on participation rates to deliver highly targeted materials to its least sustainable neighborhoods. In doing so, the city increased its RRR by 10 percent in one year. The remainder of this section will estimate the value of impact for Chattanooga if similar results were achieved.

Route Optimization

Table 1: CPWD Refuse Truck Data. March 2018.

Truck #	Miles Driven	Gallons Used	Est. MPG	Average Fleet MPG
WGL609	1074.5	675	1.592	
WGL610	1136.33	724	1.570	
WGL615	1577.88	899	1.755	
WL1282G	1290.6	733	1.761	1.669

These four of the nine total garbage routes were selected due to the following: 1. These routes produced the most consistent miles driven from week to week; 2. The drivers had the least amount of idle time; 3. As a result of less idle time, the MPG for these routes is optimal for projecting cost savings.

According to the Federal Highway Administration, the average MPG for refuse trucks in 2016 was 2.53 MPG. This number is 34 percent higher than that achieved by CPWD garbage and recycling trucks for the sample period.

$$Cost\ per\ Mile\ Driven = ((Miles\ Driven/MPG) * Cost\ per\ Gallon))\ /\ Miles\ Driven$$

Table 2: CPWD Fuel Cost Data. March 2018.

Average Miles Driven	Miles per Gallon	Cost per Gallon	Cost per Mile
1269.83	1.67	$2.11	$1.27

The savings from reduced mileage will vary according to the cost of gas. If Chattanooga were able to repeat Atlanta's mileage reduction, the sample period cost of gas would result in annual savings of $1509.80 per route. The CPWD currently has nine garbage routes and three recycling routes. As mentioned in the Case Description, the CPWD has not reoptimized any routes since 2015. Again, the CPWD does not have an exact count of either garbage or recycling participants, but it has manually added an estimated 5,000 garbage stops and 3,500 recycling stops since 2015. Meaning, the routes often change, and drivers rarely drive the same mileage on the same route from week to week. These inefficiencies shed some light on the differences in fleet efficiency between Chattanooga and the national average, and suggest CPWD is capable of matching or exceeding Atlanta's mileage reduction.

Table 3: Projected Fuel Cost Reduction Under Atlanta Optimized Route Assumptions

% Reduction in Miles Driven	Monthly Savings per Route	Yearly Savings per Route
1 %	$16.13	$193.56
5 %	$80.65	$967.81
10 %	$161.30	$1935.62

Reduced Landfill Usage

Table 4: Projected Cost Savings from Reduced Landfill Costs, Chattanooga Yearly Average, 1/1/17 - 12/31/17

Average Monthly Landfill Tonnage	Cost per Tonne	Average Monthly Cost Savings per 1% Reduction in Landfill Tonnage
3,317.9	$29.84	$990.07

The largest expenditure besides labor for the CPWD is overwhelmingly landfill usage fees. This cost presents a tremendous opportunity and a significant incentive for the CPWD to increase citizens' recycling efforts. At the current contracted rate of $29.84 per tonne of waste deposited, the city could save nearly $1,000 per month for each percent reduction in monthly landfill tonnage. If Chattanooga were able to repeat the success of Atlanta, it would result in monthly savings of nearly $10,000 for the CPWD. To achieve similar results as the APWD, the CPWD management must utilize the data for both blanketed and targeted initiatives. While completing the internship, research was conducted on cities with the highest RRR in the country. Sarah Davis, an Environmental Specialist with the Oceanside, CA Public Works Department, explained the simplest and most immediate method for improving a city's RRR is to reduce waste, rather than recycle more. As mentioned previously the RRR is calculated as total municipal waste recycled divided by total municipal solid waste. Davis detailed her experiences leading household waste reduction campaigns that have pushed Oceanside's RRR to 85 percent. Meaning, the city only pays landfill fees for 15 percent of its waste. In 2017, Chattanooga paid landfill fees on 89 percent of its waste. On the other hand, the city earns revenue for any recycled materials deposited at the five recycling centers. Although there is not a direct trade-off between waste and recycled materials, it creates a slight multiplier effect on cost savings from reduced landfill tonnage – i.e., as participants reduce their waste, they tend to recycle more and generate additional revenue for the city.

The calculations and estimates of environmental impacts are outside the scope of this work. With that said, there are three achievable impacts in need of further detail — the first two reductions in footprint stem from eliminating inefficiencies via route optimization. Not only will the trucks consume less gas, but will spend less time on the road emitting CO2. Per mile, refuse trucks are the least environmentally viable vehicles on the road. The third environmental impact is dependent on the citizens of Chattanooga reducing household waste. Landfills naturally emit carbon dioxide and methane as a result of bacteria breaking down the material. Also, many landfills burn trash to conserve space. The city of Chattanooga deposited 40,619 metric tonnes of solid waste into landfills in 2017. According to the EPA's greenhouse gas emissions calculator, these emissions are comparable to those that would be generated by consuming 94,464 barrels of oil.

DISCUSSION

Implications for Smart City Concepts

The research conducted suggests a rare opportunity for a city to connect sustainable development with smart city to create a smart sustainable city initiative. The smart city literature is vast and multidisciplinary, but often model-based and focused solely on the potential for the concept to change urban planning, monitoring, and assessment. Also, many smart city examples given in the literature are expansive applications aimed at connecting all urban functions and systems. The literature is lacking publications on smaller, less expensive initiatives aimed at improving one or two specific urban inefficiencies. This case study served as an opportunity that could be implemented quickly and inexpensively, and it is suggested to cause immediate economic and environmental impacts.

Both scholars and practitioners can gain insight into the true value of refuse trucks. The CPWD has spent between $260,000 - $360,000 on various trucks during the period 2016 - 2018. Garbage and recycling trucks are invaluable pieces of equipment and are not being utilized to full capacity. The data collection capabilities of garbage and recycling are invaluable and unparalleled in any public asset because garbage and recycling trucks are the only vehicles to turn on every road in the city. And if not every one, certainly the most of any government vehicle - more than police cars, fire trucks, and DOT vehicles. With basic sensors and accompanying software, trucks can become mobile data gathering hubs. Not only can the trucks be used to gather objective data about citizens' sustainable behavior efforts, but that data can also be used to make the trucks more sustainable. The city managers must look to the PWD and the trucks if the city wants to maximize its urban functions and transition towards a sustainable urban form.

Implications for the City

The most significant economic benefit and environmental impact both are derived from the city reducing the amount of waste deposited at the landfill. With this great opportunity come many challenges. The measure of impact will be dependent on households changing their waste habits. Chattanooga has rallied as a city once before when the pollution became publicized in the 1960s. In the process of knowledge transfer, the city can obtain a better understanding of citizens' sentiment towards sustainability and citizens' willingness to change. The people of Chattanooga are not aware that the "green outdoorsy" city they love recycles at a rate one-third the national average. The city can rally again, but the citizens lack transparency. Studies of small towns around the world have indicated that residents exhibit a natural sense of cooperation due to the density of their social networks (Tolbert et al., 2002). Citizens with attachment to a city develop bonds with people and places, and this affects their behavior and judgment (Casakin et al., 2015). Colby et al. (2003) argue active citizens strive to make improvements in their communities. It would be interesting to see how quickly the citizens of one of America's largest outdoor tourism economies could change their behavior once transparency is achieved.

Directions for Future Research

Given the proposal be accepted, a continuation of this research could entail following the proposal through implementation; then analyzing the data collected and assessing the impact of the data-driven initiatives undertaken. The impact of these initiatives could be compared to similar such projects conducted in various ICT-enabled PWDs. As it stands currently, Chattanooga and the CPWD are unaware of the extent to which inefficiencies plague the curbside services. Another continuation of this research could be to calculate the economic value and environmental cost of these route inefficiencies in another effort to convince the city to advance. This proposal omitted cost estimates for the implementation and service fees; another area of research could entail completing a full cost-benefit analysis and project a return on investment. Lastly, further research could question how and why a city so reliant on its outdoor economy could recycle at such relatively low rates.

Concluding Remarks

Belanche et al. (2016) underscore the increased use of urban services as a route towards sustainability, and James (2009) determined more frequent use of urban services related closely with strong operational performance, increased satisfaction with city management, and a higher quality of life. It will take immense effort from not only megacities, but cities of all size to change the trajectory of the planet. Recognizing and reporting on the value of smaller, less expansive smart sustainable city initiatives may be crucial to gaining investment from small and mid-sized cities.

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