Winning the SDG Battle in Cities: How an Integrated Information Ecosystem Can Contribute to the Achievement of the 2030 Sustainable Development Goals

Jacqueline Corbett
Department of Management Information Systems, FSA ULaval
Université Laval
Quebec, Canada

Sehl Mellouli
Department of Management Information Systems, FSA ULaval
Université Laval
Quebec, Canada

Published in *Information Systems Journal*

To cite:

Corbett, J. & Mellouli, S. (2017). Winning the SDG Battle in Cities: How an Integrated Information Ecosystem Can Contribute to the Achievement of the 2030 Sustainable Development Goals. **Information Systems Journal**, 27(4), 427-461.

Winning the SDG Battle in Cities: How an Integrated Information Ecosystem Can Contribute to the Achievement of the 2030 Sustainable Development Goals

ABSTRACT

In 2015, the United Nations adopted an ambitious development agenda comprised of 17 Sustainable Development Goals (SDGs) which are to be reached by 2030. Beyond SDG 11 concerning the development of sustainable cities, many of the SDGs target activities falling within the responsibility of local governments. Thus, cities will play a leading role in the achievement of these goals and we argue that the information systems (IS) community must be an active partner in these efforts. This paper aims to contribute to the achievement of the SDGs by developing a conceptual model to explain the role of IS in building smart sustainable cities and providing a framework of action for IS researchers and city managers. To this end, we conduct grounded theory studies of two green information systems used by an internationally-recognized smart city to manage water quality and green space. Based on these findings, we articulate a model explaining how an Integrated Information Ecosystem enables the interactions between three interrelated spheres – administrative, political and sustainability – to support the development of smart sustainable cities. Moving from theory to practice, we use two real-world scenarios to demonstrate the applicability of the model. Finally, we define an action framework outlining key actions for cities and suggest corresponding questions for future research. Beyond a simple call-to-action, this work provides a much-needed foundation for future research and practice leading to a sustainable future for all.

KEYWORDS

Sustainable Development Goals, Smart city, Sustainability, Green IS, Grounded theory, Information system ecosystem

INTRODUCTION

In September 2015, recognizing the urgent need to 'transform our world', the United Nations adopted an ambitious international development agenda, comprised of 17 Sustainable Development Goals (SDGs) and 169 targets. Home to more than half the world's population, cities consume three-quarters of the world's energy (Jackson, 2012) and create a host of environmental problems (Borja, 2007; Marceau, 2008; Toppeta, 2010; Washburn et al., 2010). So, it is not surprising that the SDGs for 2030 include a specific goal, SDG 11, to "make cities and human settlements inclusive, safe, resilient and sustainable" (United Nations, 2015, Goal 11). Other SDGs include targets, such as sustainable water management, sanitation, climate change, and sustainable use of terrestrial ecosystems (United Nations, 2015), that fall within the prevue of city governments (Peinhardt, 2015). With responsibility for policy setting, urban planning, built infrastructure, and management of natural resources, cities have a significant influence on the trajectory of sustainable development (Choi et al., 2016; Jackson, 2012; Peinhardt, 2015), leading some to suggest "the battle for the SDGs will be won or lost in cities" (Poon, 2015).

As evidenced by their participation in events such as COP21 and the Compact of Mayors (Compact of Mayors, 2015), city managers seem interested in building sustainable cities. Yet, they face a multitude of challenges, including economic constraints, demographic changes, limited access to data and metrics for measuring progress (Choi et al., 2016; Lucci, 2015; Peinhardt, 2015). As a result, cities around the world have made uneven progress toward sustainability over the past 30 years, struggling to convert vision into reality (Freeman, 2004; Satterthwaite, 1997) and maintain the trajectory of sustainable development over the long term (Freeman, 2004). As arguably one of the most complex and important challenges ever faced by the global community, reaching the SDGs by 2030 will require the engagement of all stakeholders. We argue the information systems community, made up of both researchers and practitioners, can and must be an active, committed partner in these efforts.

Such a partnership approach between city managers and the IS community is starting to emerge in the development of 'smart cities'. Smart cities seek to leverage advanced communication technologies and information systems (IS) in order to improve all areas of city administration, enhance citizens' quality of life, engage citizens and provide more sustainable and resilient public services (Boulton et al., 2011; Hollands, 2008; Schaffers et al., 2011). Although local governments have been using IS to support environmental management for several decades (Page & Voigt, 2003), their application has largely been limited to administrative-type functions, rather than supporting broader sustainability efforts (Danzinger et al., 1978). Attempting to change this trajectory, various authors have suggested the use of 'green' IS by cities will enable them to manage environmental resources, reduce their negative environmental impact and engage citizens in environmentally positive behaviours (Brauer et al., 2015). However, despite both the need and interest, the use of green IS by cities is a heavily underexplored area in practice and research (Brauer et al., 2015). This situation reflects a larger gap in current IS research. Concerns have been raised about a lack of theory related to IS solutions for sustainability (Elliot, 2011). Further, IS researchers have been called upon to engage in impactful research for improving global environmental conditions (Malhotra et al., 2013) and it has been suggested that new solution-based approaches are required to achieve more rapid progress in this area (Watson et al., 2011).

In response to these concerns, the overarching aim of this paper is to contribute to the achievement of the 2030 SDGs. Our intention is to present research outcomes that will have an immediate impact on the future direction of IS research and will also assist city managers in responding to the challenges presented by the SDGs. Recognizing that "the impact of solution-based research approaches depends on how the academic community is able to collaboratively engage with problems faced by practitioners and policy-makers" (Oldekop et al., 2016, p. 57), we have chosen to concentrate our investigation on two environment-related SDG targets relevant to cities: quality drinking water (Target 6.1) and public green spaces (Target 11.7). Using these two targets to bound our research context permits us to engage deeply with the problems faced in practice, while also allowing us to elaborate on the role of IS in building smart sustainable cities at a broader level.

The paper is structured as follows. In the next section, we provide the contextual background for our research. Then, we outline our research design, and follow it with a description of the research implementation and research findings. We then present the research outcomes, which include the emergent conceptual model and illustrate its applicability using real-world scenarios. After this, we define an action framework for research and practice. We conclude with a discussion of the paper's principal contributions and a call to action.

BACKGROUND: SMART CITIES AND SUSTAINABLE DEVELOPMENT

The term 'smart city' has been used to describe aspects of modern urbanism (Caragliu et al., 2011; Kramers et al., 2014). The modern urban vision aims to build a more liveable and attractive urban environment within a smart and agile government (Al Awadhi & Scholl, 2013). The recent emphasis placed on sustainable development has led to the vision of smart sustainable cities where environmental quality is counted among the eight principal components of a smart city (Chourabi et al., 2012; Dameri, 2013). With respect to the environment, smart cities aim to reduce greenhouse gas emissions (Zygiaris, 2013), efficiently manage energy through the use of new technologies (Vanolo, 2014) and information systems, and undertake other technology-based initiatives to support the sustainable development of their communities

The concept of sustainable cities is well-aligned with the Sustainable Development Goals (SDGs) for 2030. As Table 1 illustrates, the SDGs cover a wide range of issues, from poverty, gender equality, water and sanitation, energy, sustainable cities, to climate change and peace. Investigating the role of IS with respect to each of the SDGs targets individually would be nearly impossible in a single research project, thus, we confine the scope of our investigation to two targets relevant to environmental sustainability in cities: Target 6.1 with respect to quality drinking water and Target 11.7 with respect to public green spaces. From these specific cases, we are then able to generalize to the broader range of SDGs of interest to cities.

--- Insert Table 1 about here ---

Quality Drinking Water

As a life-enabling resource, safe drinking water is an undeniable priority for sustainable cities (Polenghi-Gross et al., 2014). However, managing drinking water quality is a complex task fraught with a high degree of uncertainty (Hrudy et al., 2012). Among current challenges faced by cities are aging water infrastructure, high maintenance costs, new contaminants, increasingly stringent environmental regulations, extensive information requirements and advanced analytical techniques, risks of systemic and accidental pollution of water sources, and a lack of consensus on public expectations for 'safe' water (Chukwuma, 1998; Hou et al., 2013; Hrudy et al., 2012; Polenghi-Gross et al., 2014). Added to these challenges are future threats from continued urban population growth, increased water demand and the effects of climate change (Polenghi-Gross et al., 2014).

Effective water management is an intensely knowledge-based activity (Hrudy et al., 2012) involving two inter-related activities: i) monitoring, assessment and management of water resources; and ii) the social and political work associated with policy development and implementation (Booty et al., 2001; Chukwuma, 1998). Complicating these activities is the fact that both factual and perceptual elements are associated with water quality. For example, consumers may not trust the quality of drinking water even when health officials deem it to be safe. In turn, this perception of quality (or lack thereof) may lead consumers to engage in political activism. Because of the variety of factors involved in determining water quality, a holistic approach is needed (Hrudy et al., 2012). When this is not the case, serious consequences may ensue. For example, the water crisis in Walkerton, Ontario in 2000 that killed seven people resulted because many of the operational, regulatory and political systems failed in the face of a serious contamination threat (CBC, 2010; Hrudy et al., 2012). However, such failures are not limited to small communities, as evidenced by the experiences in the United States where both Flint, Michigan (Laylin, 2016) and Washington, D.C. (Leonnig, 2010) have suffered the consequences of system failures resulting in dangerous levels of lead in their drinking water.

Efforts to improve drinking water safety have focused primarily on local-scale technologies, with less attention given to systematic, integrative theories and practices for water quality monitoring and control (Hou et al., 2013). However, to achieve the SDG target of universally accessible drinking water, preventative approaches directed at understanding the system, its contaminant challenges, capabilities and limitations are needed (Hrudy et al., 2012). Two examples of this broader vision include the development of an early warning and control system for water quality in China (Hou et al., 2013) and the creation of frameworks for collaborative water quality knowledge and information networks in Europe (Dalcanale et al., 2011).

Still, there is a tremendous opportunity for the IS community to contribute to improving the quality of drinking water around the world. Technological advances such as real-time monitoring, artificial intelligence, space-based environmental monitoring, predictive modeling, computer-based optimization and simulation models offer opportunities for designing plans and developing policies to maximize the desired impacts and minimize the undesirable ones (Cosgrove & Loucks, 2015). Research supporting these efforts must be inter-disciplinary and collaborative (Hrudy et al., 2012), combining the physical and natural sciences with social sciences (Booty et al., 2001; Cosgrove & Loucks, 2015) and enhancing the science-policy interface (Quevauviller, 2007). This research will require new thinking and social research leading to new water management approaches and their political and social acceptance (Cosgrove & Loucks, 2015).

Public Green Space

Green spaces are an essential part of sustainable cities because they provide a wide range of aesthetic, environmental, financial, cultural, and health benefits. Within green spaces, urban trees contribute to the improvement of local microclimates and offer longer term environmental benefits for cities due to their air cleansing capacities (Jim & Chen, 2008). However, determining these effects is no trivial matter, as the air cleansing capacities of trees are influenced by a variety of factors such as the type of species, canopy area, type and characteristics of air pollutants and local meteorological conditions (Jim & Chen, 2008). Another important benefit of urban green space is its influence on physical activity and improved health (Schipperijn et al., 2013). Characteristics such as proximity, size, availability of sporting equipment, cycling trails, water features or wooded areas, and lighting (among others), influence the impact of green space on physical activity. However the effects of these offerings are not consistent the world over (Schipperijn et al., 2013), meaning that cities must take into account their own particularities when designing urban green spaces.

When managing green spaces, cities must also be cognizant of the inherent risks associated with urban trees. These risks increase when trees are improperly or inadequately maintained. Fallen trees can disrupt movement within a city, cause damage to physical property and infrastructures and, in the worst case, harm or kill people (e.g., Laanela, 2016). The importance of urban forests has led researchers to develop measures and models to help city managers determine the susceptibility of their urban forests to extreme events, pests and other stressors (Foran et al., 2015). Although various models have been developed to define quality of urban green space, there is not one unified understanding of what this means (Lindholst et al., 2015). Due to multiple user groups accessing green spaces, each with their own priorities and interests, the definition of quality is inherently a political process around the allocation of who gets what, when and how (Lindholst et al., 2015). Still, cities rarely consider the specific air cleansing capacities of urban trees in planning green spaces (Jim & Chen, 2008) and many costs of tree maintenance (or lack thereof) are not fully taken into account (Vogt et al., 2015).

Managing urban green space sustainably requires cities to consider the perspectives of multiple stakeholders and make trade-offs between benefits and risks. IS could support these choices by consolidating diverse information (e.g. tree cleansing capacities, the costs of not maintaining trees, and the perceived value and benefits of recreational offerings) and making it available for systematic green space planning, management and maintenance (pruning, watering, pest monitoring and control, and ensuring overall plant health). Traditionally, management of green spaces has been done by city managers who regularly contract out certain activities, such as routine maintenance. However, cities are beginning to contract out more complex responsibilities such as financing, policy, strategy, planning, development, stakeholder involvement and/or management (Lindholst & Bogetoft, 2011). Also, there is a move toward a co-governance approach in which citizens participate in policy setting and maintenance activities (Molin & Van den Bosch, 2014). Such trends are creating new demands for city managers and raising concerns with respect to the representativeness and transparency actually realized within more participative management processes (Molin & Van den Bosch, 2014). Herein lies another opportunity for IS to enhance sustainable green space management.

RESEARCH DESIGN

As the preceding sections highlight, there are many opportunities for IS to support cities' efforts to become more environmentally sustainable. However, this remains an underexplored area in both research and practice (Brauer et al., 2015). This situation is symptomatic of the field of green IS research more generally. Despite growth over the past 15 years, research has focused more on raising awareness of the sustainability challenge (El Idrissi & Corbett, 2016) with the result that progress toward IS solutions and action-oriented research is not being made fast enough (Malhotra et al., 2013; Watson et al., 2012). With the goal of helping to change the trajectory and contributing to the achievement of the SDGs, our research seeks to better understand the role of IS in building smart sustainable cities. Our research is guided by the following questions: how do IS support cities in their efforts to manage water quality and green space? What type of IS are needed by cities in order to achieve the SDGs by 2030?

Methodology

The grounded theory method (GTM) was chosen for this research. As an inductive approach, the core purpose of GTM is to generate theory from data (Corbin & Strauss, 2008; Glaser & Strauss, 1967; Urquhart et al., 2010) through the application of robust and systematic procedures, analytical skills and theoretical sensitivity (Urquhart & Fernandez, 2013). This method is particularly attentive "to issues of interpretation and process" without binding one "too closely to long-standing assumptions" (Suddaby, 2006, p. 641) IS researchers have found GTM useful for investigating a variety of questions (e.g., Orlikowski, 1993; Vannoy & Salam, 2010) as GTM are particularly appropriate for investigating questions of process and context (Urquhart & Fernandez, 2013) and new organizational phenomenon, such as we seek to understand in the present research. Using GTM, researchers engage in a constant dialogue with the data to discover within the central theoretical formulation (Corbin & Strauss, 2008; Jones & Noble, 2007). GTM involves continuous comparison between data and emergent concepts which allows for theoretical sampling and theoretical saturation (Glaser & Strauss, 1967; Urquhart et al., 2010) where data gathering stops and a substantive theory starts to emerge.

In the literature, there has been significant debate around the evaluation of GTM (e.g., Corbin & Strauss, 2008; Jones & Noble, 2007; Urquhart et al., 2010), from which several key criteria emerge. First is reliability, meaning the consistency and care used in applying the research methods (Miles et al., 2014). In this respect, we implemented a number of practices: we clearly defined our research questions and ensured the study design was congruent with them (Miles et al., 2014); the selection of our research site and the two green IS systems was purposive (Miles et al., 2014) affording us a rich and relevant sample; we took care to ensure that the transcripts were accurately transcribed (Corbin & Strauss, 2008) in their original language by a professional unrelated to the research in order to prevent mistranslations; we employed structured analytical procedures with each author independently coding the data and reviewing together individual analyses to ensure agreement (Miles et al., 2014); and we analyzed the two systems sequentially and independently before final elaboration of the model.

A second quality criterion relates to validity, or whether the findings make sense and provide an authentic portrait of the phenomenon (Corbin & Strauss, 2008; Miles et al., 2014). The research should also demonstrate a clear chain of evidence that links the findings with the data, such as through the use of quotes (Myers, 2009). To ensure validity, we used data triangulation (Miles et al., 2014), both from different sources (primary and secondary) (e.g., Gregory et al., 2013) and different cases (LabIS and TreeIS) (e.g., Lehmann & Gallupe, 2005) to develop the model. In addition, we have provided illustrative quotes in the Research Findings (and the Appendix available online) to demonstrate the link between the data and conceptual development.

A third quality criterion relates to the generalizability or applicability of the grounded theory itself (Urquhart et al., 2010). In other words, the study should create theoretical generalizations that extend beyond the particular context of the study (Corbin & Strauss, 2008; Myers, 2009). Scaling up, which involves moving from narrow seed concepts to higher levels of abstraction associated with substantive and formal theories, improves the generalizability of a grounded theory (Urquhart et al., 2010). As discussed below, while the emergent model is grounded in data from two specific systems, it has wider applicability to a range of IS relevant to the achievement of the SDGs in cities.

RESEARCH IMPLEMENTATION

Successful use of GTM relies on the selection of an appropriate research site. Through the second author's previous unrelated research, we were able to secure our research site, Q-City. As a large urban area in the Province of Quebec, Canada, Q-City afforded us sufficient scope and depth to explore our research questions. This francophone city has a diversified economy and a long term vision of developing all resources in a sustainable manner based on human capital, social, economic and environmental considerations. Since 2007, Q-City has initiated several smart city initiatives, and has been recognized as one of the Top7 Intelligent Communities in the world by the Intelligent Community Forum.

Our initial request for participation was made to the director of the information technology and telecommunications (IT) department (Figure 1). At the time of data collection about twenty developers supported the needs of the environmental services (ES) department and , the IT department was managing sixteen different systems and applications for ES in the areas of water management, land management, hazardous materials, and greenhouse gas emissions (Table 2). After our request for participation was approved by the director, the team lead for ES systems development became our primary contact.

--- Insert Figure 1 and Table 2 about here ---

Theoretical Sampling

Theoretical sampling involves the selection of data sources based on the needs of the emerging theory (Ransbotham & Mitra, 2009). In other words, the data is useful for illuminating relationships and logics between concepts of interest (Eisenhardt & Graebner, 2007). The number of IS being used by the ES department allowed us a choice of systems to study. We engaged in initial discussions with the IT director and the lead developer of ES systems to understand the purpose and scope of each system. Based on this information, we chose two systems – LabIS and TreeIS - that addressed two different sustainability concerns - water quality (SDG Target 6.1) and green space (SDG Target 11.7), respectively.

It should be noted that these two systems were selected and data was collected in 2013, prior to the adoption of the SDGs. At the time, Q-City was using the systems to manage water quality and green spaces as described below. Accordingly, our data collection and analysis took place over the same time during which the SDGs were being defined, determined and accepted by member nations. In effect, the rapidly evolving global context around the SDGs redefined the potential significance of our research findings for academia and practice. The changing context did not necessitate further data collection. It did, however, require that we examine the literature from multiple disciplines and perspectives in order to identify and better understand the emerging challenges to the sustainability of cities and to validate the applicability of our work to those challenges. In response to calls for the IS community to become more engaged in dealing with real world challenges (Malhotra et al., 2013), we paid particular attention throughout this process to the relevance and potential contribution of the IS community.

Description of LabIS

LabIS is a laboratory information system used by the ES department since 2000 to perform water quality assurance. This system has become the lab's central nervous system and is essential to the lab's ISO 17025 certification and Ministry of the Environment (MoE) accreditation. LabIS users have formal education in natural sciences (e.g., microbiology, chemistry), and specialized practical skills related to laboratory work. There are about twelve permanent users of LabIS, but the total number can grow to thirty as students and temporary workers are hired to meet the demands of the peak summer water testing season. Approximately half of the current core employees were present during the initial implementation of LabIS. Ensuring water quality within Q-City is a shared responsibility between Public Works, which manages the water system, and ES, which provides independent verification. The verification process is outlined in Figure 2.

--- Insert Figure 2 about here ---

Although the core of LabIS is off-the-shelf software, Q-City has enhanced and extended its functionalities over the last decade. Specialized excel spreadsheets and macros, along with Access interfaces, have been developed by the IT group for end users such as Public Works, ES, and Engineering Services. Custom links have also been built between automated testing devices and LabIS. At the time of data collection, LabIS was not integrated with Q-City's other enterprise systems including the geographic information system (GIS).

Description of TreeIS

TreeIS is an in-house system initially developed in 1995, used by ES to manage trees, green spaces, city parks and gardens. TreeIS is used by several different types of users: field technicians (employees of Q-City, hired contractors and students) have responsibility for on-site work, while planners and supervisors are responsible for overall green space management. Users are primarily educated in horticulture or urban forestry and include professional arborists, landscapers, horticulturalists, inspectors and other specialists. During the winter, there are about 20 permanent users of TreeIS, however, this number grows to fifty during the summer. Green space management at Q-City is a highly event-driven activity that follows a logical sequence, which TreeIS helps to enforce. An overview of the process is included in Figure 3. Data in TreeIS related to the inventory and tree maintenance events are retained indefinitely as the historical information is used for green space planning and by other city departments (e.g., Public Works, utilities).

--- Insert Figure 3 about here ---

At the core of TreeIS is an Oracle database. From this, an interface has been built to allow different users to enter and retrieve the information. WeBI, BusinessObjects' web intelligence platform, is used to provide the analysis and reporting, and TreeIS has been integrated with Q-City's GIS to allow users to quickly and easily identify the location of a given tree and to permit coordination between ES and departments such as Public Works (for roads), and external organizations such as telephone and electricity utilities. The inventory of trees is also available through Q-City's open data portal for citizens and other interest parties.

Data Collection

Primary data collection was achieved through semi-structured interviews. Participants were suggested by the primary contact and by other participants during the course of interviews. Nine participants were interviewed from two departments - four from IT and five from ES – representing multiple levels of the organization, from front-line staff to senior management. The average tenure of participants in ES was over 21 years, compared with less than 9 years for IT participants (Table 3). At least one participant had been involved in the initial implementations of the two systems.

--- Insert Table 3 about here ---

Our base interview protocol was structured around broad themes related to the design, implementation and use of the system in the context of the environmental work being done (i.e., water quality and green space management). The protocol also included questions regarding the approach to sustainable development and smart city initiatives at Q-City. From the base protocol, questions were tailored taking into account the participant's role. Eight face-to-face interviews were conducted in French, ranging from 35 to 95 minutes in length. Both authors participated in five of the interviews; three interviews were conducted by the first author only. All interviews were recorded and transcribed. A total of 405 minutes of formal interviews were conducted, resulting in 180 pages of single-spaced transcripts. We also received clarifying information via email, watched a demonstration of the workflow for LabIS, toured laboratory facilities, and collected various secondary data from the media and other public online sources.

Analyses

Following the collection of data, we proceeded with analysis. We applied a structured, multi-step approach that forced a constant comparison between the data and emerging theory as demanded by GTM. Beginning with LabIS, we conducted open coding and axial coding similar to the approach of Harrison and Rouse (2014). Open coding involved a deep reading of the primary data to break down the data to identify and understand the underlying concepts, while axial coding involved evaluations across concepts to reveal relationships and second order themes and integrating dimensions (Strauss & Corbin, 1990). During open coding, we remained very close to the data. To guide our analysis, we interrogated the data using two 'seed' (Urquhart et al., 2010) questions: what are the challenges faced by cities and how do traditional IS address these challenges? These questions helped to define our substantive area and facilitated the initial phase of identifying concepts and categories (Urquhart et al., 2010), leading to the development of the grounded theory. Each author conducted open coding for each of these two questions independently. Then, we met to discuss and refine our understanding of the various concepts identified. We then independently conducted axial coding to identify themes and integrating dimensions.

After reaching consensus on the concepts and themes, each author again worked independently to try to discern the patterns and theoretical insights emerging from the data. A main part of this process involved questioning the data in order to interpret the central meaning and core category of the data (Corbin & Strauss, 2008). From this analysis, three integrating dimensions – the sustainability sphere, the political sphere and the administrative sphere – emerged, each supported by underlying first order concepts and second order themes. After these individual efforts, we compared results and, through numerous discussions and reviews of the data, came to a common view of the three spheres as essential integrating dimensions, and the critical role of an Integrated Information Ecosystem (IIE). Again, this was an iterative process as we coded separately, discussed jointly, returned to the data, and then regrouped to come to a common view of the emerging structure.

Once we were satisfied that the emergent model provided a good representation of LabIS, we repeated the same process for TreeIS. We attempted to conduct our initial analyses (open and axial coding) of TreeIS free of bias from the findings of LabIS to the extent possible given our already deep immersion in the data. In doing so, we were able to observe points of convergence and also divergence between the two systems. This approach of using GTM to analyse two systems sequentially also adds to the rigour of the research and the generalizability of the emergent model. We present our data structure in Figures 4, 5 and 6.

--- Insert Figures 4, 5 and 6 about here ---

Our final step involved elaborating the analysis (Corbin & Strauss, 2008) to construct the final version of the conceptual model of the IIE as presented below. We reviewed and reflected on the emergent model, comparing it across both cases and with relevant literature in order to deepen the theoretical meanings (Urquhart & Fernandez, 2013). As suggested by GTM, the analyses concluded when the theoretical story was complete and 'felt right' (Corbin & Strauss, 2008).

RESEARCH FINDINGS

A major challenge of GTM is to distil all the data and analyses into a rich and concise presentation accessible to the intended audience (Corbin & Strauss, 2008; Lehmann & Gallupe, 2005). With this in mind, we adopt a presentation structure that mirrors the process of scaling up our theory, with the objective of leading readers to the final articulation of the model.

Building Blocks: Challenges Faced by Cities and How IS Addresses these Challenges

The first research question asks: how do IS support cities in their efforts to manage water quality and green space? To answer that question, we used our seed questions to explore the challenges faced by cities and then how IS are able to alleviate these challenges. As shown in Figures 4 and 5, we uncovered a wide range of challenges faced by Q-City in managing water quality and green spaces, which we regrouped into eight second order themes[1]. In terms of dealing with these challenges, we find IS are used in many ways, which we regroup into six themes.

One of the most important challenges affecting both water quality and green space management is mastering complex workflows. As illustrated in Figures 2 and 3, the processes involve multiple steps and a variety of stakeholders. Each activity, whether planning a maintenance event for a city park or conducting a test of water quality, involves a variety of different steps, considerations and constraints. A LabIS user gave the following example:

> *"Suppose the test is for lead, there are several methods: there is a method for lead in the waste water, there is a method for lead in surface water, there is a method for lead in drinking water. The client requests 'lead', but the client has no idea that it is so complicated. It is necessary that the person* [in the lab who receives the sample and] *who chooses the parameter is capable of doing so."* (P3, LabIS user)

In conjunction with complex workflows, city workers face the challenge of managing large volumes of data and disseminating information in a timely manner to the appropriate stakeholders. These challenges are compounded by the potential harmful impacts that may arise if monitoring,

[1] Due to space limitations, we are unable to discuss in detail all second order themes. We provide various examples herein to provide readers with insight into our analysis and to support the development of the model.

planning, maintenance and management are not effective. Continuing with the case of LabIS, many people rely on the city to ensure the quality of drinking water and city workers recognize their responsibility for protecting the public health and the implication for robust IS solutions:

> *"LabIS, it is a laboratory application on which lives could depend. There needs to be much more effort expended; there needs to be twice the vigilance so as to create products whose level of quality is very, very high."* (P5, IT)

Faced with these challenges, a major benefit of using IS comes from improved efficiency provided through automation, streamlined workflows and easier and faster access to data. Under budgetary and other pressures related to their work, city staff are continually asked to do more and more quickly. A well-designed and implemented IS allows this to happen. For instance, one lab technician explained how LabIS allowed them to better organize their work:

> *"It is having the system where everything is entered, all requests for tests entered. Then you can go into the system to know how many samples are waiting* for me, *when they were entered, by what date do they have to be done. It allows you to have a better organization of your work days."* (P8, LabIS user)

The improved organization and efficiency afforded by LabIS was one of the reasons the system had become the "central nervous system" for the lab and also permitted this group to take on additional responsibilities without increasing the number of staff. Other benefits afforded by IS include the extraction and dissemination of information, enforcing compliance and providing robust platforms.

Our analysis of TreeIS allowed us to identify two additional challenges that we had not previously found in the case of LabIS: locating in physical space and enhancing quality of life. The importance of locating a resource within its specific geographic location is important, in part, because of the various interconnections between natural systems, as a participant explained:

> "[Along] *a long line of shoreline, the condition of these trees* [is important], *if a disease affects these trees, it could [lead to] broken electrical lines and there could be land erosion."* (P2, IT)

Although this challenge was not directly identified by LabIS users, we observe from the data and confirm in the literature (e.g., Chukwuma, 1998; Patra & Pradham, 2005) that geographic properties and ability to locate a natural resource within its physical space is also an important challenge for overall water quality management.

Beyond the benefits of IS already described, IS helps to alleviate these challenges enabling geolocalization and facilitating mobile work. The latter was particularly important for green space management, which involves a high number of temporary and contractual workers who go into the field to conduct maintenance. A participant explained the evolution of the TreeIS system and how it now more easily facilitates this field work:

“At first, TreeIS was just a big computer at the office. One had to make a paper copy. Today, with the [GIS], *they pick up a sector and then they go there. Today, they go with a tablet computer and they’re set.”* (P6, IT)

RESEARCH OUTCOMES

Thus far, the findings presented have been largely descriptive. We now adopt a higher level of abstraction as we begin to develop theory (Urquhart et al., 2010). From the basic building blocks, continued questioning of our data led us to the realization that managing water quality and green space is not merely a technical or administrative activity. Instead, we came to understand that managing water quality and green spaces (and by extension, sustainable development) occurs within three distinct ‘spheres of engagement’ - the sustainability sphere, the political sphere and the administrative sphere - as illustrated in Figure 6.

Integrating Dimensions: Three Spheres of Engagement

We conceptualize spheres of engagement as multi-dimensional ‘spaces’ in which stakeholders assemble and activities are accomplished. These spheres incorporate dimensions of similar concepts found in the literature, but are conceptually distinct. We view spheres of engagement as amalgamations: they incorporate resources within the direct control of cities (i.e., sphere of control) (e.g., Crang, 2000); include resources or stakeholders over which cities have influence (i.e., sphere of influence) (e.g., Fernando, 2012; Santos & Eisenhardt, 2005); and are shaped by the scope of responsibilities and activities of the city (i.e., sphere of activity) (e.g., Dowling & Pfeffer, 1975). Further, our conceptualization of the spheres of engagement is not based on particular actors. Instead, within each sphere, actors from government, business and other organisations and individuals in society – the three essential players in sustainability (Fernando, 2012; Stern, 2008) - are present. Finally, we view these three spheres as separate from the three pillars (economic, environment, social) of sustainability, which allows for a richer understanding of the context in which IS must operate to support sustainability efforts (Caldelli & Parmigiani, 2004).

The Administrative Sphere

The administrative sphere represents the space in which the day-to-day work of managing cities takes place. Activities are largely carried out by city employees and immediate stakeholders, and are defined by the existing processes and obligations of the city. As Figure 6 illustrates, many of the challenges faced by cities and their attendant IS solutions play out in this sphere, which is consistent with previous research suggesting that IS solutions have been built primarily for administrative activities of cities (Brauer et al., 2015; Danzinger et al., 1978). Cities have tended to focus on the known benefits that can be achieved through traditional IS, especially the deployment of GIS to support city management (Robey & Sahay, 1996; Roche, 2014), such as we observed in the

TreeIS integration with the Q-City GIS. Another important way in which IS support cities in the administrative sphere is through the provision of robust platforms to address data wrangling challenges. For example, with respect to water quality, the city is obligated to perform various quality tests and engage in corrective action in cases of non-compliance. This situation results in a large quantity of data that must be managed and maintained, a task that would be virtually impossible without IS, as one participant noted:

> *"We have 340 000 samples, for a little more than ten years that the database has been in place. It would be unmanageable to have no database, it would be mayhem." (P3, LabIS user)*

Based on our interpretation of the data, we suggest that traditional IS applied in the administrative sphere help cities build the necessary capacities to address the myriad of challenges they face. A priority is placed on the minimum requirements and the continuity of core services, protection of citizens and city assets, risk reduction and compliance with applicable legal structures and laws. In the administrative sphere, robust data and IS infrastructure platforms provide improved efficiency, information extraction, geolocalization, mobile work and enable compliance. Systems must be resilient, able to withstand various pressures, including changing political priorities.

The Political Sphere

The political sphere represents the space in which city priorities and resource allocations are negotiated; in effect, it hosts the political processes that are inherent in water quality and green space management. The political sphere tends to be more volatile than the administrative sphere because many different stakeholders with competing interests participate in this sphere. Many participants in this sphere, like elected officials, have shorter tenures than city employees and may seek to maintain their electability by championing popular initiatives. The political sphere for cities is also influenced by political discourse at different levels: state governments can promote discussion of environmental issues to "create a political atmosphere that educates and encourages local action on these issues" (Homsy & Warner, 2015). The challenges in the political sphere differ from those in the administrative sphere and principally concern the dissemination of information to a varied group of stakeholders in a manner that is open and transparent, enhancing citizens' quality of life, and activating the political will necessary to advance sustainable development.

With respect to the dissemination of information, the data suggests that cities are politically conflicted with questions of who should get what when. On one hand, smart cities are placing an increasing emphasis on open government, transparency and citizen participation (Chourabi et al., 2012; Justice et al., 2015). However, on the other hand, the use of IS to support these activities is still limited. For instance, although Q-City's inventory of trees was available through an open data portal, information regarding water quality was not. Research participants held mixed opinions on whether such information should be made more available to citizens and under what circumstances. We also found, consistent with the previous research (e.g.,Brauer et al., 2015), there was limited capability for citizen involvement in both water quality and green space management.

Another challenge that exists within the political sphere concerns the desire to enhance quality of life, beyond simply protecting public health. Quality of life is an important consideration for smart cities (Chourabi et al., 2012) as it affects their competitiveness and ability to attract businesses and people to the city. There are many ways in which quality of life can be enhanced, for instance through recreational activities provided in urban green spaces. In fact, trees themselves may represent part of the cultural heritage of a city and preserving that heritage contributes to quality of life. This wealth of opportunities, coupled with the fact that quality of life is not generally well-defined, means that this challenge is subject to continual negotiation within the political sphere.

In the political sphere, the challenges of information dissemination and enhancing quality of life (as well as other challenges) are less a technical issue and more a question of political will, that is, the interest and commitment by stakeholders to pursue a particular course of action. Cities continually face a variety of competing demands and sustainability itself requires navigating though complex and sometimes competing economic, social and environmental priorities. For water quality and green space management, this means competing with other city services for resources, including IT and IS, as one participant explained:

> *"Since I've been here, there have not been many IT projects implemented* […] *because there is no political will, there is not a big demand. It* [ES] *is important, but without having priority."* (P2, IT)

In effect, the lack of political will to invest in sustainability initiatives adds an extra layer of difficulty to responding to the sustainable development challenges faced by cities.

The Sustainability Sphere

The third sphere of engagement is the sustainability sphere. While the administrative sphere is the space where the work gets done and the political sphere is the space in which priorities are set, the sustainability sphere is the space in which we come to understand the 'grand challenge' of sustainability (Hovorka & Corbett, 2012). The planet is a key stakeholder in this sphere and while it can 'speak' through changes in climate, extreme weather events and natural disasters, humans also give voice to planetary concerns (e.g., Brundtland, 1987; Rockström et al., 2009; Stern, 2008). In this sphere, stakeholders across multiple levels and sectors seek to understand the historical, current and future conditions, define sustainability and set targets that direct attention to the most pressing concerns. Cities may participate in this sphere through their involvement in national and international associations. For instance, as we observed, Q-City was an active participant in many such associations, such as the International Association of Francophone Mayors, with the goal of understanding what it means to be a sustainable city and learning how to work collaborative with other cities to achieve global sustainable development goals.

Our data highlighted two major challenges in this sphere: the desire to continually enhance quality of life and sharing responsibility for sustainability. The challenges associated with ensuring quality of life (as discussed above) also apply within the sustainability sphere. Yet, we also observe an additional complexity: in the sustainability sphere, ensuring quality of life is not only applicable to human populations, but also to living species that share the planet with us. A participant reflected on this challenge as follows:

> *"Today, 98% of the lake is dedicated to humans. In summer period, from July to August, practically all the water of this one lake is monopolized by a single species - humans. It's a bit unfair! What this says is that we must gradually help the other populations* [species] *there."* (P9, LabIS user)

Related to this challenge is the complexity associated with the interconnectedness of natural systems and the fact that these systems are shared resources that must be respected across geographic and political boundaries. During the interviews, participants spoke about water resources (e.g., rivers) being used and shared by multiple cities and how decisions made in one location can have downstream implications for other cities and users. In Quebec, for example, the St. Lawrence river is a major waterway and a key economic, environmental and social asset of the province. Spanning a large geographic distance with interconnections with other ecosystems, the quality of the water in the river and the environment surrounding it cannot be assured by a single city.

If effect, within the sustainability sphere everything is connected and sustainable development must be viewed in a holistic fashion, not simply as a series of activities in a business process, nor as a set of compromises to be negotiated. Despite the profound challenges in the political and sustainability spheres, we found little evidence of traditional IS being used to alleviate these challenges as compared to the administrative sphere. This observation led us to reflect on our second question regarding the type of IS needed by cities in order to achieve the SDGs by 2030.

Conceptual Model of an Integrated Information Ecosystem

In order to achieve the SDGs by 2030, major transformations will be needed at all levels, including in the IS used by cities. Based on our findings, we suggest that progress may be constrained by IS that do not support cities across the three spheres of engagement. We further theorize that a new type of IS, an integrated information ecosystem (IIE), which serves to address challenges and coordinate activities across spheres, may be what cities require in order to make more rapid progress toward achievement of the SDGs.

The concept of an IEE, illustrated in Figure 7, draws on a biologically inspired logic of organizing, such as found in nature. Ecosystems are complex adaptive systems, comprised of a large set of living and non-living elements that interact to produce a stable system (Levin, 2009; Winn & Pogutz, 2013). These elements are mutually interdependent, as they simultaneously influence and are influenced by each other. Organizational arrangements based on these logics are typically distributed, decentralized, and largely self-organizing (Tiwana, 2014). In turbulent and complex environments, ecosystem approaches to IT can help organizations build strategic advantage (El Sawy et al., 2010).

--- Insert Figure 7 about here ---

Drawing on these views, we define the IIE as an adaptive collection of independent, yet inter-related and integrated information technologies and systems that dynamically interacting holistically to support activities in the administrative, political and sustainability spheres in support of the development of smart sustainable cities. Within the IIE, existing and emergent technologies, such the Internet of Things (IoT), cloud computing, mobile technologies, open data, augmented reality, and big data analytics, among others, will support cities' data collection, permit deep analysis, and enable broad communication and collaboration. To further elaborate the role of IS in building smart sustainable cities we propose that there are six interactions between the administrative, political and sustainability spheres that an IIE can enable. Although described sequentially as a matter of convenience, the influences described next take place continually and simultaneously. We begin in the top left corner of the Figure 7.

As described previously, the sustainability sphere represents the space in which the parameters of sustainability are defined. As such, it requires the collection of a broad range of information on the state of the natural environment, threats and trends (Christensen et al., 2011). This information may come from various sources including scientists, researchers, practitioners, politicians and ordinary citizens, and be contained within the IIE. Equipped with this information, participants in the sustainability sphere can engage in science and fact-based discussions which allow for more informed decisions, better definitions around sustainability and identification of the critical challenges for sustainable cities (Figure 7, arrow 1).

In the political sphere, the challenges set forth in the sustainability sphere are debated and negotiated in the context of each city. Such discourse serves to cultivate the political will needed to advance key initiatives and objectives. Here, the IIE provides not only a rich dataset of information to inform these debates, but also tools to support detailed analysis. Using innovative technologies, such as participatory GIS (Ganapati, 2011), the IIE can also provide the platforms necessary for collaboration from the broadest range of citizens and stakeholders (Chourabi et al., 2012; Kellogg & Mathur, 2003). From the debate in the political sphere emerges a shifting set of priorities for action in the administrative sphere (Figure 7, arrow 2).

Responding to the priorities set out within the political sphere, stakeholders in the administrative sphere take action, seeking to turn the vision into reality. The IIE can support these activities and help cities build the necessary capacities. As we observed in our studies of TreeIS and LabIS, traditional IS, databases and workflow systems, can support efficiency, compliance, and information dissemination. In addition, we suggest other technologies including the IoT coupled with big data analytics will allow for automatic capture and analysis of data to support better environmental management. Through these new organizational capacities, cities can make concrete progress toward building a smart sustainable city (Figure 7, arrow 3).

The importance of the administrative sphere is not limited to implementing the priorities as set out within the political sphere. Instead, the administrative sphere also influences both the political and sustainability spheres. Participants in the administrative sphere are most closely positioned to the natural environment in the day-to-day operations, thus, they are able to provide ground-up insights on environmental conditions. Highlighting this role of voice, one of our participants remarked:

> *"If you don't have a little environmentalist fiber when you work in a department like this, it's like you're not quite in the right place, because you need to be able to say: "this doesn't make sense here", to be able to go ring the alarms at a higher level."* (P8, LabIS user)

Through the use of an IIE, information captured in the administrative sphere can help to inform political discourse and political decision-making (Booty et al., 2001), providing feedback on the work being done and the consequences of various city programs and initiatives (Figure 7, arrow 4). At the same time, the administrative sphere can also identify new potential threats to sustainability as they begin to emerge. Through the IIE, these new challenges can be brought to the sustainability sphere, adding to the collective understanding sustainable development in the urban context (Figure 7, arrow 5).

The last interaction involves feedback from the political sphere to the sustainability sphere. As with all three spheres, many of the participants within the political sphere (e.g., elected officials, citizens) also engage in the sustainability sphere. Although cities around the world face similar challenges with respect to urban development, transportation, preservation of green space and cultural heritage and the protection of public health, trade-offs, at least in the short-term, are often required between the three (economic, environment and social) pillars of sustainability. Thus, although the sustainability sphere serves to define sustainable development goals, the discourse in the sustainability sphere may at the same time be influenced by perceptions and priorities emanating from the political sphere (Figure 7, arrow 6).

In order to build smart sustainable cities, effective and purposeful interactions must occur between the administrative, political and sustainability spheres. Interactions between these spheres take place continually, creating a complex and somewhat chaotic environment in which all elements are changing simultaneously. An IIE thus plays an essential role by enabling the flow of information and integrating activities across these three spheres.

APPLYING THE CONCEPTUAL MODEL

Moving now from theory to practice, we present two real-world scenarios that allow us to illustrate the applicability of the model in building smart sustainable cities.

Scenario 1: A Holistic View of Water Quality Management

In this scenario[2], we consider a city that relies on water from a nearby lake for its drinking water. Even before the adoption of SDG Target 6.1, the quality of water in local watersheds has represented an important preoccupation for cities (e.g., Morden, 2015). Years of unsustainable practices involving the discharge of untreated waste water and deforestation along the waterfront have created high levels of pollution, threatening the water source and raising treatment costs. To rectify the situation, the city invests in major infrastructure upgrades and builds treatment systems in order to prevent pollution. During these upgrades the physical infrastructures are outfitted with IoT technologies, such as underwater sensors and cameras, to capture critical data on water quality and pollution levels and to trigger automated responses in the event of critical incidents. For instance, in the event of impending overflow, the system is able to divert waste water to retention basins, or the identification of certain microorganisms in the water can provide early warning signals (Hou et al., 2013) and prompt automated treatments in sanitation plants.

On a regular basis, the city's accredited water-testing laboratory collects samples at key points and conducts independent tests to verify water quality. Laboratory staff are able to access a range of information regarding the state of the water network, including previous, ongoing or planned work that might affect test results. Efficiency in the laboratory testing permits the identification of any non-compliant results within hours, followed by a detailed report to oversight bodies within 24 hours and public diffusion through electronic communications media and the city's open data portal.

Over time, information collected through an IIE allows city scientists and researchers to identify new threats, such as the build-up of plastic micro-beads in the water. Local governments,

[2] This scenario is based on publicly available information (newspaper articles, blogs and government reports) that relate to water quality management in Quebec. While based on real events, it does not refer to a single city. Rather, it is a combination of challenges and actions that could face any given city with similar geopolitical contexts.

working in conjunction with researchers, are able to quantify the potential risk of these contaminants to marine life, waterways and eventually the human food chain (Castañeda et al., 2014). This emerging scientific knowledge, coupled with increasing public pressure by environmental groups through social media, leads companies to voluntarily remove micro-beads from their product formulations and contributes to more permanent legislative changes (see Drahl, 2016).

To supplement investments in built infrastructure for water sanitation and treatment, the city also undertakes a long-term program for shoreline remediation. Using a green space management system, the city creates an inventory of existing plants and human-built structures within the area. Integrating this information with water tests, the city is able to show that an accumulation of phosphorous in the aquifer is due to deforestation around the lake caused by human activity. To remedy the situation, scientists determine it is necessary to remove all non-permanent structures, restrict activities within a buffer zone, eliminate invasive plants and re-establish native plants along the shoreline. Such measures require changes to city land-use and building by-laws. Using data and simulations provided by an IIE, the ES department explains and visually demonstrates the potential impacts to the elected officials and citizen groups. Further integration with financial systems allows the city to answer questions about the potential impacts on property values and to implement a grant program to help compensate property-owners participating remediation programs. These actions help to reduce the negative reactions and generate support from local environmental organizations, allowing for quick passage and implementation of the necessary legislative changes.

As remediation efforts continue, water quality reaches safe levels for swimming and recreational activities with low environmental impact. The results of automated testing (through sensors on submergible rafts) are published for residents and visitors through an open data portal and mobile apps. These services make it easy for people to determine if the water is safe for recreational use. To further enhance people's experience of the city's natural areas, the city develops a GPS-enabled app which is integrated with other systems to provide users with information about the location and augmented reality 3D applications to allow users to explore its native fauna and flora and historical or cultural significance.

This scenario highlights several key dimensions of the conceptual model. First, it demonstrates the importance of creating an IIE that integrates many different information technologies and systems: the water management system, the laboratory information system, the green space management system, geographic information systems, and city planning systems, IoT and sensor technologies, advanced business analytics functions including simulations, as well as social media and electronic communications systems, mobile technologies and augmented reality. In the administrative sphere, this integration allows for more rapid identification of risks to public health (i.e., contamination), improved decision-making that considers environmental problems in a more holistic fashion and sensitive to the different stakeholder groups and potential trade-offs in short and long-term. This scenario also demonstrates how the provision of information to the political sphere can inform the discourse and facilitate the enactment of necessary laws to support environmental sustainability initiatives, such as in the case of micro-beads pollution of fresh water sources. Open data, simulations and social media are all types of IS applications that can help to provide the necessary feedback loops. Moving to the sustainability sphere, using data accumulated over time and ever-increasing analytical capabilities, cities can build relevant knowledge about environmental sustainability. As certain problems are addressed, it is likely that others will emerge. Working in conjunction with other cities and organizations to protect waterways that cross multiple municipal boundaries allows for action on a more global scale.

Scenario 2: A Coordinated Approach to Sustainable Cities of the Future

By 2030 it is expected that 60% of the global population will reside in cities, creating new, and intensifying existing, demands placed on cities, such as those with respect to the need for affordable housing, reducing greenhouse gas emissions, putting in place sustainable transportation systems, managing solid waste, and providing health and social services (United Nations, 2016a). Thus, the second scenario takes a more futuristic perspective than the first scenario, looking at the role of IS in cities of tomorrow. It is inspired by UN's vision of sustainable cities as described in the World Economic and Social Survey of 2013. According to this vision, cities must adopt a holistic view of "social development, economic development, environmental management (at the local, national and global levels) and governance components" (United Nations, 2013, p. 69). Cities of the future will need to coordinate objectives and programs among divergent stakeholders and create links across different sectors. Sustainable cities will have to, among other things, invest in renewable energy sources, define a clear strategy for an efficient use of electricity and water, increase green areas, provide a fast, reliable and affordable public transportation system, and finally improve waste and recycling systems. Consistent with an integrated approach, cities will have to develop institutional and managerial capacities and foster the active participation of all stakeholders (United Nations, 2013). Hence, the development of a sustainable city requires substantial political will at multiple levels. At the global level, strong international organizations such as the United Nations and the World Bank challenge national governments to explore how the concept of green planet that can be realized through the creation of smart sustainable cities. Meanwhile, at the local level, city politicians can prioritize the environment, knowledge and green innovation.

Fundamental to achieving a sustainable city is the development and deployment of a robust infrastructure of systems and devices for capturing, processing and transmitting data from a variety of different sources. It truly represents the arrival of big data in which cities receive continuous streams of diverse data such as environmental conditions (e.g., water quality), transportation and systems and smart grid-enabled energy systems. The collection of such data would allow complex analytics to be applied in order to compute and track key environmental indicators across a range of services such as transportation, biodiversity and human health. Further, these systems would have communications capabilities to inform all stakeholders from elected city decision-makers to the general population about the environmental state and sustainability trajectory of the city.

All data collection systems will need to be integrated because the calculation of one indicator may require data collected from different sources and a single data element may contribute to multiple indicators. In other words, we can imagine this future sustainable city as a connection of objects monitoring different indicators in relation to the natural and built infrastructures. Thresholds for acceptable limits on these indicators, determined within the political sphere, provide boundaries for the range of activities in the city. If the aggregate activities within the city do not comply with thresholds associated with environmental indicators, cities can take immediate actions to change behaviors or curtail activities in order to achieve compliance. For example, if greenhouse gas emissions over a certain period exceed a pre-determined threshold, a city could change driving regulations (transportation services) and send automated requests to citizens and the business sector informing them of the need to take further actions to reduce emissions (economic activities).

Returning to the conceptual model presented above, this scenario demonstrates how an IIE will be essential in achieving the UN vision. Within the sustainability sphere, supranational organizations with cross-sectoral representation will continue to work together to define and refine objectives, such as the SDGs, as well as mechanisms for measuring progress in achieving them (e.g., United Nations, 2016b). As cities look to implement programs in support of these goals, compromises and trade-offs will be required. As the UN report states: “cities’ priorities are determined by their own urban planning capacities and by the pressing development challenges that they face” (United Nations, 2013, p. 74). Therefore, stakeholders must come together within the political sphere to discuss these pressing challenges and opportunities, to find common ground and a workable plan for implementation. From these discussions, local priorities can be set for the administrative sphere, particularly in terms of building and IIE that enables the integration of all city services, from economic and social development, transportation, the natural environment to public health. An IIE of this nature would create new organizational capacities for the city and provide a technological and knowledge platform for the co-creation of new services (Gouillart & Hallett, 2015) and evidence-based policy (Head, 2008). These efforts would be enhanced by an IIE that is able to capture the data and perform the analyses necessary to calculate key sustainable development indicators at both the national and local levels, and would go a long way to ensuring a sustainable future for all.

DISCUSSION

If cities are to achieve the goals set out before them by 2030, immediate action must be taken. A city manager may be asking how the IIE can be useful, or what can I do when I look at this model, or how can this model improve my work? All these questions, and others, are legitimate in order to make the model actionable. The two previous scenarios highlight concrete ways in which IS can support the development and management of smart sustainable cities. In this section, we go further with the aim of extending the impact of our research, which IS senior scholars define as "making a difference" (Neiderman et al., 2015, p. 128) by proposing a framework for action as summarized in Table 4. We combine both actions for practice and research directions in the framework to emphasize that building smart sustainable cities will require multi-disciplinary collaboration between both practitioners and academia.

--- Insert Table 4 about here ---

We begin with the sustainability sphere, where the main issue is to build smart sustainable cities. Building and managing this type of city requires IIEs to allow stakeholders to monitor the state of, and manage progress toward the, achievement of the SDGs through universally accepted indicators, such as the set of indicators proposed by the Inter-agency and Expert Group on Sustainable Development Goal Indicators (Bizikova & Denton, 2016) (for more information, see: http://unstats.un.org/sdgs/indicators/indicators-list/). For example, a city may have an existing IS system, similar to TreeIS, to manage green spaces. However, to meet Target 11.7, an IIE would also have to permit the city to measure 'accessibility'. Going further, it would also be useful for cities to collect information related to physical activity in green spaces (Goal 3, ensuring healthy lives) or the air cleaning capacities of urban trees (Goal 13, combating climate change). To fulfill these requirements, an IIE could incorporate cameras, sensors or other emerging IoT technologies, to facilitate and automate the collection of large volumes of data. Clearly, data collection is not an end in itself. The data must be used to inform stakeholders and create shared knowledge about sustainability. Analytical tools capable of processing big data would also be required and business intelligence tools, along with visualization and simulation capabilities would also be needed to transform the data into something meaningful for city managers.

Within this context, two main actions for practice are implied. To begin, cities must first translate global indicators to the local level, and second, they must implement within an IIE the capabilities needed to measure, manage and assess SDG indicators. For city managers, these actions may be new and, as such, will require the development of new expertise and perspectives. The IS research community can be an important partner for developing the knowledge required by investigating two main questions. First, how can global sustainability indicators be effectively captured, managed and monitored within an IIE? Investigating this question means that research and practice collectively look beyond the administrative sphere to translate global sustainability indicators into elements that can be effectively and appropriately measured, managed and monitored by cities. An early example of this type of work can be found in the work of Choi et al. (2016) who evaluate the potential for national urban IS and open geospatial technologies to support the measure of SDG 11. Second, how can cities integrate new information technologies within an IIE to monitor and manage progress toward achievement of the SDGs and develop new insights into the impacts of urban development sustainability? The findings from this stream of research should enable cities to better conceptualize the value of an IIE and implement one within their own unique context.

Moving to the political sphere, a key priority is to facilitate debate among all stakeholders in order to assess the compatibility and trade-offs between different SDGs. For example, with the increased use of cameras and image recognition capabilities, cities could have the opportunity to identify individuals in the green space and monitor what their actions. Both of these actions are threats to privacy. Consequently, in deciding to install cameras or other surveillance technologies to monitor progress toward the SDGs, cities will have to consider privacy issues and be attentive to legal and social issues. Thus, the IIE must also be able to support public debate and facilitate a holistic and integrated evaluation and management of the benefits, risks, and long-term contributions and impacts of competing policy alternatives. To fulfill these two needs, an IIE should include participatory platforms, based on Web 2.0 and mobile technologies, such as social media, to enhance public debate about specific issues related to environmental sustainability in local areas. The IIE can also incorporate decision-making support tools that allow city managers to evaluate the impact of different policy options and potential initiatives. As an additional advantage, by providing these capabilities, the IIE could also contribute to SDG Goal 16 for peace, justice and strong institutions.

Practitioners must determine the best way to support these debates and then implement the requisite information technologies and tools within the IIE. These public debates must be transparent and open, as research suggests that "meaningful involvement of citizens is a prerequisite for the development of just environmental policies and administrative decisions" (Kellogg & Mathur, 2003, p. 574). We propose that cities implement robust communication platforms that enable broad, cross-sectoral participation from all stakeholders. Although there is recognition that openness and transparency is important, our understanding of how to enable these processes is still somewhat lacking. Therefore, we propose that research should investigate the following question: how can an

IIE enable open and transparent political discourse among all stakeholders regarding the development of environmentally sustainable cities?

A second action we propose for practice is the development of policy decision-support tools that integrate objective data with feedback from all stakeholders. Given that many of these technologies are still emerging, practitioners will require support from the academic community. Accordingly, we propose that researchers seek to answer the question: what new types of information and IS can be developed to facilitate the evaluation and management of heterogeneous competing sustainability priorities that address both local priorities and global challenges?

In the administrative sphere, cities are confronted with the issue of building and managing physical infrastructures (e.g., water system, electricity, transportation, health, education, waste) in sustainable manner. Here, IS must no longer be perceived as a single system to support the different activities within a city, but as a new, holistic means to support cities in the achievement of the SDGs. This holistic approach creates a number of requirements for an IIE. For instance, data captured from surveillance and sensor technologies in different spaces can be used to support other city services. For example, police services may use such data to reduce security threats or to identify perpetrators of crime. Also, IIEs should be able to provide seamless communications with internal (e.g., planning, finance, purchasing, logistics) and external (e.g., legislative, disaster response) systems. With regard to these situations, practitioners must pay attention to the issue of information exchange and interoperability across the different systems included within the IIE.

For practice, we suggest the most urgent action is to expedite the development of robust, interoperable platforms that permit the integration of data and tools across all city services. As the goal of the IIE is to support the development and management of smart sustainable cities and the achievement of the SDGs, new processes and business practices will have to be designed and implemented. We propose that scholars can help practitioners and contribute to improving practice by investigating the question of how sustainable business practices in cities impact technological choices of an IIE.

Limitations

Two limitations of our work can be noted. The first limitation arises from the small number of participants. Although qualitative studies are not subject to the same sampling requirements as quantitative research, care must be taken to ensure sufficient data is collected to ensure a theoretical saturation. We believe we have done so. As the two systems served specific activities, we were able to interview an important cross-section of the relevant users and IT personnel. We also used secondary data to supplement primary interview data, allowing for a fuller understanding of the context and emergent themes. The ability to generalize our results is also a potential limitation. The emergent model is based on the experience of one city in managing water quality and green spaces. Although the examination of two systems allows for greater applicability, it still does not capture all the possible challenges and systems used by cities as they strive to become more sustainable. Nevertheless, this work breaks new ground in IS research as it is one of the first to specifically examine the role of IS in addressing the UN's ambitious agenda for global transformation as embodied within the SDGs. Collectively, the conceptual model and framework provide a solid foundation for concentrated action leading to an improved and sustainable future for all.

CONCLUSION

The goal of this work is to contribute to the achievement of the 2030 SDGs. To this end, we have attempted to present research outcomes – a conceptual model as well as a framework of action - that will shape the future direction of IS research and that assist city managers in their response to the challenges presented by the SDGs. Our work was guided by two questions. In response to the first research question, we found that exiting information systems provide benefits such as improved efficiency, compliance, information management and robust transactional platforms that support cities in their efforts to be more sustainable. However, these benefits largely address challenges faced in the administrative sphere and not those of the political and sustainability spheres. Building smart sustainable cities requires coordinated and integrated activities across these three spheres of engagement. Therefore, in response to the second research question, we propose that in order to advance progress toward the attainment of the SDGs by 2030, cities need to develop and implement a new type of IS, an IIE, that supports a holistic and multi-disciplinary approach to sustainable development across all three spheres as described in the conceptual model. Viewing IS for sustainability in this way allows us to develop a framework of action for practice and research.

Contributions

The contributions of this work are both theoretical and practical in nature. Theoretically, the paper contributes to the scholarly literature by providing new insights into the challenges faced by cities and how IS can help to alleviate these concerns. From these insights, the paper develops an empirically grounded theory explaining the role of an integrated information ecosystem (IIE) in the building of sustainable cities. As such, our work responds to calls both for green IS research in the context of cities (Brauer et al., 2015), and deeper theoretical reflection regarding IS solutions for sustainability more generally (Elliot, 2011). Our study reveals the application of IS in the administrative sphere is only one part of a holistic approach to advancing environmental sustainability. An IIE is needed to integrate interactions between the administrative, political and sustainability spheres of engagement. Through our definition of each of these spheres and the interactions between them, we provide greater clarity into the dynamic environment surrounding smart sustainable cities. The model overall provides a robust conceptual foundation for understanding how IS can contribute to the SDGs by demonstrating how IS must operate in an integrated fashion across the three spheres to permit a holistic, multi-disciplinary approach to managing city operations and policy-making. Drawing this model, we also formulate five questions to serve as future directions for impactful, multi-disciplinary research.

The second major contribution of this work is its contribution to practice, specifically for those with responsibility for designing, developing and implementing IS within cities. Not only does the emergent model provide novel insights around the dynamics between IS and the three spheres of engagement, but the illustration of the model using two real-world examples also demonstrates more practically the role of an IIE in smart sustainable cities today and in the future. Further, based on the model, we are able to identify practical implications and offer actionable suggestions for city managers and IT practitioners. Thus, this work offers concrete directions for cities seeking to leverage IS to achieve important sustainable development goals.

A Call to Action

In 2015, the United Nations and its member countries set out to change the trajectory of sustainable development around the world. Since then, the global community has continued to make progress. With the ratification and entering into force of the Paris Agreement in November 2016, the world is moving away from "making commitments to delivering action" (Waskow, D. as cited in Phillips et al., 2016). Cities will be key players in the realization of both the Paris Agreement and the SDGs, but they will not be able to go it alone. We believe the IS community, both researchers and practitioners, must be active partners in these efforts. Moreover, we do not have the luxury of time: to achieve the goals by 2030, action must begin immediately. We hope the present work - the conceptual model and the framework of action based upon it - will inspire and motivate IS scholars, practitioners and city managers to work together, and serve as a guide for collaborative, multi-disciplinary, and solutions-oriented projects. Working together, we can win the battle for the SDGs in our cities.

Acknowledgements

Removed for blind review. To be added upon acceptance.

REFERENCES

Al Awadhi, S. & Scholl, H. J. (2013) Aspirations and realizations: The smart city of Seattle. *46th Hawaii International Conference on System Sciences*.

Bizikova, L. & Denton, P. (2016) How should we measure sustainable development? Retrieved December 2 2016, from http://www.huffingtonpost.ca/development-unplugged/sustainable-development-goals_b_9829340.html

Booty, W. G., Lam, D. C. L., Wang, I. W. S. & Siconolfi, P. (2001) Design and implementation of an environmental decision support system. *Enviornmental Modelling & Software*, **16**, 453-458.

Borja, J. (2007) Counterpoint: Intelligent cities and innovative cities. In: *Universitat Oberta de Catalunya (UOC) Papers: E-Journal on the Knowledge Society*, **5**, Retrieved August 7, 2013, from http://www.uoc.edu/uocpapers/5/dt/eng/mitchell.pdf

Boulton, A., Brunn, S. D. & Devriendt, L. (2011) Cyberinfrastructures and “smart” world cities: Physical, human, and soft infrastructures. In: *International handbook of globalization and world cities,* Taylor, P., Derudder, B., Hoyler, M. & Witlox, F. (eds.). Edward Elgar, Cheltenham, UK.

Brauer, B., Eisel, M. & Kolbe, L. M. (2015) The state of the art in smart city research - a literature analysis on green IS solutions to foster environmental sustainability. *Pacific Asia Conference on Information Systems (PACIS) Proceedings*.

Brundtland, G. (1987) Our common future. World Commission on Environment and Development, Brussels.

Caldelli, A. & Parmigiani, M. L. (2004) Management information system - a tool for corporate sustainability. *Journal of Business Ethics*, **55**, 159-171.

Caragliu, A., Del Bo, C. & Nijkamp, P. (2011) Smart cities in Europe. *Journal of Urban Technology*, **18:2**, 65-82.

Castañeda, R. A., Avlijas, S., Simard, M. A. & Ricciardi, A. (2014) Microplastic pollution in St. Lawrence river sediments. *Canadian Journal of Fisheries and Aquatic Sciences*, **71:12**, 1767-1771.

CBC (2010) Inside Walkerton: Canada's worst-ever e. Coli contamination. Retrieved April 27, 2016, from http://www.cbc.ca/news/canada/inside-walkerton-canada-s-worst-ever-e-coli-contamination-1.887200

Choi, J., Hwang, M., Kim, G., Seong, J. & Ahn, J. (2016) Supporting the measurement of the united nations’ sustainable development goal 11 through the use of national urban information systems and open geospatial technologies: A case study of south korea. *Open Geospatial Data, Software and Standards*, **1:4**, 1-9.

Chourabi, H., Nam, T., Walker, S., Gil-Garcia, J. R., Mellouli, S., Nahon, K., Pardo, T. A. & Scholl, H. J. (2012) Understanding smart cities: An integrative framework *45th Hawaii International Conference on System Sciences*, Kauai, Maui: IEEE, 2289-2297.

Christensen, S. W., Brandt, C. C. & McCraken, M. K. (2011) Importance of data management in a long-term biological monitoring program. *Environmental Management*, **47**, 1112-1124.

Chukwuma, C., Sr. (1998) Development and implementation of environmental monitoring and information systems for water resources. *Enviornmental Management and Health*, **9:4**, 153-159.

Compact of Mayors (2015) Ten global cities present climate action plans ahead of Paris COP21. Retrieved December 7, 2015, from http://www.compactofmayors.org/press/ten-global-cities-present-climate-action-plans-ahead-of-paris-cop21/

Corbin, J. & Strauss, A. (2008) *Basics of qualitative research: Techniques and procedures for developing grounded theory*, 3rd ed. Sage Publications, Inc., Thousand Oaks, CA.

Cosgrove, W. J. & Loucks, D. P. (2015) Water management: Current and future challenges and reseach directions. *Water Resources Research*, **51**, 4823-4839.

Crang, M. (2000) Public space, urban space and electronic space: Would the real city please stand up? *Urban Studies*, **37:2**, 301-317.

Dalcanale, F., Fontane, D. & Csapo, J. (2011) A general framework for a collaborative water quality knowledge and information network. *Environmental Management*, **47**, 443-455.

Dameri, R. P. (2013) Searching for smart city definition: A comprehensive proposal. *Journal of Computers & Technology*, **11:5**, 2544-2551.

Danzinger, J. N., Kraemer, K. L. & King, J. L. (1978) An assessment of computer technology in U.S. Local governments. *Urban Systems*, **3**, 21-37.

Dowling, J. & Pfeffer, J. (1975) Organizational legitimacy: Social values and organizational behavior. *The Pacific Sociological Review*, **18:1**, 122-136.

Drahl, C. (2016) What you need to know about microbeads, the banned bath product ingredients. *Forbes* Retrieved May 2016, 2016, from http://www.forbes.com/sites/carmendrahl/2016/01/09/what-you-need-to-know-about-microbeads-the-banned-bath-product-ingredients/#237b57e15f35

Eisenhardt, K. M. & Graebner, M. E. (2007) Theory building from cases: Opportunities and challenges. *Academy of Management Journal*,, **50:1**, 25-32.

El Idrissi, S. C. & Corbett, J. (2016) Green IS research: A modernity perspective. *Communications of the Association for Information Systems*, **38:Article 30**, 596-623.

El Sawy, O. A., Malhotra, A., Park, Y. & Pavlou, P. A. (2010) Research commentary - seeking the configurations of digital ecodynamics. *Information Systems Research*, **21:4**, 835-848.

Elliot, S. (2011) Transdisciplinary perspectives on environmental sustainability: A resource base and framework for IT-enabled business transformation. *MIS Quarterly*, **35:1**, 197-236.

Fernando, R. (2012) Sustainable globalization and implications for strategic corporate and national sustainability. *Corporate Governance*, **12:4**, 579-589.

Foran, C. M., Baker, K. M., Narcisi, M. J. & Linkov, I. (2015) Susceptibility assessment of urban tree species in Cambridge, MA from future climatic extremes. *Environmental Systems and Decisions*, 389-400.

Freeman, C. (2004) Sustainable development from rhetoric to practice? A New Zealand perspective. *International Planning Studies*, **9:4**, 307-326.

Ganapati, S. (2011) Uses of public participation geographic information systems applications in e-government. *Public Administration Review*, **71:3**, 425-434.

Glaser, B. & Strauss, A. (1967) *The discovery of grounded theory: Strategies for qualitative research* Aldine, Chicago.

Gouillart, F. & Hallett, T. (2015) Co-creation in government. Retrieved May 11, 2016, from http://ssir.org/articles/entry/co_creation_in_government

Gregory, R. W., Beck, R. & Keil, M. (2013) Control balancing in information systems development offshoring projects. *MIS Quarterly*, **37:4**, 1211-1232.

Harrison, S. H. & Rouse, E. D. (2014) Let's dance! Elastic coordination in creative group work: A qualitative study of modern dancers. *Academy of Management Journal*, **57:5**, 1256-1283.

Head, B. W. (2008) Three lenses of evidence-based policy. *The Australian Journal of Public Administration*, **67:1**, 1-11.

Hollands, R. G. (2008) Will the real smart city please stand up? *City*, **12:3**, 303-320.

Homsy, G. C. & Warner, M. E. (2015) Cities and sustainability polycentric action and multilevel governance. *Urban Affairs Review*, **51:1**, 46-73.

Hou, D., Song, X., Zhang, G., Zhang, H. & Loaiciga, H. (2013) An early warning and control system for urban, drinking water quality protection: China's experience. *Environmental Science and Pollution Research*, **20**, 4496-4508.

Hovorka, D. S. & Corbett, J. (2012) IS sustainability research: A trans-disciplinary framework for a 'grand challenge'. *International Conference on Information Systems*, Orlando, FL.

Hrudy, S. E., Fawell, J., Leiss, W., Rose, J. B. & Sinclair, M. (2012) *Managing uncertainty in the provision of safe drinking water* Canadian Water Network.

Jackson, F. (2012) Rio+20 business focus: What role will cities play in driving sustainable development? Retrieved August 7, 2013, from http://www.rtcc.org/2012/06/11/rio20-business-focus-what-role-will-cities-play-in-driving-sustainable-development/

Jim, C. Y. & Chen, W. Y. (2008) Assessing the ecosystem service of air pollutant removal by urban trees in guangzhou (China). *Journal of Environmental Management*, **88**, 665-676.

Jones, R. & Noble, G. (2007) Grounded theory and management research: A lack of integrity? *Qualitative Research in Organizations and Management: An International Journal*, **2:2**, 84-103.

Justice, D. N., Justice, J. & NcNutt, J. G. (2015) Smart cities are transparent cities: The role of fiscal transparency in smart city governance. . In: *Transforming city governments for successful smart cities*, Rodriguez-Bolivar, M. P. (ed.). Springer International Publishing, Switzerland.

Kellogg, W. A. & Mathur, A. (2003) Environmental justice and information technologies: Overcoming the information-access paradox in urban communities. *Public Administration Review*, **63:5**, 573-585.

Kramers, A., Höjer, M., Lövehagen, N. & Wangel, J. (2014) Smart sustainable cities - exploring ICT solutions for reduced energy use in cities. *Environmental Modelling and Software*, **56**, 52-62.

Laanela, M. (2016) B.C. Windstorm: Tree smaches house, kills Port Moody woman in her bed. *CBC News* Retrieved April 26, 2016, from http://www.cbc.ca/news/canada/british-columbia/b-c-windstorm-tree-smashes-house-kills-port-moody-woman-in-her-bed-1.3485549

Laylin, T. (2016) How michigan's Flint river came to poison a city. *The Guardian* Retrieved April 25, 2016, from http://www.theguardian.com/environment/2016/jan/18/michigan-flint-river-epa-lead-contamination-mdeq-pollutants-water-safety-health?CMP=new_1194&CMP

Lehmann, H. & Gallupe, R. B. (2005) Information systems for multinational enterprises - some factors at work in their design and implementation. *Journal of International Management*, **11**, 163-186.

Leonnig, C. (2010) CDC misled district residents about lead levels in water, House probe finds. *The Washington Post* Retrieved April 27, 2016, from http://www.washingtonpost.com/wp-dyn/content/article/2010/05/19/AR2010051902599.html

Levin, S. A. (ed.) (2009) *The Princeton guide to ecology*. Princeton, NJ: Princeton University Press.

Lindholst, A. C. & Bogetoft, P. (2011) Managerial challenges in public service contracting: Lesson in green-space management. *Public Administration* **89:3**, 1036-1062.

Lindholst, A. C., Sullivan, S. G., van den Bosch, C. C. K. & Fors, H. (2015) The inherent politics of managing the quality of urban green spaces. *Planning Practice & Research*, **30:4**, 376-392.

Lucci, P. (2015) Five challenges the sustainable development goals present to city leaders. Retrieved April 29, 2016, from http://www.citymetric.com/politics/five-challenges-sustainable-development-goals-present-city-leaders-1625

Malhotra, A., Melville, N. P. & Watson, R. T. (2013) Spurring impactful research on information systems for environmental sustainability. *MIS Quarterly*, **37:4**, 1265-1274.

Marceau, J. (2008) Introduction: Innovation in the city and innovative cities. *Innovation: Management, Policy & Practice*, **10:2-3**, 136-145.

Miles, M., B., Huberman, A. M. & Saldana, J. (2014) *Qualitative data analysis: A methods sourcebook* SAGE Publications, Inc., Thousand Oaks, CA.

Molin, J. F. & Van den Bosch, C. C. K. (2014) Between big ideas and daily realities - the roles and perspectives of danish municipal green space managers on public involvement in green space maintenance. *Urban Forestry & Urban Greening*, **13**, 553-561.

Morden, P. (2015) Sarnia-Lambton preparing for great lakes conference. Retrieved May 11, 2016, from http://www.lakeshoreadvance.com/2015/01/07/sarnia-lambton-preparing-for-great-lakes-conference

Myers, M. D. (2009) *Qualitative research in business & management* Sage Publications Ltd, London.

Neiderman, F., Crowston, K., Koch, H., Krcmar, H., Powell, P. & Swanson, E. B. (2015) Assessing IS research impact. *Communications of the Association for Information Systems*, **36:Article 7**, 127-138.

Oldekop, J. A., Fontana, L. B., Grugel, J., Roughton, N., Adu-Ampong, E. A., Bird, G. K., Dorgan, A., Espinoza, M. A. V., Wallin, S., Hammett, D., Agbarakwe, E., Agrawal, A., Asylbkova, N., Azkoul, C., Bardsley, C., Bebbington, A. J., Carvalho, S., Chopra, D., Christopoulos, S., Crewe, E., Dop, M.-C., Fischer, J., Gerretsen, D., Glennie, J., Gois, W., Gondwe, M., Harrison, L. A., Hujo, K., Keen, M., Laserna, R., Miggiano, L., Mistry, S., Morgan, R. J., Raftree, L. L., Rhind, D., Rodrigues, T., Roschnik, S., Senkubuge, F., Thornton, I., Trace, S., Ore, T., Valdés, R. M., Vira, B., Yeates, N. & Sutherland, W. J. (2016) 100 key research questions for the post 2015- development agenda. *Development Policy Review*, **34:1**, 55-82.

Orlikowski, W. (1993) Case tools as organizational change: Investigating incremental and radical changes in systems development. *MIS Quarterly*, **17:3**.

Page, B. & Voigt, K. (2003) Recent history and development of environmental information systems and databases in germany. *Online Information Review*, **27:1**, 37-50.

Patra, B. & Pradham, B. (2005) Designing an environmental information system for monitoring water and air quality in urban areas. *Disaster Prevention and Management*, **14:3**, 326-342.

Peinhardt, K. (2015) How cities can drive the sustainable development goals. Retrieved April 29, 2016, from https://www.greenbiz.com/article/how-cities-can-drive-sustainable-development-goals

Phillips, T., Harvey, F. & Yuhas, A. (2016) Breakthrough as US and China agree to ratify Paris climate deal. Retrieved December 2, 2016, from https://www.theguardian.com/environment/2016/sep/03/breakthrough-us-china-agree-ratify-paris-climate-change-deal

Polenghi-Gross, I., Sabol, S. A., Ritchie, S. R. & Norton, M. R. (2014) Water storage and gravity for urban sustainability and climate readiness. *Journal of the American Water Works Association*, **106:12**, E539-E549.

Poon, L. (2015) What the un's new sustainable development goals will (and won't) do for cities. Retrieved April 29, 2016, from http://www.citylab.com/politics/2015/09/what-the-uns-new-sustainable-development-goals-will-and-wont-do-for-cities/407812/

Quevauviller, P. (2007) Water protection against pollution. Conceptual framework for a science-policy interface. *Environmental Science and Pollution Research*, **14:5**, 297-307.

Ransbotham, S. & Mitra, S. (2009) Choice and chance: A conceptual model of paths to information security compromise. *Information Systems Research*, **20:1**, 121-139.

Robey, D. & Sahay, S. (1996) Transforming work through information technology: A comparative case study of geographic information systems in county government. *Information Systems Research*, **7:1**, 93-110.

Roche, S. (2014) Geographic information science I:Why does a smart city need to be spatially enabled? *Progress in Human Geography*, **38:5**, 703-711.

Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin, F. S. I., Lambin, E., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., De Wit, C. A., Hughes, T., van de Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R. W., Fabry, V. J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. & Foley, J. (2009) Planetary boundaries: Exploring the safe operating space for humanity. *Ecology and Society*, **14:2**, 32-65.

Santos, F. M. & Eisenhardt, K. M. (2005) Organizational boundaries and theories of organization. *Organization Science*, **16:5**, 491-508.

Satterthwaite, D. (1997) Sustainable cities or cities that contribute to sustainable development? *Urban Studies*, **34:10**, 1667-1691.

Schaffers, H., Komninos, N., Pallot, M., Trousse, B., Nilsson, M. & Oliveira, A. (2011) Smart cities and the future internet: Towards cooperation frameworks for open innovation. *Lecture Notes in Computer Science*, **6656**, 431-446.

Schipperijn, J., Bentsen, P., Troelsen, J., Toftager, M. & Stigsdotter, U. K. (2013) Associations between physical activity and characteristics of urban green space. *Urban Forestry & Urban Greening*, **12**, 109-116.

Stern, N. (2008) The economics of climate change. *American Economic Review: Papers & Proceedings*, **98:2**, 1-37.

Strauss, A. & Corbin, J. (1990) *Basics of qualitative research* Sage, Thousand Oaks, CA.

Suddaby, R. (2006) From the editors: What grounded theory is not. *Academy of Management Journal*, **49:4**, 633-642.

Tiwana, A. (2014) Separating signal from noise: Evaluating emerging technologies. *MIS Quarterly Executive*, **13:1**, 45-61.

Toppeta, D. (2010) The smart city vision: How innovation and ICT can build smart, "livable", sustainable cities. In: *Sustainable Cities*, , from http://www.thinkinnovation.org/file/research/23/en/Toppeta_Report_005_2010.pdf.

United Nations (2013) World economic and social survey 2013: Sustainable development challenges. Retrieved December 20, 2015

United Nations (2015) Sustainable development knowledge platform. Retrieved December 8, 2015, from https://sustainabledevelopment.un.org/sdgs

United Nations (2016a) Sustainable development goal 11. Retrieved November 23, 2016, from https://sustainabledevelopment.un.org/sdg11

United Nations (2016b) UN statistical commission agrees on global indicator framework. Retrieved May 11, 2016, from http://www.un.org/sustainabledevelopment/blog/2016/03/un-statistical-commission-endorses-global-indicator-framework/

Urquhart, C. & Fernandez, W. (2013) Using grounded theory method in information systems: The researcher as blank slate and other myths. *Journal of Information Technology*, **28**, 224-236.

Urquhart, C., Lehmann, H. & Myers, M. D. (2010) Putting the 'theory' back into grounded theory: Guidelines for grounded theory studies in information systems. *Information Systems Journal*, **20**, 357-381.

Vannoy, S. A. & Salam, A. F. (2010) Managerial interpretations of the role of information systems in competitive actions and firm performance: A grounded theory investigation. *Information Systems Research*, **21:3**, 496-515.

Vanolo, A. (2014) Smartmentality: The smart city as disciplinary strategy. *Urban Studies*, **51:5**, 883-898.

Vogt, J., Hauer, R. J. & Fischer, B. C. (2015) The costs of maintaining and not maintaining the urban forest: A review of the urban forestry and arboriculture literature. *Arboriculture & Urban Forestry*, **41:6**, 293-323.

Washburn, D., Sindhu, U., Balaouras, S., Dines, R. A., Hayes, N. M. & Nelson, L. E. (2010) Helping CIOs understand "smart city" initiatives: Defining the smart city, its drivers, and the role of the CIO. Forrester Research, Inc., Cambridge, MA.

Watson, R. T., Bourdreau, M.-C., Chen, A. J. & Sepulveda, H. H. (2011) Green projects: An information drives analysis of four cases. *Journal of Strategic Information Systems*, **20:1**, 55-62.

Watson, R. T., Corbett, J., Boudreau, M.-C. & Webster, J. (2012) An information strategy for environmental sustainability. *Communications of the ACM*, **55:7**.

Winn, M. I. & Pogutz, S. (2013) Business, ecosystems, and biodiversity: New horizons for management research. *Organization & Environment*, **26:2**, 203-229.

Zygiaris, S. (2013) Smart city modèle de référence: Aider les planificateurs de conceptualiser l'édifice de smart city écosystèmes de l'innovation. *Journal de l'économie du savoir*, **4:2**, 217-231.

Supporting Information

See Appendix for illustrative quotes related to second order themes.

Author Biographies

To be added upon acceptance.

Figure 1: Partial Q-City Organizational Chart

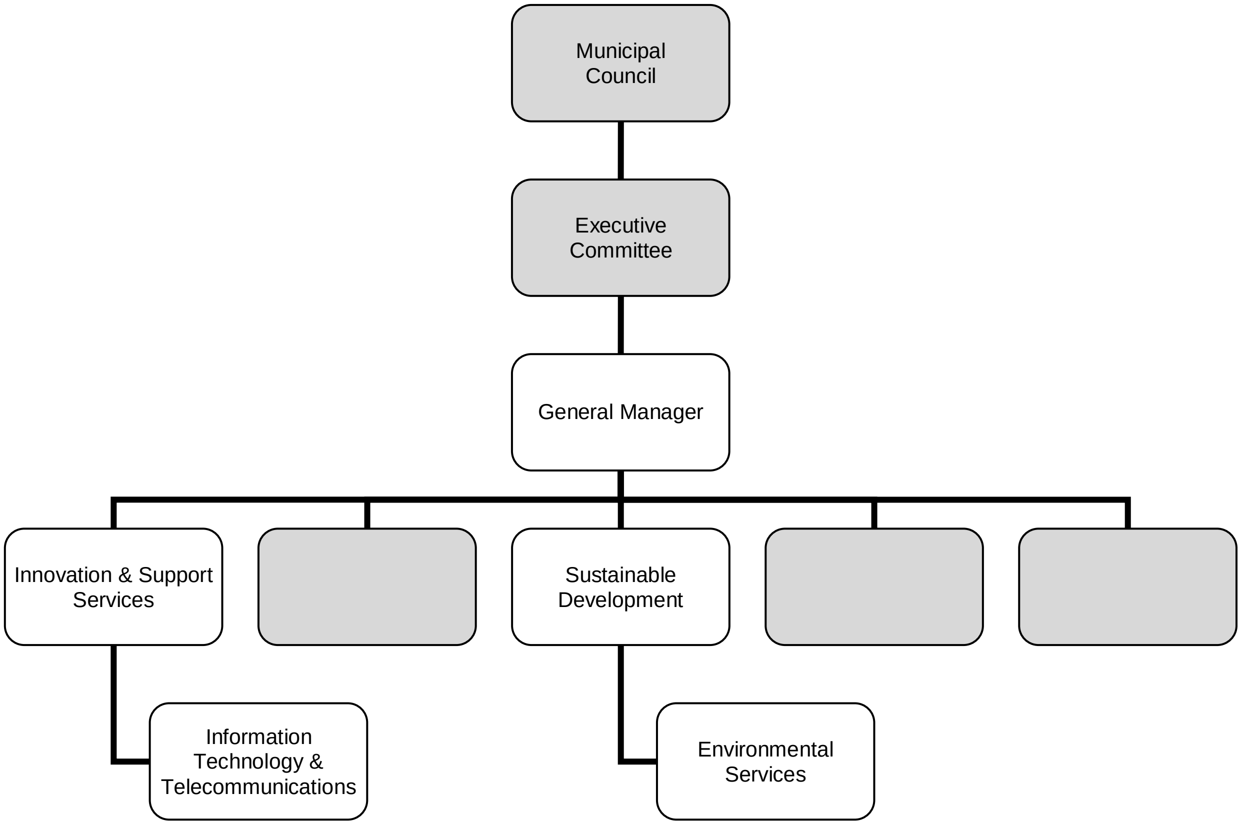
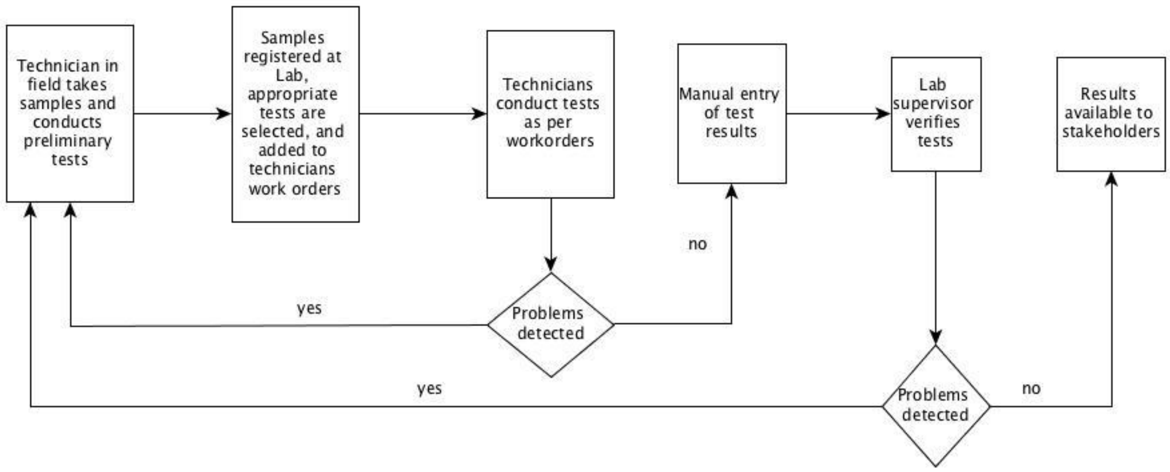
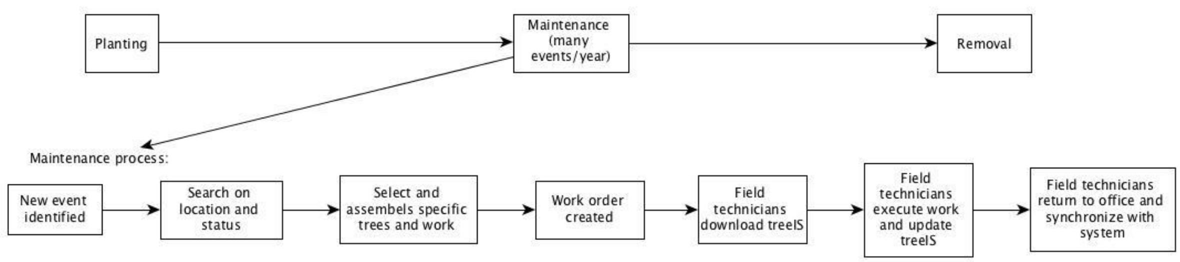


Figure 2: Water Quality Testing Workflow



The verification process begins when field technicians take samples from predetermined points. While on site, technicians verify water colour, odour, and sediment - quick indicators that could suggest an immediate problem. Samples are then taken to the laboratory and entered into LabIS. Appropriate tests are specified and these requests are transferred to the lab technicians' daily worksheets. Technicians perform tests and once the tests are completed, the results are entered manually or automatically. When problematic results are detected, the lab supervisor and field technicians are alerted so that they can initiate follow-up by Public Works. Lab supervisors verify test results, following which the data becomes available to authorized internal and external users. On a regular basis, the supervisor prepares the required reports for the Ministry of the Environment (MoE).

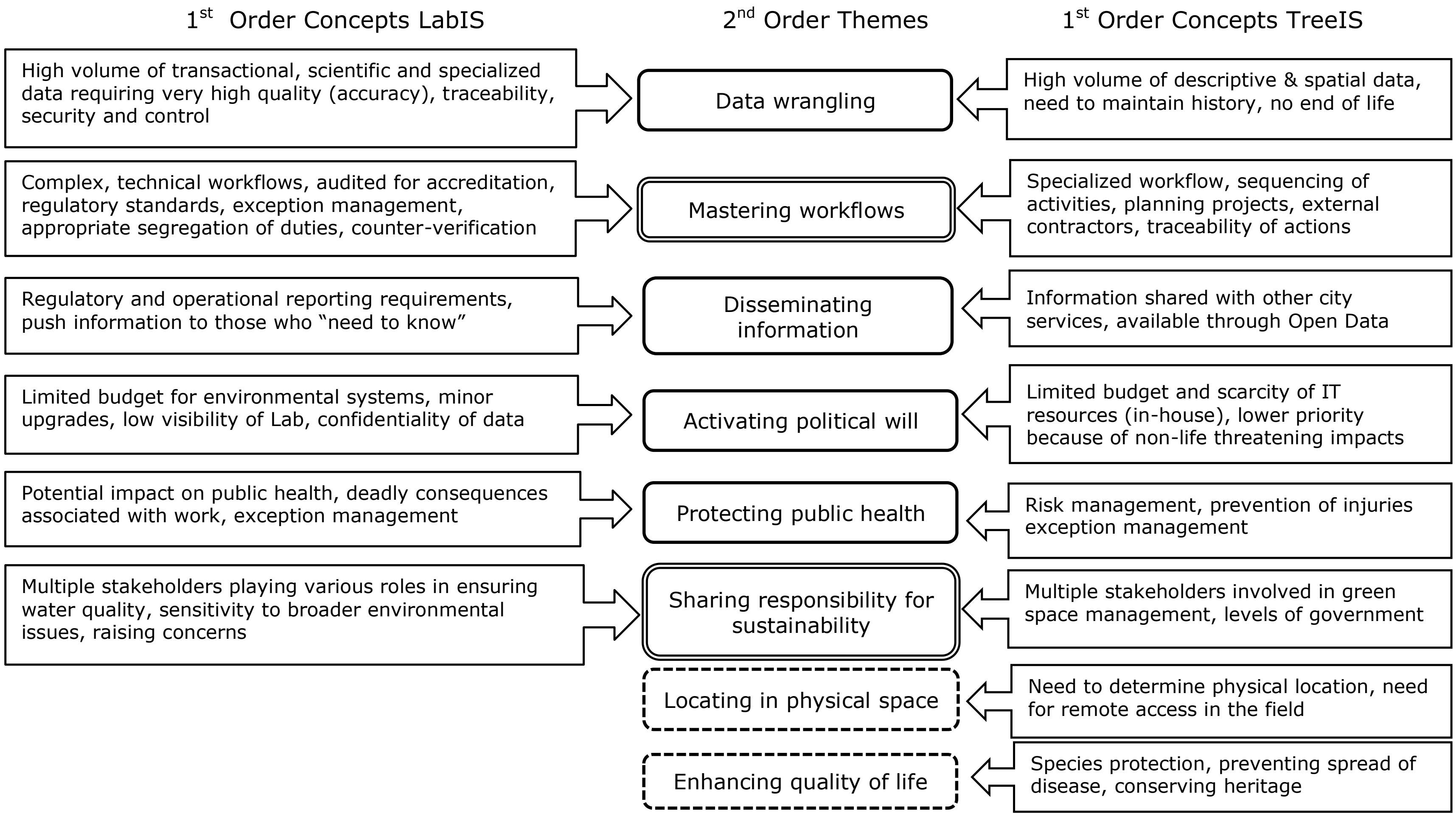
Figure 3: Green Space Management Workflow



For an individual tree, its record begins when it is planted. Throughout its life, additional maintenance events (e.g., trimmings, inspections, treatments) are added. Eventually, a tree might die or be cut down, removing it physically from a certain location and closing its record.

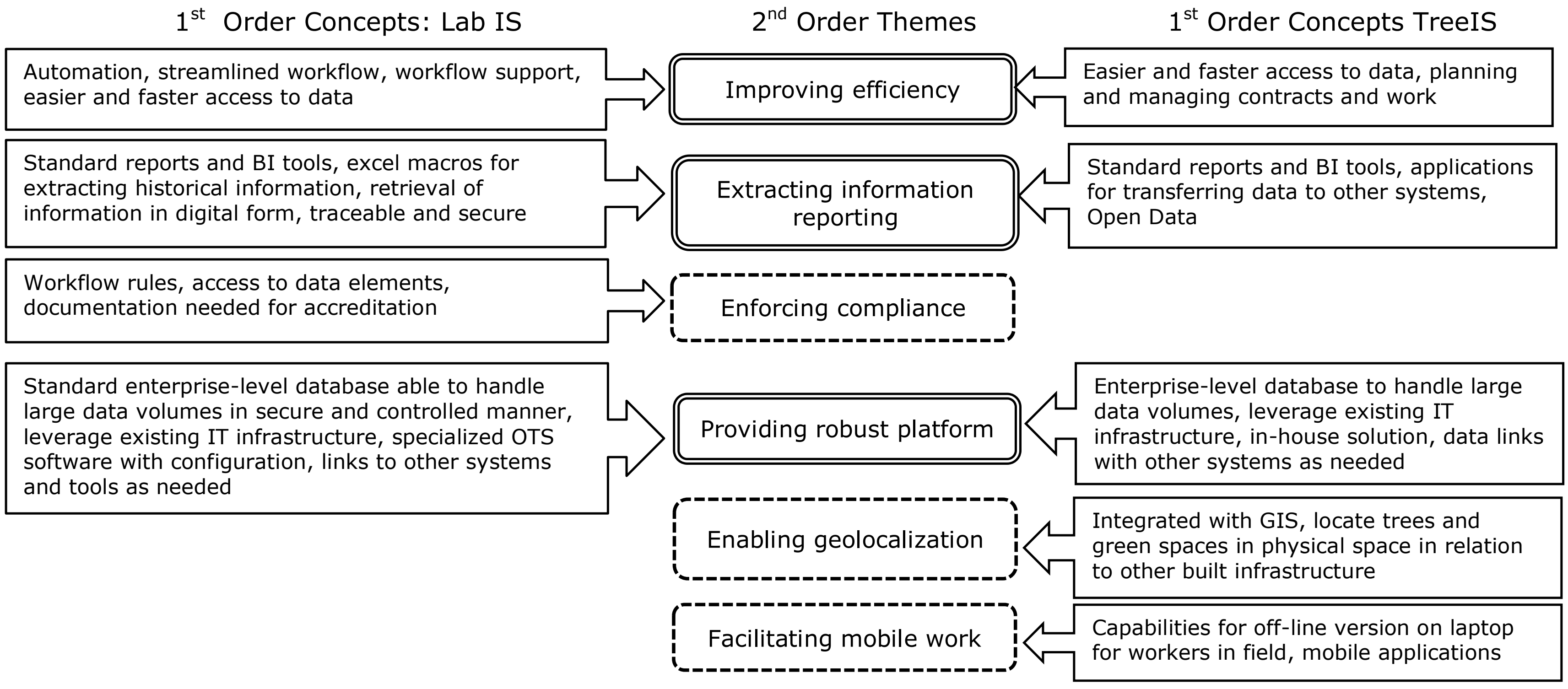
For work events, the process begins when a particular intervention is identified, whether directly by ES, or from citizen complaints or requests. ES planners identify the particular location within TreeIS using the geomatics capabilities and research the history of the location to ensure the proper conditions are met. Once the event is planned, work orders are generated from TreeIS and distributed to the field staff and external contractors. Field technicians are able to download a copy of TreeIS to portable devices where they can access and update it off-line. Changes made in the field are synchronized with the main system upon the technician's return to the office.

Figure 4: Data Structure: Challenges Facing Cities



Boxes with double lines represent concepts evident in both cases
Boxes with single lines represent concepts evident in both cases with some variations
Boxes with dotted lines represent concepts evident in only one of the cases

Figure 5: Data Structure: How Traditional IS Can Alleviate Challenges



Boxes with double lines represent concepts evident in both cases
Boxes with dotted lines represent concepts evident in only one of the cases

Figure 6: Integrating Dimensions: Three Spheres of Engagement

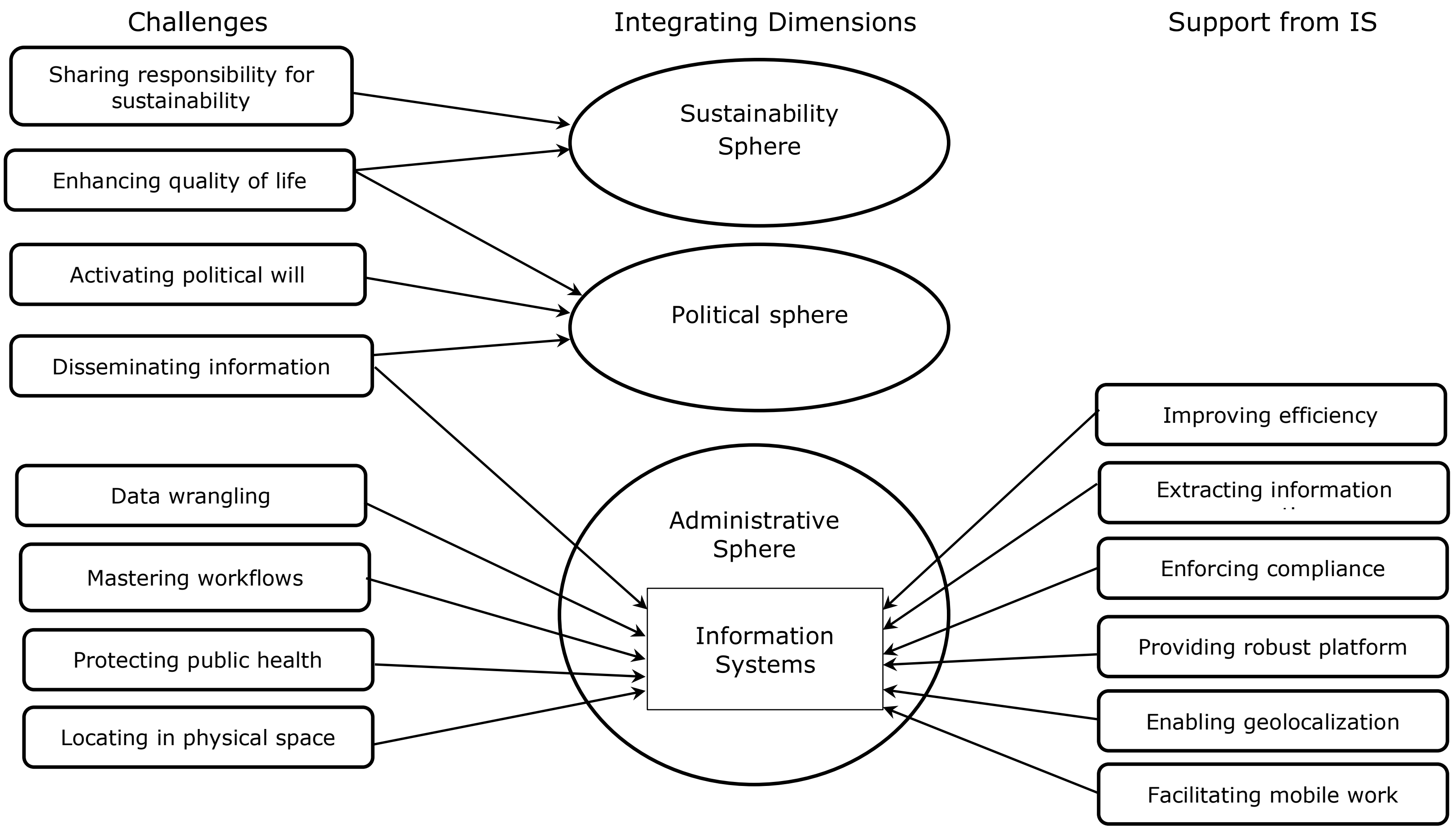


Figure 7: Model of an Integrated Information Ecosystem for Smart Sustainable Cities

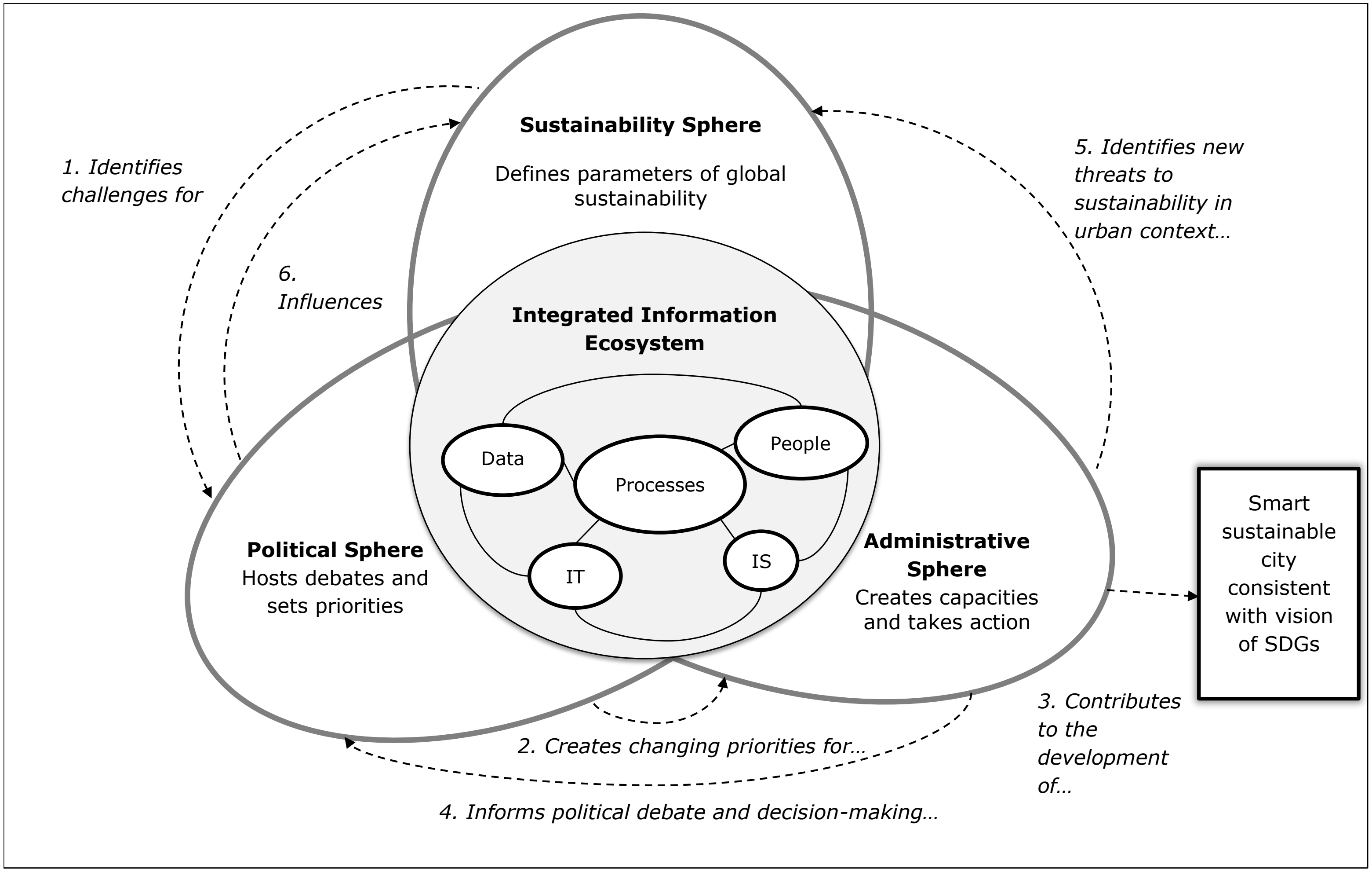


Table 1. Summary of Sustainable Development Goals[1]

#	Goal
1	End poverty in all its forms everywhere
2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
3	Ensure healthy lives and promote well-being for all at all ages
4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5	Achieve gender equality and empower all women and girls
6	**Ensure availability and sustainable management of water and sanitation for all** **6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all**
7	Ensure access to affordable, reliable, sustainable and modern energy for all
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10	Reduce inequality within and among countries
11	**Make cities and human settlements inclusive, safe, resilient and sustainable** **11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities**
12	Ensure sustainable consumption and production patterns
13	Take urgent action to combat climate change and its impacts
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
17	Strengthen the means of implementation and revitalize the global partnership for sustainable development

1 Targets examined by this research are highlighted in bold
Source:United Nations Sustainable Development Knowledge Platform
https://sustainabledevelopment.un.org/sdgs

Table 2: Information Systems Used by Environmental Services Department at Q-City

Category	Number of systems	Descriptions of tasks supported
Water management	10	Water (potable and non-potable) water quality, storm water management, sceptic system installations, river stabilization
Land management	4	Greenspace (tree) management, sports fields, contaminated properties
Hazardous products	1	Inventory of dangerous chemicals and materials located in city
Greenhouse gas emissions	1*	Inventory of greenhouse gas emissions, tracking, and management

*under development

Table 3: Demographic Profile of Interview Participants

Department	IT	ES	Total
Total number of participants	4	5	9
Management	1	1	2
Analysts and technicians	3	4	7
Male	4	2	6
Female	0	3	3
Average tenure (years)	8.75	21.40	15.78

Table 4: Framework of Implications for Practice and Questions for Research

Issue for cities	Integrated Information Ecosystem		Actions for Practice	Questions for Research
	Requirements of IIE	Types of IS required in IIE		
Sustainability Sphere				
Build and manage smart sustainable cities in line with the visions of the United Nation's SDGs for 2030	• Monitor state and manage progress toward achievement of SDGs through universally accepted indicators	In this sphere, IS focuses on end result: are we on track to achieve the SDGs? The focus is more on what the data is telling us rather on how data is collected. Hence, we suggest cities implement technologies and tools for management, visualisation and/or simulation, such as: • A "big data" IS that collects data about quality of diverse natural resources (e.g., air, land, water, biodiversity) and urban conditions • Business intelligence systems that provide for simulations, complex analytics, or augmented reality	A1: Translate global indicators to the local level. A2: Implement within the city's IS the capabilities needed to measure and assess SDG indicators.	RQ1: How can global sustainability indicators be effectively captured, monitored, and managed within an IIE? RQ2: How can new information technologies be integrated by cities within an IIE to monitor and manage sustainable development and develop new insights regarding the impacts of urban development on sustainability?
Political Sphere				
Facilitate public debate, evaluate trade-offs and make choices between different elements of sustainability (e.g., economic, environmental, social) in	• Provide mechanisms for evaluating and managing the benefits, risks and long-term contribution/impacts of competing	This sphere emphasizes technologies that can be used to engage with citizens and support political debate. Cities should consider implementing tools such as: • Communications	A3: Implement robust communication platforms that enable broad, cross-sectoral participation from all stakeholders A4: Develop policy decision-support tools that	RQ3: How can an IIE enable open and transparent political discourse among all stakeholders regarding the development and management of

local context	alternatives • Provide awareness of public opinions and citizen priorities (enable citizen engagement)	platforms to support citizen engagement, co-creation of knowledge, the analysis of qualitative data from citizens and other stakeholders using Web 2.0 technologies and social networks • Decision support systems, providing simulation capabilities, what-if analyses, taking into account varied quantitative and qualitative data.	integrate objective data with feedback from all stakeholders.	environmentally sustainable cities? RQ4: What new types of information and IS can be developed to facilitate the evaluation of heterogeneous competing sustainability priorities that address both local priorities and global challenges?
Administrative Sphere				
Build and manage physical infrastructures (e.g., water system, electricity, transportation, health, education, waste) in sustainable manner without compromising natural resources and while improving the quality of life of citizens	• Provide highly granular, real-time information to support the efficient and sustainable delivery of diverse range of city services • Provide seamless communications with internal (e.g., planning, accounting, purchasing, logistics) and external (e.g., legislative, regulatory, disaster response) systems	The IIE is an essential mechanism for collecting data from the field (in real-time or off line), using this data to achieve the sustainable development of cities. The IIE must provide an interoperable platform to integrate data and IS.	A5: Develop robust interoperable platform to support data sharing and integration across different IS.	RQ5: How do sustainable business practices in cities impact technological choices of an IIE?