A Multilevel Analysis of Public Value creation in Smart City using Action Design Science Research: A Systems Thinking Perspective

by

Stephen N. Dawe

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Approved by

Dianne Hall, Chair, Torchmark Professor Department of Systems and Technology
Kang Bok Lee, EBSCO Associate Professor Department of Systems and Technology
Ashish Gupta, Associate Professor Department of Systems and Technology
David Paradice, Professor Harbert Eminent Scholar Department of Systems and Technology

Abstract

In the last 20 years significant innovations in technology and its implementation have enabled cities to become smart cities? With this increase in cities embarking on smart city projects, there has been very little focus on smart city business processes and ensuring the knowledge generated by smart city projects in converted into learning by the city. Smart city's generally engagement in smart city projects without documenting why those projects are chosen or explaining the public value of these projects. This work reviews the design and implementation of a smart city, creating a framework for approving smart city projects, managing the implementation and lifecycle of each project, while ensuring the public value of the smart city project, is measured, recorded, reported. Action Design Research (ADR) was chosen as the vehicle for this set of works. ADR provided a view of smart city, that included people. Processes, and technology. The purpose of this research was to address the need to provide and management and governance structure for a city to become smart, by ensuring the process, was not driven by technology, but by business processes with a focus on outcome derived from the city's mission statements.

This research produced a designed multi-level ADR process, capable of capturing individual smart city project implementation knowledge, which maintain a focus on city level operations and city level knowledge generation which is focused on the operation of all city systems. By ensuring the generated feedback from each smart city project from both the project itself and from the city level. This ensured system performance and its specific data attributes are producing benefits as expected by stakeholders at the city level. The smart city system of systems framework allows city managers to choose projects based on city strategy and

stakeholder priorities while maintaining a level of transparency via the feedback mechanisms required throughout the framework.

This work reviews the design and implementation of several smart city projects and explored how the results of these projects can used produce or change the value of city metrics so that success can be defined in terms of the city’s mission statement and strategic plan. This research produced generalizable frameworks that can be used by any city to implement smart city customized to their own strategic plan and mission.

To build these frameworks, the Action Design Research paradigm was used to identify system designs and business processes that can support smart city projects and an adaptability that is required when dealing with the ever-changing nature of a city. The primary focus was to create a framework that uses these ADR designs where city managers can address city issues in a planned and coordinated way that ensures new systems, and its requirements are integrated with the current system so that the new system and current system benefit from current data and any new data generated.

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List of Abbreviations

ICT	Information and Communication Technologies
IoT	Internet of Things
CIO	Chief Information Officer
ADR	Action Design Research
DSR	Design Science Research
BIE	Building, Intervention, and Evaluation
ISO	International Standards Organization
BOLO	Be on (the) Look-Out
MIS	Management Information Systems
FTTH	Fiber to the Home
CAS	Complex Adaptable System

Introduction

There have been many efforts to describe how cities should be designed and developed to create interactive infrastructure for citizens. These allow researchers to further understand how to build cities where people want to work and live. While the term “smart city” is relatively new and references a city’s appropriation of technology as infrastructure, city planners have been looking to build “smart cities” for over 2000 years. Examples include Plato’s theoretical Utopia (Plato, Ferrari, & Griffith, 2000), development of the Renaissance hub and spoke city design, and the 1856 Industrial Age Octagon City in Kansas that was designed for vegetarians. In 1924, architect Le Corbusier presented the concept of Ville Radieuse (Radiant City), a city where telecommunication and machine cooperation would be a primary means of ordinary tasks, such as ordering groceries (Merin, 2016). As technology has progressed, and particularly today with relatively low technology cost and complex features, ubiquitous computing power and fast computer networks make it possible to provide city infrastructure that will sense and report what is happening. City designers now speak of smart cities as an evolution of the city that includes the integration of information communication technologies (ICT) to monitor city conditions in real time (Li et al., 2020).

Much work has been done in the academic and government communities to define what a smart city is and to define what is required to make a city “smart” (Chourabi et al. 2012., Gil-Garcia et al. 2015). However, there is currently little agreement in the academic community as to a singular definition of what constitutes a smart city (Albino et al. 2015). For example, Lombardi et al. (2012) define a smart city as “not limited to the role of ICT infrastructure but is mainly on the role of human capital/education, social and relational capital, and environmental issues.” (p. 137); whereas Bakici et al. (2017) define a smart city as “a high-tech intensive and advanced city that connects people, information, and city elements using new technologies in order to create a sustainable, greener city, competitive and innovative commerce, and an increased life quality” (p. 139). These two definitions focus on different areas of city improvement but place heavy emphasis on technology. Because city planners focus on different goals in different cities, each municipality goes through a process of defining and designing its smart city components anew with each new implementation.

The disjointed focus of smart city development, along with lack of a cohesive and agreed on definition, has led to such development and implementation being done in a piecemeal fashion, resulting in fragmented systems and reduced effectiveness in the ability of a smart city government to serve its citizens (Komninos & Mora, 2018). This fragmentation also led to convenient definitions and concepts that fit the particular project being undertaken. Recently, the focus of smart city research and practice has changed, viewing projects in terms of a citizen centric city, or connected community. While the emphasis is still on individual projects, the development lens is focused on the output of a project in terms of the effect the project has on citizens.

Smart city research has largely been focused on individual projects and the technology required to deliver these projects. Subsequently, the measurement of a smart city's key performance indicators has been project-focused (Lombardi, Giordano, Farouh & Yousef, 2012) (Ramaprasad, Sanchez & Syn, 2017) rather than city focused. This has resulted in a focus on technology within public sector practice and has caused cities to procure and manage technology with the technology as the primary focus rather than technology being the tool that is used in public sector modernization efforts such as building a smart city. These modernization efforts include, but are not limited to, ICT capacity, business processes, government operations, and/or workflows (Organization for Economic Co-operation and Development (OECD) - Public Governance and Territorial Development Directorate, 2014).

Cities generally rely on vendor specific solutions as academic solutions may not be translatable into a practical and sustainable solution for cities to implement and use long term (Tompson, 2017). In this dissertation, I focus on the gap between smart city project research and practitioner requirements by producing a holistic smart city framework and testing it by building a smart city strategy. Then, I implement this strategy as a case study in Opelika, AL where I am CIO and enjoy city management support from a forward-thinking board.

Focusing on individual projects may be helpful when researching and/or implementing a specific information technology; however, a smart city is more than simply a set of smart city projects. As such, neither the information systems nor the public administration fields are equipped to fully investigate smart cities and smart city development. Smart city as a research field and as a practice must look to many fields of study and expertise, including those above, but also economics, urban development, sociology, and business management. By approaching smart city via its instantiation within a smart city government, we can utilize these fields and a priori research to develop and use theory and the associated frameworks to allow us to operationalize and study a smart city instantiation systematically and holistically.

The framework of a smart city project (Dawe, Paradice & Hall, 2017) that encompasses all the systems needed in a city begins the arc of research that covers how to instantiate a complete "smart city" project, and how its benefits should be measured in terms of the city's mission and goals. However, this framework does not account for creation of public value (Moore, 1995) for each smart city project. Moore defines public value as an equivalent of shareholder value in the public sector, noting that intervention being considered is (or should be) in the best interest of the collective. A smart city should therefore define the public value of a project in terms of how a smart city program will help the city by comparing the benefits against the city's mission statement and its citizens' desires.

Smart city research has focused on individual components of a city or a sub-set of components. Little agreement on the full definition of a smart city exists and there is no theory defined for smart cities to explain or predict phenomena contained within cities. One potential reason is that theories and definitions are difficult to apply to chaotic and complex systems with constantly changing boundaries. A city is a complex composite system that is built from a very large number of subunits or elements (e.g., citizens). It is non-linear, synergistic, and dynamic. It is beyond the scope of this work to create a new definition of Smart City; rather, I will focus on the generic content of extant smart city definitions that indicate a smart city includes the use of technology to solve the problems a city may face. This simple definition supports the use of Action Design Research (ADR) (Sein et al., 2011., Mullarkey & Hevner, 2019) and Design Science Research (DSR) focusing on the creating of a single artifact that includes technology (Hevner et al., 2004, Gregor & Hevner, 2013, Peffers, et al., 2007). ADR and DSR together help solve the wicked problem (Rittel & Webber, 1973) inherent in creating a framework to design the components of a smart city.

Wickedness of a problem is not necessarily based solely on complexity, but by the recognition that such a problem may not have a definitive, true/false answer, has little definition, or whose solution may not immediately prove to be a viable solution (Rittel and Webber, 1973). The reasons that building a smart city is a wicked problem is the complexity of a city coupled and the need to specify a solution. In a wicked problem, "The information needed to understand the problem depends upon one's idea for solving it" (Rittel and Webber, 1973, p. 161). The meta–requirements of a city's information systems that are required to build a smart city must be synthesized within a system-of-systems approach (Ackoff, 1971) (Ackoff, 1999), where each system may require its own designed ADR/DSR artifact. Smart city e-government business models will require a significant ADR/DSR program that will bring together many aspects of smart city design, digital business models, economic theory, and government theory to produce an integrated, operationally optimal system that provides information and thus learning not only to each system but also to the city as a whole.

Using ADR/DSR to define and test the designed smart city artifacts (Peffers, et al. 2007, Mullarkey & Hevner, 2019), I describe a broad and robust smart city digital framework that operates in the context of the overall goals of a city. My starting position is that a city is smart if it uses information systems to achieve its goals, not that smartness is defined by incorporating any specific technology into the city's infrastructure. While many papers identify technologies that can be used to build smart cities, none to my knowledge identify the requirements and measures needed to assess the success of a smart city technology project. I contend that smart city projects that have been deemed successful simply because a technology was implemented have missed the point because there was no focus on any citywide or strategic planning goal beyond that of the technology implementation. By changing the focus of smart city development from a technology focus to a city mission focus, I provide a measurable link between smart city projects and city goals, thus providing a way to measure the public value of smart city. By meeting the city goals as set out by city leaders, I maintain that a smart city strategy, including all smart city projects implemented as part of that strategy, has public value (Moore, 1995). Management of city planning posits that much like a rational organization wherein all members of the organization will collaborate to meet the goals of the organization (Markus, 1983), all of the various departments of a smart city collaborate to achieve the city's goals. Municipal government organizations are bureaucratic in nature because they are created via the explicit legal authority of the state government (Adler and Borys, 1996) and, therefore, function according to the municipalities' own chosen form of government structure (Meyer and Rowan, 1977., Weber, 1921). Thus, in applying the rational view of an organization to cities I note the rules of states and society give the city organization legitimacy (Meyer and Rowan, 1977). Any measurable outcome should be related to the goals of the city, so citizens, city employees, and other stakeholders will support the project (Markus, 1983., Desdemoustier et al., 2019) and so that project will be perceived to have a public value worth the investment (Moore, 2013).

In this 3-paper dissertation, I explicitly describe how the ADR/DSR approach provides the means to design, implement, and evaluate a city's ICT artifacts and the city's compete system of systems (artifacts) (Ackoff, 1971) over time in a rigorous and integrated fashion. However, the requirements of a city mean that the ADR/DSR approach to artifact design must be modified to work both at the artifact level and at the systems of systems level to ensure optimization of artifact output at the integrated city level. In the first paper, I promulgate an ADR-inspired approach to a smart city framework using theory to guide the artifact design and operation within a city context. This approach allows a city can be transformed into a synthesized smart city and learning organization (Ackoff, 1999., Beckman & Barry, 2007). This allows a system of artifacts to be optimized for the achievement of the goals of the city, not necessarily for the operation of the individual artifact. Kernel theories (Kuechler and Vaishnavi, 2008) that guide the elucidation of the meta-requirements needed to build a smart city and thus generate public value (Hartley et al., 2019) are presented.

Using systems thinking (Ackoff, 1971., Gharajedaghi, 2011) as a basis, I describe cities as a set of social systems. These purposeful systems should be able to produce similar outputs in different ways in similar environments or in different environments (Gharajedaghi & Ackoff, 1984). Therefore, smart city research must examine the creation and interaction of these system artifacts (Churchman, 1968., Ackoff, 1971). Paper 2 of this dissertation examines ways a city can authorize smart city projects that subsequently require ADR/DSR artifacts for their operational implementation. Every city has different leadership, culture, and citizen expectations. It follows the development of the authorization process for the city of Opelika and the resulting framework that can be generalized for use across cities and projects. This process may be unique in every city or for any project but ensures that stakeholders are aware of the effects a smart city projects may have.

Paper 3 considers the building of city artifacts and their subsequent instantiation using the models build in papers 1 & 2, I will study the performance of the artifact individually and as part of the system of artifacts using case studies (Yin, 2014). The case study will allow for the empirical evaluation of the frameworks proposed and the public value created by the smart city.

Dirks and Keeling (2010) recognized the need for an integration of city systems. In this 3-paper dissertation, the linking of city systems occurs at two levels. The first is the city's organization level, such as the road system linking with the storm drain system. The second is at the information systems level, where the linkage between systems facilitate the sharing of information between systems (Dodgson and Gann 2011). A city's systems need to be integrated to gain the maximum benefits; they need to share a set of common knowledge and wherever possible a common technological base (Suh and Sohn 2015).

Cities can be considered open systems (Aguilera et al., 2017., Pereira et al., 2017, Ackoff, 1971) as they tend toward self-organization but never settle into a static state of behavior. This is partly because a city's environment is constantly changing. It may be impossible to identify all exogenous variables that must be accounted for in a complete model of a smart city given that it is a wicked problem, making prediction of a specific city's state is nearly impossible. Therefore, feedback must be considered when thinking about a smart city; feedback is simply taking part or all the output of an artifact and making it an input into the ADR and DSR design processes for the city system of artifacts. Positive feedback should increase the rate of change within the city system(s) and negative feedback should reverse or change the direction of change.

Engineering and management both subscribe to the view that you cannot improve what you do not measure. The ability to enhance the quality and efficiency of the operations and services of a city depends upon being able to measure the effects the ADR/DSR artifacts have both on the city government and on the community at large. The smart city strategy thus expands to include the city environment and the effects of city-policy and people on the environment; this is consistent with many smart city definitions (Gil-Garcia et al. 2015). The implementation of various information technologies allows for the measurement of many variables within a city. These measurements can then be fed into decision-based systems and be given to city managers to enhance decision making and learning (Ackoff, 1999).

This leads me to the research questions this dissertation will address: -

Paper 1: *Can a generic smart city systems framework ensure knowledge creation and learning take place within a smart city?*

Paper 2: *Does a theory bound authorization process for smart city/smart city projects help ensure predicable outcomes and transparency?*

Paper 3*: Does utilizing a Multilevel ADR framework enable a systems-based view of a smart city implementation?*

Together these 3 papers also consider the following research question: -

What should a smart city do?

Current research has focused primarily on, of what a smart city is made. Instead, I ask the question, what should a smart city do, therefore putting the emphasis on the actions of the city, including its goals, strategic planning, and management processes.

In this dissertation, I focus on cities containing fewer than 100,000 citizens. In 2019 in the United States, there were 79,757 such counties and cities. (US Census Bureau, 2021), which makes this work immediately relevant on a wide scale. The frameworks developed in this dissertation consider the limited budgets and limited technical resources available to smaller cities. This dissertation supports researchers by producing a framework by which to view smart city research, but it is also relevant to practitioners. City managers are presented with a framework from which to start building a smart city while ensuring stakeholders are involved and that learning, and knowledge generation takes place within the smart city. Designing for feedback will offer information from which to develop system improvements and increase the public value of the smart city process.

A Multilevel Theory Based Action Design/Design Science Research Approach to Creating Public Value in a Smart City.

The development of smart cities has largely been done on a project-by-project basis. Little attention has been paid to developing a complete smart city strategy, with a set of strategic outcomes, implementation goals, and project objectives. This is partly because of the lack of theory being applied to the concept of a smart city. Further, a clear definition of what smart city means has been lacking and without such a definition, statement of concrete goals to attain smart city status is difficult.

Smart city researchers have defined many ways of becoming a smart city (Albino et al., 2015). Becoming a smart city is a journey (Angelidou, 2015); it is never ending as new software and hardware make new systems possible. Many researchers have put forward methods of measuring smartness (Lombardi et al., 2012) or provided a technology that solves a specific problem with a city and that, by extension, makes that city smart. To my knowledge, no research has set out to define a framework that can be used by any city to move toward non-project specific smartness – however it may be defined by its managers and citizens. Herein, I develop such a framework using theory-based action design and design science which may be used by any city when developing projects or ecosystems to support its smartness goal. Specifically, I use systems thinking (Simon, 1996) (Gharajedaghi, 2011) and suggest that a theory-based framework can be built that focuses smart city service outcomes on the citizen (Lee & Lee, 2014) while ensuring city resources are deployed to maximize their value to the city (Pfeffer & Salancik, 2003). Utilizing the triple helix model allows for industry best practices to be followed while providing a framework that allows the city to learn from its smart city system implementations.

The triple-Helix model (Etzkowitz and Leydesdorff, 2000) of University – Government – Industry has been promulgated as a rigorous method of increasing innovation or smartness in knowledge-based societies. However, it too falls into the trap of measuring the smartness of individual projects rather than taking a holistic systems approach to a smart city. The encouraged partnerships within the triple helix combine to provide the operational capacity (Geuijen et al., 2017., Moore, 1995) required for public value to be created. It is through ensuring that rigorous knowledge is created and stored (Hevner et al., 2004) and that organizational artifacts (Sein et al., 2011) are designed within an organization's capacity to manage and govern them that will dictate the public value that can be created from becoming a smart city.

Theoretical Foundations

In this section I review the literature on which I base my research. I explain the theoretical backdrop that provides the foundation for Action Design Research/Design Science artifacts and the use of the system of systems concept to create a smart city framework that is sustainable and provides for the creation of public value. I then review the literature used to provide the processes followed in the building, use, evaluation, and induction of knowledge both before and after instantiating artifacts in a city environment.

Smart City as a Value Proposition

Smart city lacks a common definition (Albino et al., 2015) leading to a project-by-project approach to smart city implementation based on an identified need or identified problem that requires an ICT based solution (Gregor and Jones., 2007., Hevner et al., 2004). Much work has been done concerning smart cities; however, there is a significant gap in the research related to smart city design as a holistic endeavor. To my knowledge, holistic smart city design has not been addressed in the extant research. There is a lack of agreement on common definitions, ontology, and epistemology of the smart city concept (Ramaprasad et al., 2017), and while there are defined measures for a smart city (e.g., ISO, 2018., ISO, 2019), no practical methodologies for implementation and the use of these measures exists. It is of little surprise that smart city research and implementations are approached in an ad hoc fashion. There is also little agreement on how to define outcomes for a smart city (Baccarne et al. 2014). I propose that, given the nature of a city's responsibility to its citizens, it can be argued that outcomes must come from the organization (city) itself, through its mission statement and defined strategic plans (Senge, 2006). Becoming a smart city is a journey; and therefore, a smart city maybe thought of as an ideal seeking system (Ackoff & Emery, 2005). Thus, being a smart city must be part of the mission and strategic planning of the city as whole (Moore, 1995. & Janowski, 2015). This begets the application of Moore's Framework for generating public value to the creation of a smart city. Moore's framework for public value is a starting point and a guide for the creation of a sustainable smart city that meets the objectives of the city stakeholders. Designing both the policies necessary for governance of a smart city and the technology systems required to support those policies requires a design process that allows for the creation of organizational policies and a set of integrated technology artifacts that can share both design knowledge and operational knowledge (Churchman, 1979., Hevner et al., 2004., Senge, 2006., Ostrowski et al., 2014) within the city at the single system level and at the city level. This multilevel view of smart city creation, organizational learning, and system governance is the overarching guideline of the framework that follows.

Hirschheim (2019) argues that the goal of creating a theory for designing a smart city could be secondary to understanding how a smart city can be instantiated; this requires empirical contributions that validate generic design kernel theories (Hevner et al. 2004) used to build the ADR artifacts and policies required of a smart city. It is these theories that allow us to partially predict how a designed artifact will behave within a smart city system (Ackoff, 1973., & Silver et al., 1995). The analysis of multiple artifacts requires a systematic approach to the designed set of systems. A System of Systems (Ackoff, 1971., Ackoff, 1972., Gharajedaghi, 2011) or systems thinking approach to smart city design is therefore required to ensure each system and ICT artifact is designed with integration into the whole smart city as a central design goal.

Systems Thinking

Cities are in a constant state of change. Even when a city may seem to be in a stable state, many government services exist to control change. Zoning laws and permitting processes, for example, are systems that exist to control and measure change within the physical systems of a city (Jensen & Meckling, 1976., Hill & Jones, 1992). The world/national economy also affects the city, through jobs availability and the opening and closing of businesses within the city. These are examples of exogenous variables that affect social systems within a city. Other effects on the system include elections that may bring in new city leadership, thus changing the political stakeholders, and perhaps the goals of current city systems.

Instability may be predictable (e.g., turnover of city officials following an election), or not. Systems can be used to reduce random, unpredictable events by providing new data and finer measurements of current data to help seek out the relationships between phenomena within a city. Each smart city project helps determine the hidden order to natural phenomena, thus every city develops in its own unique way based on the goals of its stakeholders, the decisions of its managers, or in response to the outputs of smart city systems that enable stakeholders to meet the defined goals of the city (Davis et al., 1997). This variation from initial conditions supports the use of systems thinking as we attempt to design smart city systems through ADR artifacts and through DSR to measure the system at the city level, while taking into account predicable and unpredictable behaviors of all the individual parts of a city and the interactions of those parts. While ADR/DSR provides us with a methodology for designing the requirements of individual IT artifacts and organizational policies, smart cities are a system of systems, with each system having socio-technical components and each technical component being a system that may have one or more IT artifacts and/or organizational policies. Analysis of a smart city requires focus on the emergent properties of the whole system of systems as well as focus on the functioning and emergent properties of each system (Simon, 1996., Gharajedaghi, 2011). A city is a complex dynamic system, defined as a system of systems that change unpredictably over time (Ackoff, 1971., Simon,1996., Lyytinen & Grover, 2017). Systems thinking allows designers to create a structure, set of functions, and processes/policies for a system in each environment (Gharajedaghi, 2011). Complexity in systems thinking can have two meanings. First, there is the complexity of the system being used to generate information from which to make decisions (Lyytinen & Grover, 2017) such that we do not fully understand how the system works (Ackoff, 1967). Second, a city is made up of thousands of individuals and private organizations, therefore the systems being designed are unable to reach a stable state as each system user reacts differently to the system and those users are in frequent flux, requiring the city level system to constantly interact with changing stimulus (Freeman, 1984) (Flak & Rose, 2005). Such complexity requires that a smart city be considered a complex system of systems where technology is used to measure the state of the system of systems at any given time so that city managers can make evidence-based (empirical) decisions.

Public Value

In Mark Moore’s seminal book *Creating Public Value: Strategic Management in Government* (Moore 1995) he creates a conceptual framework for public sector managers that allows them to make sense of the choices and challenges they face in providing services to citizens. Moore’s framework encourages an entrepreneurial approach to strategic choices, enabling managers to seize the opportunities created by new technology availability (OECD, 2016). Utilizing Moore’s

(1995) strategic triangle for the creation of public value enables me to provide focus within the multilevel systems view and governance process framework (Figure 1) for smart city projects that considers which kernel theories should be used to build a smart city. This allows me to produce a set of ADR artifacts for a smart city that considers smart city project support, and that the operational capabilities to both deliver the service and provide governance services to ensure regulatory compliance and management goals are met. This provides the detail and guidelines for smart city government operations, while ensuring the public value proposition of smart city is created and delivered.

Theory in Smart City Creation

The theories upon which to base the multilevel systems and governance view of a smart city provide either an explanatory basis for system operation or explain a causal relationship thus helping predict the possible benefits of the implementation of a smart city project. Each theory chosen for this work and discussed below adds a specific element to the design of the smart city framework allowing for a management of people, processes, or ICT based systems, to produce public value in terms of the smart city goals.

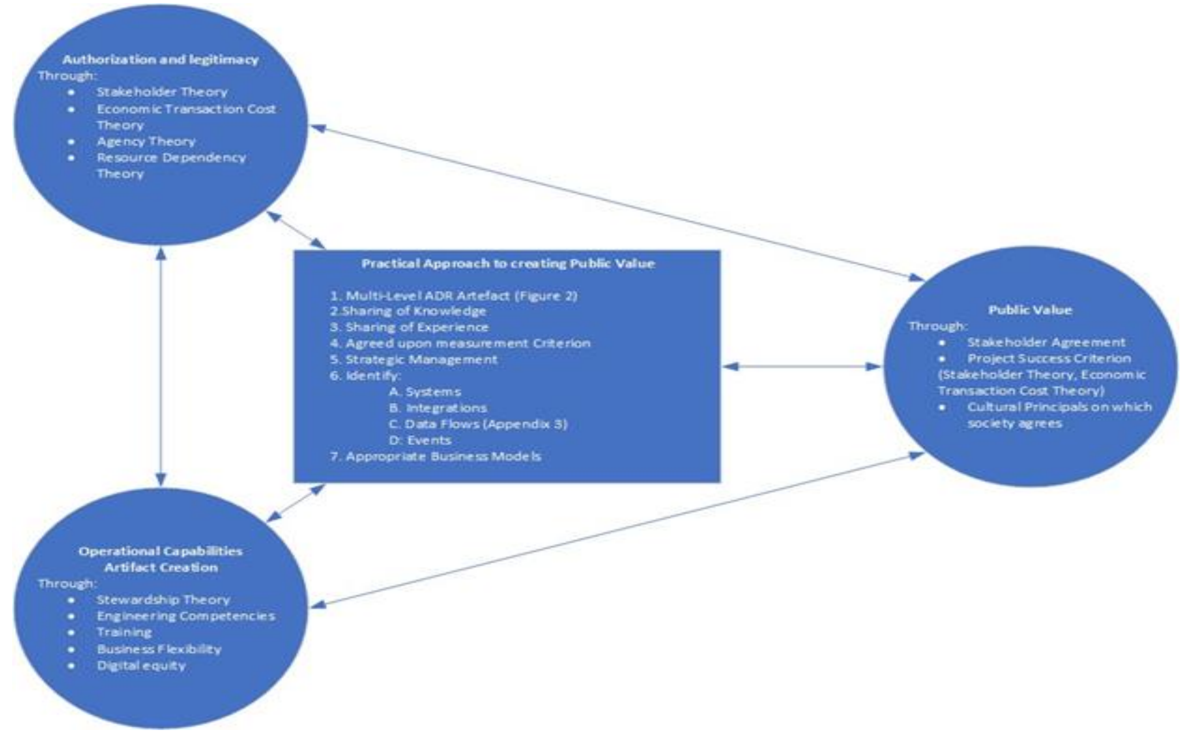

Figure 1. Public Value and its relationship to smart city theory

Agency Theory

Agency Theory in the context of a smart city explains the relationship between the project owner, the smart city project owner, the individual project owner, and the operational project manager (Jensen & Meckling, 1976). Agency theory governs the control of project owners over the operational project managers levels of authority and decision making based on project owners' risk attitude through controlling mechanisms such as contracts. Within the smart city design framework, Agency Theory offers a model for management control of the smart city projects undertaken. This can be seen through the project management process contained within Figure 2.

Economic Transaction Cost Theory

Some argue that the central tenets of American democracy - separation of powers, periodic elections, and majority rule - work against efficiency in the public sector (Williamson, 1999). Lack of efficiency often results in increasing costs whereas efficiency is associated with reducing costs. To counter this, the economic theory of transaction costs (ETC) takes the view that a transaction (in the case of government, the use of a service) should be completed with the minimum cost possible (David & Han, 2004). Smart city government can be a method for reducing the cost of delivering a governmental service (Neubert, Dominguez & Ageron, 2011). Government is generally perceived as inefficient; the transaction cost economics view of smart city government provides a lens through which the stakeholder experience must be maintained, and the cost-of-service transactions needs to be reduced.

Stakeholder Theory

Stakeholder theory provides the counterbalance to ETC. At the extreme, the objective of ETC is to reduce the transaction cost to zero, but at some point, the experience of smart city government customers/stakeholders would suffer (Flak & Rose, 2005). Stakeholder Theory implies a contract between the city government and the stakeholders as to the services they receive from the government. Therefore, a strong set of stakeholders can cause the government to implement policy and create artifacts that increase the cost of information systems transactions (Rowley, 2011). It must also be recognized that new service delivery in the private sector can also cause stakeholders to demand similar smart city services, or additional service features, from their city government (Musa, 2018). A smart city must identify stakeholders, so they can be included in the design process for individual smart city artifact creation.

Stewardship Theory

Stewardship theory considers project managers as stewards of the systems to be created and operated, and that through their actions the project manager's position improves by improving organizational performance or adding to the public value of the smart city. Thus, stewardship theory argues that project managers' decision making is not constrained by their personal short-term needs. Rather, it is a trust in the project owners and the organizational objectives, or city mission and strategic plan that governs project managers' behavior (Davis et al., 1997). Project based organizations will be more successful in satisfying stakeholders if they empower their project managers (Biesenthal & Wilden, 2014; Joslin and Müller, 2016) to make project-based decisions without seeking approval from project owners. Stewardship theory is focused on project managers and their effect on governance.

Resource Dependency Theory

Decisions concerning the allocation and prioritization of the external and internal resources of the smart city are the focus of resource dependence theory. In resource dependency theory, the success of the smart city is dependent on the city's ability to manage and marshal its resources (Pfeffer and Salancik, 1978). This theory explains how a city meets its strategic objectives through the appropriate allocation of resources via long-term and short-term targets. The application of this theory in the smart city context would be through monitoring decision making in allocation of resources across different smart city projects. Therefore, this theory relates to those stakeholders discussed above.

Table 1. provides a summary of how each theory contributes to the creation of the smart city framework shown in figure 2 and to the project authorization framework shown in figure 7.

Table 1: Summary of Theory used to create Smart city ADR framework

Theory	**Theory Summary**	**How use to generate smart city frameworks**
Agency Theory	Explains relationships between project owners, and operational project managers	Explains relationships between project owners, and operational project managers.
Economic Transaction Cost Theory	Provides for system efficiency	Defines Public Value in terms of unit cost and unit cost reductions
Stakeholder Theory	Allow for city to respond to demands from stakeholders regardless of cost	Defines effectiveness of smart city via the services it offers and systems it maintains.
Stewardship Theory	Defines the actions of city managers and system designers	Allow framework to define managers actions as in the best interest of the city.
Resource Dependency Theory	The success of the smart city is dependent on the city's ability to manage and marshal its resources	Through authorization and measurement, the decisions to adopt new services, maintain current services, replace current services or to end the life of a service based on data from external sources and from within the system of systems.

DSR Review

In DSR, an artifact is defined as an IT system that solves a specific problem (Hevner, et al. 2004). There are two types of knowledge produced by this DSR endeavor. Ω, or descriptive knowledge, focuses on the theoretical knowledge required to predict the effects of the IT artifact in question and inform the design process. Λ, or prescriptive knowledge is generated to inform the instantiation process of each artifact leading to a design theory (Gregor & Hevner, 2013). To my knowledge, there are few DSR research articles that examine DSR within a government context. When Λ knowledge is lacking, DSR is a creative process that operates arbitrarily until a body of Λ knowledge is developed and enough instantiations of artifacts have been created that agreement can be reached on appropriate **Ω** knowledge for each artifact (Hevner et al., 2004).

A city is a complex system of systems (Dodgson & Gann, 2011) with each system containing an IT artifact, people, integrations with other systems, and a set of outputs, and a purpose (Ackoff, 1971) (Ackoff, 1967) (Lyytinen & Grover, 2017). As with DSR, feedback is required (Peffers, et al., 2007) to make each system and the IT artifact adaptable and responsive to its environment and to changes in output requirements for the system (Simon,1996) (Ackoff, 1971) (Marshall & McKay, 2005).

DSR in the smart city context must therefore be applied with multiple levels of design processes for (1) each individual IT artifact and the system in which it will operate, (2) the system of systems design and the system integrations required and (3) the environment in which these systems will operate. This whole system view of artifacts, systems, and system of systems, (Senge, 2006) (Gregor and Hevner, 2013) will require a less deterministic approach to DSR and a multilevel, dynamic perspective of the DSR process and the underlying creative design process.

Action Design Research Review

Wicked problems (Hevner et al., 2004) are problems that are hard to solve or are of sufficient scale that a single theory or framework is inadequate as the basis of a solution. In his book *Against Method*, Feyerabend (1975) argues that a fixed simplistic methodology that agrees with current theory does not provide for the scale of the systems required within a city. Additionally, Hirschheim (2019) adds that theory must be developed to address the “new problems” of practitioners. ADR (Sein et al., 2011) answers this conundrum by providing a design methodology that allows for the creation of novel ICT artifacts that are organizationally focused (Hevner et al., 2004, Iivari, 2005) yet provides additional context for the artifact that includes stakeholders, organizational goals, and organizational policy. Smart city requires that a municipal government strategically embark on a program of technology implementation that is both driven by organizational policy and which the results inform organizational policy and decision-making.

ADR as a method has two goals, (1) to provide a design solution to a wicked problem where context and technology requirement are inseparable, and (2) to provide a solution within an organizational context that is unique to that organization rather than a technological solution to a general class of problems (DSR).

ADR provides for collaboration as required by the triple-helix model (Etzkowitz and Leydesdorff, 2000) to instantiate a design, and then generalize the knowledge generated, to inform theory for the building of a smart city. Smart city must be researched in the field, requiring the implementation of smart city systems and smart city policy with a rigorous design process that requires that both researchers and stakeholders understand the objectives of each group. Researchers must capture the knowledge generated during the design process and during the operational life cycle of the designed artifact, while working with practitioners who in turn must deliver functionality and value from the artifact. ADR requires a theory-based design approach that offers a perspective through which to view the design and operation of the artifact. This grounded approach provides the researcher and practitioner with a heuristic approach to the artifact through which success and goal achievement can be measured.

ADR as proposed by Sein et al. (2011) merges DSR with action research to study DSR artifacts and their design through designing, building, and evaluating an ensemble artifact within an organization to address a problem. ADR is broken up into seven (7) principles across four (4) stages.

Stage 1 - Problem Formulation: Principle 1: Practice-Inspired Research

Stage 1 - Problem Formulation: Principle 2: Theory-Ingrained Artifact

Stage 2 – Building, Intervention, and Evaluation: Principle 3: Reciprocal Shaping

Stage 2 – Building, Intervention, and Evaluation: Principle 4: Mutually Influential Roles

Stage 2 – Building, Intervention, and Evaluation: Principle 5: Authentic and Concurrent Evaluation

Stage 3 – Reflection and Learning: Principle 6: Guided Emergence

Stage 4 – Formalization of Learning: Principle 7: Generalizing Outcomes

The first 3 stages are defined in an iterative cycle. In stage 1, we must first organize the problem-solving team that is made up of practitioners and researchers that can not only both help solve the problem at hand, but also generate generalizable knowledge based on the class of problem. Sein et al. (2011) used Gregor (2006) for their criterion of theories that can be used within the ADR artifact during Stage 1 with the focus on Type IV (explanation and prediction theories) and Type V (Design and formulation theories). At Stage 2, ADR offers two (2) focuses, either IT-Dominant or Organization-Dominant, defined as a continuum between the focuses rather than a simple choice between the focuses. Smart city as argued by Albino et al., (2015), is applied to both physical systems where technology artifacts can play a significant role in system operation and social systems where technology plays a supporting role to the system. This places smart city directly in the middle of the Building, Intervention, and Evaluation (BIE) continuum, therefore the DSR technology artifact works within the IT-Dominant BIE paradigm, whereas the organizational and policies aspect of smart city works within the Organization-Dominant BIE. Principles 3, 4, and 5 form the BIE process that the entire ADR team works on to build the DSR artifact (Gregor & Hevner, 2013) that evaluates the design knowledge through the DSR iterative process, of building constructs, models, methods, and instantiations of the DSR technology Artifact. The DSR artifact is then evaluated through the BIE process on its performance within the organization itself, relative to organizational policy, procedures and decision making.

Once the organization accepts the artifact and the BIE process cycle is stopped, stage 3 or principle 6 starts. The process consists of taking the design and learning from stage 2 and creating a meta-design to generalize the knowledge gained during the problem design and BIE stages for a class of field problems. Stage 4 then results in a generalized problem and solution.

The Concept of a Smart City

Researchers tend to define a smart city with respect to the research they are conducting. Instead, I believe that the cities themselves should be allowed to define what smart city means to them; I focus on what a smart city is with respect to its government. This allows me to define and build a smart city model framework using ADR and DSR as the design process for the smart city systems and systems thinking to enable a holistic multilevel system of systems design to build a smart city. Governmental systems design with reference to smart city literature is relatively scarce as most research has focused solely on smart city initiatives and/or smartness in government. Gil-Garcia, Zhang, and Puron-Cid (2016) identified fourteen dimensions of smartness within city government. These dimensions include innovation, evidence-based decision making, citizen-centricity, sustainability, integration, equality, citizen engagement, openness, resiliency, creativity, effectiveness, efficiency, technology skills and entrepreneurialism. Table 10. in Appendix 2 shows a summary of the definitions for each of these fourteen dimensions. A gap appears in the research at this point as Gil-Garcia et al. (2016) did not extend these fourteen dimensions into a framework that practitioners could use for designing and implementing a smart city.

The provision of the required dimensions of smart city government (See Appendix 2) gives us the design guide on which to base the systems, DSR IT artifacts, and system integrations that are required to build a smart city government. To fill the gap in the research, a process of designing a set of artifacts (Hevner et al. 2004) (Peffers et al. 2007) (Sein et al., 2011) (Gregor & Hevner, 2013) capable of producing the necessary system integrations and outputs to build the system of systems that is a smart city must be undertaken. ADR and DSR provides the guidelines and the tools necessary to build the generic artifacts necessary for the transition to a smart city government (Gregor & Jones, 2007) (Kuechler & Vaishnavi, 2008). The use of information theory (Wiener, 1954) allows us to measure the effectiveness of system integrations in three dimensions. (1) The technical dimension: Is information transferred between systems accurately? (2) The semantic dimension: Is the meaning of the data transferred precisely and interpreted correctly by the receiving system? (3) The effectiveness dimension: How does the data affect the behavior of the receiving system, or its output as synthesized by a system user? Managing the transformation process to smart city government by utilizing a systematic design process ensures the system outputs are citizen-centric and provide public value (OECD 2014).

Epistemological Approach

The ADR/DSR constructivist epistemological approach is one that often utilizes a subjective ontology where each individual stakeholder gives meaning to the variables of smart city (Estevez & Janowski, 2013). Taking the constructivist approach allows researchers to view the individual stakeholder of a city government as being interested in how interaction with a smart city government can help with his or her individual real-world problems, rather than the stakeholder being interested in the statistical significance of a relationship between variables within a specific theoretical model (Heeks & Bailur, 2007). This approach ensures that during the artifact design process, the user-experience and specific government processes that solve the identified citizen/business problems are the focus of the design process (Janowski, 2015). By taking this constructivist approach, my research goal is to create a shared understanding of the phenomena that affects a smart city and the design of a smart city government (Peirce, 1960).

Taking a constructivist approach to the ADR/DSR, I use a process of learning by building (Popper, 2002) while following a structured design process, DSR (Hevner et al. 2004) (Gregor and Hevner, 2013), to design and implement an artifact and the system of systems. Design by its nature is a creative process making the instantiation of the artifact the assertion (Popper, 2002) and the evaluation of the artifact becomes what Popper (2002) refers to as a test. In this iterative process of artifact design and build (Hevner, 2004) (Sein et al., 2011), artifact evaluation requires reflection upon both the design process and the suitability of the artifact in solving the smart city problem, while also generating knowledge that can be used and further refined in subsequent iterations of the artifact design process and build process (Schon, 1983) (Nunamaker et al. 2013). The ADR/DSR process can be used to design a generalized smart city government with a set of artifacts that are configured as a system of systems (Ackoff 1971) and guide the practical implementation of each artifact within each smart city system and the implementation of smart city.

Smart Cities and Design Science Research

There is currently no unified theory of smart city design; however, we do have several models and theories that can explain some of the social behavior and some of the development of technologies within a municipal government context. These theories will guide the design of our smart city government ADR/DSR program. Most of the smart city research done to date either focuses on an individual smart city project and the required technology or focuses on the processes required to become a smart city but does not define a set of methods or a set smart city process (Andersen & Henriksen, 2006) (Siau & Long, 2004). City governments have begun many ICT based projects to enable better services at less cost, although these objectives may be at odds with one another. The economic theory of transaction cost (ETC) provides the lens that the ADR/DSR process can use to design artifacts that reduce the cost of doing business for the smart city government (David & Han, 2004). ETC provides guidance to the ADR/DSR program in terms of reducing the cost of government. This theory was chosen as it fits the general public expectation that government budgets decrease or stay the same while the government is expected to provide at least the same services as before (McFarland & Pagano, 2019).

Stakeholder theory governs the relationship between the smart city government and its customers, allowing for the definition of minimum levels of service and functions, regardless of cost. Stakeholder theory provides guidance to the ADR/DSR program that puts the customer or citizen first and allows the design of ADR/DSR artifacts that does not consider cost as the most important factor for service delivery. Stakeholder theory allows for artifacts to be designed based on a perceived public need by any stakeholder or group of stakeholders.

Structuration theory (Giddens 1984) frameworks offer a method of predicting the organizational learning process that describes how the organization adapts and changes when smart city processes and ICT are introduced (DeSanctis & Poole, 1994). Structuration theory will be used to define the effects the introduction of smart city processes will have upon the government at the organization level aiding evaluation principle in the Stage 2 ADR process of BIE. Using generated knowledge fits with our choice of ADR/DSR as our design process. ADR/DSR requires the generation of knowledge as part of the artifact design and use process. ADR/DSR also requires the feedback of this knowledge into the use of the artifact and the design process of the next iteration of the artifact. Being able to predict these effects will help guide the artifact construction and implementation process by providing focus on ICT systems, data flows, and workflows and their effects on citizen behavior, employee behavior, and decision making within the smart city (Akgün, Byrne, & Keskin, 2007)

In both the ADR guidelines (Sein et al, 2011) and DSR guidelines (Hevner et al. 2004) (Peffers et al. 2007) (Gregor & Hevner, 2013) published thus far, no mention occurs of government at any level, the information systems of government, or smart city. However, this does not mean that these guides to the process of ADR/DSR cannot be used in the context of smart city. Hevner et al. (2004) articulates the DSR process as an iterative process of design and evaluation. The DSR process is initiated by recognizing a business need or a problem that needs addressing (Peffers et al. 2007, Gregor & Hevner, 2013).

Hevner et al. (2004) describe seven guidelines to follow during the design of the artifact. Notably, theoretical rigor must be part of both the artifact construction process and the artifact evaluation process. Hevner et al. (2004) places emphasis on the applicability and generalizability of the artifact above the formal mathematical proofs in the artifact construction process. Many researchers agree that theory must inform the construction process (Kuechler & Vaishnavi, 2008) (Walls et al. 1992) (Goldkuhl, 2016). Theories are used in the construction process to predict that the artifact's outputs will solve the problem that created the business need. For this to happen, the artifact must have the properties or use the methods prescribed by the theory (Walls et al. 1992).

After an artifact has been designed and instantiated, the evaluation process can take place (Hevner et al. 2004, Peffers et al. 2007, Gregor and Hevner, 2013). ADR modifies approach by adding that evaluation must also take place during the build process (Sein et al, 2011). The design and use of the artifact should provide new knowledge. This is defined as either **Ω** knowledge or Λ knowledge. **Ω** knowledge is descriptive knowledge about phenomena with which the artifact interacts, through either direct observation, classification, or measurement. Λ knowledge, or prescriptive knowledge, is knowledge that comes from the design and instantiation of the artifact (Sein et al, 2011, Gregor and Hevner, 2013). Descriptive (Λ) knowledge is also formed by the artifact through a sense-making process that includes the explanation of natural law, empirical regularities, behavioral patterns, or the generation of new theories and hypotheses (Gregor & Hevner, 2013). Prescriptive (**Ω**) knowledge includes artifact characteristics, the design process, artifact behavior, ontological relationships between constructs within the system or its environment, and rules for determining outcomes, given a defined set of inputs. Theory development in ADR/DSR should be able to inform the design process and be able to make predictions about the results of artifact implementation (Nunamaker et al. 2013) (Peffers et al. 2007). The creation of knowledge in the ADR/DSR process, whether through the artifact construction process or via the evaluation of an instantiation of the artifact, must be fed back into the theory and construction process to improve the performance of the current instantiated artifact or to better guide the implementation next time the artifact is instantiated (Hevner et al. 2004). This will require cities to share their design and instantiation experiences with each other.

Building a smart city government will require a significant ADR/DSR program that will bring together many aspects of smart city, digital business models, strategy, economic theory, and government theory (Katsonis & Botros, 2015). In addition, given the complexity of a smart city system, a single ADR/DSR project will not be able to describe fully the systems and context of a smart city government. Simplifications and assumptions to design models will be required to avoid unnecessary complexity (Goldkuhl, 2016). A smart city is made up of many systems, and the elements of these systems interact both within their own system and with elements in other systems (Ackoff, 1971, Arnold & Wade, 2015). Gregor and Hevner et al. (2013) offer a design science research methodology (DSRM) that includes process iteration coupled with multiple starting points within the process. This is important because cities will be starting from different levels of ICT infrastructure maturity (Andersen & Henriksen, 2006) and with different sets of policy and procedures. This flexibility also allows for a smart city government design process that can recognize new problems, new stakeholder demands, or new smart city needs that require different entry points into the ADR/DSR process.

The design of a smart city government is driven by many external forces that generate government business needs (Janowski, 2015). During these design iterations, research rigor must be maintained to ensure validation of the design process and that any new Ω and Λ knowledge generated is relevant and grounded in theory (Hevner, 2007). Theory for DSR can be of two types, statements saying how something should be done in practice (Λ knowledge) or statements providing a lens for viewing or explaining the world (Ω knowledge). ADR/DSR is a-posteriori and comes from knowledge gained by testing designed artifacts and/or their interactions (Gregor, 2006). Utilizing this multi-methodological approach ensures that each ADR/DSR artifact that is designed (Hevner et al. 2004, Gregor and Hevner, 2013) is implemented and evaluated with sufficient rigor and with respect to the already existing artifacts. Therefore, new knowledge (Gregor & Hevner, 2013) can be fed back into any previous ADR/DSR artifacts to either make more sense of the previous artifacts or to allow better measurement of the artifacts' effects or behaviors. This system of systems concept is critical to the smart city government ADR/DSR process. The complexity of a city government requires evaluation of artifacts at multiple levels. An artifact or system must be evaluated at the single artifact or system level, and then through its interactions with other artifacts or systems (Ackoff, 1999). The artifact/system level evaluation will provide knowledge that will inform the single artifact design process, thus defining the need for more iterations of design of the single artifact (Hevner et al. 2004) (Gregor and Hevner, 2013). Also, as new theories are integrated into the artifacts and systems and the system of systems over time, more design iterations of the artifacts maybe required (Peffers et al. 2007, Gregor and Hevner, 2013). This knowledge must then be synthesized within the system of systems (Ackoff, 1971) to make sense of the whole smart city.

Utilizing ADR and DSR within a Smart City

The city being used as a testbed for this framework has already undertaken what could be considered smart city projects. However, they were implemented through a traditional ad-hoc city budget approval process. This process was initiated either by the city administration or by the IT department. Approval was then acquired through city council meetings, with neither the results or expectations for the project's success being required or reported. Also, each project has been undertaken in a stand-alone manner, thus requiring no integration with other city systems or smart city projects, and no additional usage of any data generated from the project, beyond that required for the system to be maintained. While this is typical of the piecemeal approach a city takes in its journey toward smart, it also provides an opportunity to engage the process at a theoretical level using DSR and ADR.

Research Approach

Gregor and Hevner (2013) summarize the DSR design steps outlined by Peffers et al (2007), as 1. Identify the problem; 2. Define solution objectives; 3. Design and development; 4. Demonstration; 5. Evaluation; and 6. Communication. However, a smart city is more the just a set of ICT artifacts proposed by DSR. The introduction of ADR ensures that complex social processes at work in a city and within city government can be studied as interventions are made through observance of systemic changes introduced to the city through smart city projects and resulting organization process changes, generating knowledge about the changes introduced (Baskerville,2001).

ADR is the process through which organization context is provided, and DSR is the process through which IS artifacts are designed and built (Sein et al., 2011, Mullarkey & Hevner, 2019). The ADR approach allows the researcher to take a set of measures (Gil-Garcia et al., 2016; ISO, 2018; ISO, 2019) and apply them to smart city ADR/DSR artifacts, taking improvement and innovation into account as public value is examined within each ADR/DSR system (Harley, 2011) and in integrations between all smart city systems.

To build a smart city, a multilevel hierarchy of artifacts must be developed, so that measuring the impact of the individual artifact (individual ADR/DRS projects) and measuring its effect within a system of systems (between ADR/DSR projects) is possible. While the AD/DSR approach is sufficient for the design of a single artifact, a smart city requires numerous systems containing ADR/DSR artifacts. The design process must take into account both the ADR.DSR artifact and its interactions with other systems including other ADR/DSR artifacts from other ADR/DSR projects.

While some measures have been developed for a smart city (ISO, 2018; ISO2019) and dimensions required to create a smart city have been discussed (Gil-Garcia et al., 2016), there is no guidance within research of how, from a government perspective, to use the measure or create the dimensions. I therefore use public value as a guide while designing an ADR/DSR multilevel process that has the concepts of public value built into it while considering the systems of systems concepts needed to understand the value of interactions with the smart city system. This list is not complete; it is an example to show to the complexity of creating a smart city. Table 2 shows a list of ADR/DSR artifacts that need to be created to ensure that ADR/DSR artifacts work with the systems of systems concept and that each system contributes holistically to the public value of smart city.

Table 2: Core Artifacts required by a Smart City Implementation

Artifact	**Theory or a-priori Literature**	**Dimension (Gil-Garcia et al. 2016)**
Authorization Model	Public Value (Moore, 1995) Stakeholder Theory	
Smart city Business Model	(Brocke et al. 2012) Learning Organization	Innovation, citizen engagement
IT Strategy	(Yang and Rho 2007) (Yeow et al. 2017). Economic Transaction Cost Theory, Structuration Theory	Effectiveness, Efficiency

Smart City Goals and Projects	(Brocke et al. 2012) (Dawe et al. Forthcoming) (OECD 2014), Stewardship Theory. Resource Dependency Theory.	Equality, citizen-centricity, Innovation, citizen engagement, creativity.
Smart City transformation model	Diffusion Theory, (Yeow et al. 2017) (OECD 2014), Moore (1995)	Entrepreneurialism
Smart city Workplace Processes	Economic Theory of Transaction Cost. EU – Vision for public services 2013, (OECD 2014) (Poole and DeSanctis 1994)	Sustainability, creativity, evidence-based, citizen-centricity
Smart city Governance Model	Stakeholder Theory, Triple-Helix model, (OECD 2014), Trust in Government, (Anand & Navío-Marco, 2018) (Cobit 2019)	Evidence-based, openness
Digital IT Ecosystem	(Mynatt et al. 2017) (OECD 2014) NIST CSF v1.1	Integration, citizen engagement, cyber security resiliency, technology skills

The city leadership was informed of the research goals of work and helped identify how the practical goals of the city would be impacted. Together, the following design principles of each artifact identified through the literature search were determined to be in line with the needs of the city government: -

a) Authorization Model

1: Stakeholder theory (Freeman & Phillips, 2002) requires that smart city must consider all its stakeholders for each individual project.

2: Each project should add public value to the smart city complete project (Moore, 1995) to ensure sustainability of the smart city project.

b) Smart City Business Model for government

3: A smart city government business model will utilize the city's mission to ensure the correct ICT services are delivered to meet the city's goals. Stakeholder Theory Agency Theory (Stewardship Theory)

4: A smart city government business model is the optimization of IT services to deliver smart city capabilities to city government departments, citizens, business, and customers (Gil-Garcia et al. 2016).

5: A smart city government business model will allow for a general compliance with all regulations (Janowski 2015).

6: A smart city government business model will have a default of using ICT methods of delivering service first (Mynatt et al. 2017).

b) Digital Strategy for government

7: The city government strategies and city government IT department strategies must be aligned for smart city government capability to be created successfully (Henderson and Venkatraman 1999).

8: Smart city government strategies will include data mobility between government entities.

9: Smart city should include risk assessment and cyber-security throughout every system, integration, and data at rest (National Institute of Standards and Technology, 2018).

10: Strategic partnerships with business, NGO's and universities will be formed (Afuah and Utterback 1997).

c) Smart City Projects and Goals

11: The more complex systems become the greater the influence external factors will have on the systems development (Afuah and Utterback 1997).

12: By strategically managing smart city government implementation projects, this will enhance the city government's capacity to manage and monitor a projects implementation (Doran and Daniel 2014).

13: Clear business cases must be developed to ensure sustainable funding, authorization, and success measures are aligned with the city government mission statement goals (Pfeffer & Salancik, 1978) (Janowski 2015).

d) Digital transformation Model

14: The digital transformation model will foster automation, allowing the replacement of manual processes that involve accepting, storing, processing, outputting, or transmitting information.

15: The digital transformation model will allow the creation of new ICT based services and will allow for new methods of legacy service delivery.

e) Digital Workplace Processes

16: Digital city government work processes will be flexible but digital first (OECD 2016).

17: New city government organization structures will have to be created (Layne and Lee 2001).

18: Digital workplace processes will increase communications between city governments and its customers (OECD 2014).

19: Digital smart city government will reduce the transaction cost for delivering city government services (Madhok 1996).

20: Each digital process will provide or support a public value (Moore 1995).

21: Digital city government decisions will be data driven (Eggers and Bellman 2015).

f) Governance

22: Risk management will be conducted on every service, and every transaction will be auditable (Nath 2012).

23: A well-documented governance system with transparent rules will increase trust in a smart city government (Teo et al. 2008) (ISACA, 2019).

24: City government policies will have to adapt to allow digital systems to interact and start work processes autonomously.

g) Digital IT Ecosystem

25: ICT asset purchases, including job skills, will be done based on an assessment of current capabilities (OECD 2014).

26: Ownership of data moves from internal city government departments to citizens

The city has a pragmatic view of knowledge that can be summarized as follows: Knowledge within the smart city is formed based on the feedback regarding the effectiveness of actions taken. This fits well with the ADR process that views knowledge as theory that from a practical perspective is the expectation about the effects of the ADR actions taken. ADR allows for incomplete knowledge to be added and used, and for knowledge about the changes in the system to also be recorded. From a systems perspective, the city adapts by acknowledging the new knowledge generated and the results of actions by either positively or negatively responding to internal or external changes. As argued by Ackoff and Emery (2005) and Simon (1995), when an open system is interacting with a constantly changing environment, change in system responses is constant. However, a city can choose through the project authorization process to not change its current systems regardless of the data provided by the current system.

To make this smart city a reality the researcher requires a multilevel ADR/DSR process. ADR and DSR focus on artifacts that are evaluated as stand-alone artifacts. Theory is required to inform the ADR/DSR artifact design process at the smart city level and at the artifact level (Sein et al., 2011, Gregor and Hevner, 2013). This allows artifacts to be considered as a part of a system of systems and be evaluated at the smart city level where their interaction with other artifacts can be measured and observed. They may also be evaluated at the artifact level, where artifact operation and effects can be observed. In this manner, ADR/DSR now has two levels of iteration. The first level is the artifact level to improve the function of the artifact. The second level improves the relationships between artifacts and optimizes the goals of all artifacts (Ackoff, 1971) with respect to the goals of the smart city government. Despite a lack of a unified theory of a smart city to predict all interactions and processes, ADR/DSR allows a researcher to build the artifacts required for a smart city government with sufficient rigor to generate knowledge that may lead to a theory of smart city.

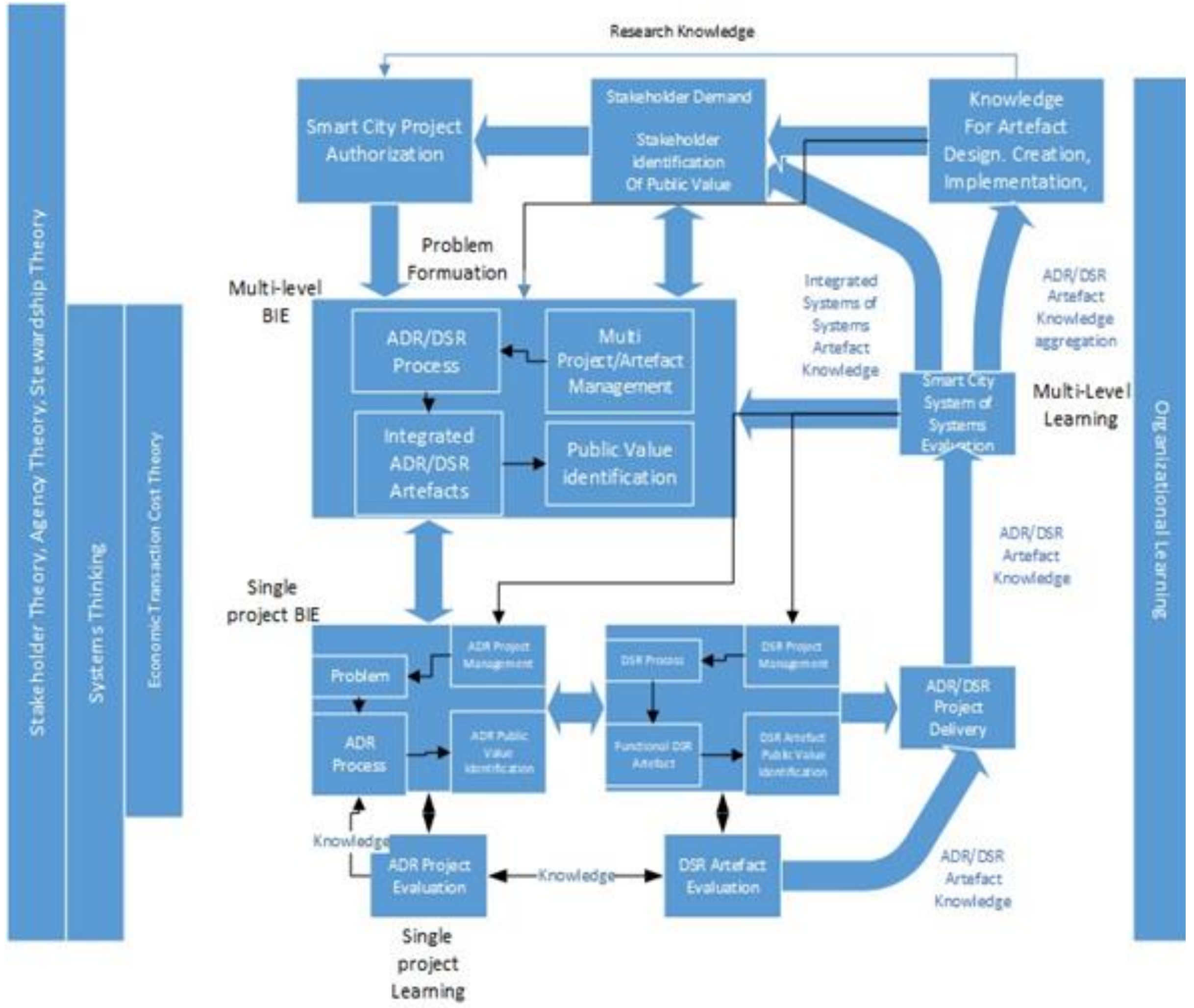

Figure 2. Multi-level ADR/DSR Artifact Design and Evaluation Model adapted from Hevner et al. (2004), Sein et al. (2011), and Ackoff (1971).

Figure 2. shows a multiple level ADR/DSR design framework and the theories that guide the design at each level to inform the knowledge sources used to begin iterations of both the smart city government (system of systems) research cycle and each DSR artifact creation/improvement process within the cycle (Nunamaker et al. 2013). This framework will add to the knowledge created and expand understanding of the behavior and effects of smart city on its stakeholders

(Venable 2006). It also helps ensure the solutions continue to fit the business needs (Hevner et al. 2004).

The process of a city transforming into a smart city is an evolutionary one, in which digital business systems artifacts and data collection artifacts are implemented through the ADR/DSR artifact development process, and then improved incrementally over time (Gil-Garcia, Pardo & Nam, 2015). The goal of a smart city municipal government is to build ICT capabilities to increase the openness of government processes, provide transparency into the decision-making process, and ensure the city government is accountable for its actions (OECD 2014).

Utilizing the 4 stages of ADR defined by Sein et al. (2011). I will design an artifact that will support the goals of a smart city (see Figure 2).

1. **Problem Formulation:** The multilevel design framework requires a project process that meets the OECD (2014) goals for a smart city. We must therefore build a smart city framework artifact that can utilize the theories that have been identified to help build a smart city (see Figure 2). This will ensure a practical need for the project and that the necessary theories are chosen to help predict the effectiveness of the proposed ADR/DSR artifact to produce public value at the individual project level and increase the public value of the smart city as a whole.
2. **Building, Intervention, and Evaluation:** ADR/DSR requires the use of theory to inform the design of an artifact. Project authorization for a smart city must therefore include the theories used to support the project within the systems of systems that will build the smart city. The inclusion of theories at this point will ensure that from artifact inception to artifact replacement, a consistent theoretical approach will be used to justify and evaluate each smart city project.

   Figure 2 shows the final version of the artifact. We started with the legacy city budget approval process. Each step of the process was discussed with the mayor's office and with the head of the IT department. This was to ensure any new process met state and local laws and city policy.

   It was determined that projects undertaken by the city came from citizen demands, the demands of elected officials or from internal needs identified by city staff. However, it was noted that projects that were generated from internal needs still needed support from the administration prior to being taken to the city council for a vote. It was therefore noted that the stakeholders for the city projects fall in to two distinct groups, citizens (External Stakeholders), and/or political (Internal Stakeholders). However, even if citizens demand service, project approval is still needed through a vote of the city council. I then initiated a process where all current projects could be prioritized and documented based on Resource Dependency Theory (Pfeffer & Salancik, 1978) prior to consideration by the city council.

This method of adding projects fits with Stakeholder theory. However, it was noted in several conversations with the political officers of the city that cost must be considered. The axiom for governments is that employees are expected to do more with the same or less budget each year. Several theories could fit this, but the city preferred the theory of economic transaction cost (ETC), as this allows for looking at each project through the lens of cost per transaction (Blomqvist, et al., 2002). It was noted that ETC and stakeholder theory are opposed to each other. After further review, it was decided that this was a good thing because it allows the city to define the services it wishes to offer (stakeholder theory) against the cost of offering those services (ETC). By taking both these theories into account, the city can gauge the financial feasibility of the project based on its public value. The city council requires a financial feasibility document for each project, in the case concerning smart city projects or services, the ability of the city IT staff to build and/or manage the technical systems required must also be considered.

A third aspect was also added as the city wanted to ensure that every citizen would have access to each service. This must be documented as part of the approval process. The city council required that noting how citizens could access the services was not enough, usage via these methods is to be reported. This helps with the digital equity goals the city has set for itself.

Implementing a smart city required redesigning the MIS department as a learning organization, fitting with systems thinking (Churchman, 1979) (Ackoff, 1967) (Ackoff, 1999), and was done to ensure that smart city projects do not constrict social practices for citizens or businesses within the city or their demanding of new services. For each project authorized or rejected, the project owners must learn from the process and must be cognizant of how smart city projects may change social structures over time.

Once a project is authorized, the development of ADR/DSR artifact designs and their instantiation is managed via the framework process in Figure 2, and more specifically by the city's internal business processes. Design for each project considers the project goals and how the new data generated by the artifact can be used by other systems within the city. Project results will be reported to the city stakeholders.

3. **Reflection and Learning:** Through citizen and business surveys, it was shown that downtown Wi-Fi was desired by citizens and businesses (Resource Dependency Theory). Having support from citizens and the mayor's office, an initial Wi-Fi design was done covering 3 blocks of the downtown entertainment district. This did not meet the expectations of the mayor's office (Stakeholder Theory). A survey was done of businesses in the downtown area, and of citizens that both live in the downtown area or visited within a 2-week period. The city asked what area should be covered with Wi-Fi. The data generated from this started two projects: Wi-Fi in all city parks and Wi-Fi covering 12 city blocks in total of the downtown area (Stewardship Theory).

   Covering 12 city blocks required a wireless engineering survey, conducted by city IT staff, to allow the choosing of suitable Wi-Fi technologies, and implementation locations, to ensure appropriate WiFi coverage and that the WiFi system is capable of multi-mesh self-organization. Designs were then drawn up based on the wireless survey for the placement of wireless access points (WAPs) and the appropriate antenna selections. After working with the fiber vendor, the WAP locations were adjusted to the closest financially feasible location to the survey location (Agency Theory).

   It must be noted here that the evaluation process in this case study is for the smart city framework artifact operation, not the Wi-Fi project that used the framework.

   Stakeholder Theory and Stewardship Theory defined the need for Wi-Fi within public areas of the city. After some basic research, city stakeholders identified a requirement for Wi-Fi in the downtown entertainment district and in city parks and recreational areas. The parks and recreational areas were not initially identified by the mayor's office as a requirement but were added to the project based on citizen demand.

ETC was used in the project design process to evaluate Wi-Fi vendors in providing the best Wi-Fi solution for the city at the least cost. This was done by changing the bid evaluation criterion to include engineering characteristics (mesh performance, cybersecurity, WAP range, ease of management, security feature, etc.) as well as cost in the solution bid process. By building in required features such as cybersecurity, the total cost of the system could be more accurately ascertained, and other ICT solutions would not have to be authorized later.

Management Information Systems department processes were changed to reflect learning organization processes (Senge, 2006) that incorporate post-iteration learning and dissemination. After each Wi-Fi system design iteration elements that were learned from the process were recorded and promulgated within the MIS department. The City MIS department became proficient at WI-FI design and WI-FI surveys to accurately predict the performance of a Wi-Fi system. The practical knowledge generated was documented and disseminated to all IT staff members for future use with similar projects.

It was also noted that during implementation, the Wi-Fi system could generate significant amounts of data concerning usage, device locations, path taken, and more. This data was not considered during the initial project definition. However, in reporting project success to stakeholders, city MIS leaders could aggregate number or users, returning vs. new users, and connection times to stakeholders.

This is a public Wi-Fi system that is also connected to the city network. Security concerns were paramount in the selection and configuration of the Wi-Fi system. Throughout the entire design cycle for the Wi-Fi system, cybersecurity, and network traffic monitoring solutions were installed, and tested at every stage. However, details are not available for publication.

4. **Formulization of Learning:** This paper represents the communication of artifact usage and its design process. Appendix 1 shows how the Wi-Fi was designed using the ADR multilevel framework, operated, and a report of Wi-Fi system usage provided to the mayor’s office and subsequently to the city council.

A Design Process for a Smart City

Building a smart city is a complex task that will require skills from multiple disciplines, including information systems, geospatial studies, public administration, and urban planning. Building a design science research plan for smart city government will allow for a focused research program that can give smart city government the theoretical underpinning it requires while dividing the research into more manageable pieces for each design science artifact. This approach takes a conceptual research program through several design science research cycles to the last research mile (Nunamaker et al. 2013).

The following actions can guide the selection of design processes for individual or specific smart city government artifacts based on the Framework built in Figure 2. Based on the process used in the Wi-Fi case study, the following best practices were developed.

- Understand the problem that needs to be solved, who the users are, and in what socio-technical context the solution should be optimized.
- Give all reasonable approaches to solving the problem the same attention.
- Ensure the data used to verify artifacts does not influence the results of a comparison between two artifacts that solve the same problem.
- Evaluate all artifacts based on the extent to which they address all relevant facets of the problem (cost and user experience).
- Evaluate the negative impacts different artifacts have on the smart city system, and the external environment. Consideration should be given to mitigation of these negative effects.
- Validate the arguments used to justify artifact design from the perspective of all target users.

The ADR/DSR research program needed to bring together the many aspects of smart city design, digital business model use, economic theory, and government theory is significant, but DSR provides the most feasible theoretical basis on which to build a smart city.

Smart city researchers have identified many dimensions (Gil-Garcia et al. 2016) and focuses for smart city projects (Janowski, 2015) (Nam & Pardo, 2011) (Katsonis & Botros, 2015) (Janssen & Estevez, 2013). Using prior literature, we have discovered some of the main artifacts necessary for the creation of a smart city government (See Table 2). Much of the prior research into smart city government focuses on models that explain the processes of smart city government including Gartner’s four stage model (Baum & Di Maio, 2000), the World Bank three stage model, the UN’s five-stage model (UNASPA, 2001), Deliotte and Touche’s six-stage model (Deloitte & Touche, 2001), Layne and Lee’s four stage model (Layne & Lee, 2001), and Moon’s five-stage model (Moon, 2002). However, these models do not offer enough design detail or guidance on how to transition between stages for practitioners to implement a smart city government. These models lack any mechanism to ensure knowledge that is captured during the implementation process can be fed back to inform theory (Nunamaker et al. 2013) and the creation process.

Each artifact that requires a ADR/DSR process works within the smart city environment described in Figure 2. Utilizing Nunamaker et al. (2013) for guidance, a multilevel design science project can be undertaken, where individual artifacts can be developed as per Peffers et al. (2007) and Hevner et al (2004). Each individual artifact can be developed and implemented, thus generating Ω knowledge in the form of new theories, observations, available measurements, and patterns (Hevner et al. 2004). This knowledge generated at the single artifact level can then be abstracted and synthesized at the smart city system of systems level of design, thus informing the design and behavior of other artifacts within the smart city government (Beckman & Barry, 2007). Λ knowledge is also generated as the implementation of each artifact is undertaken. The knowledge generated during each design iteration will inform the current artifact (Hevner et al. 2004) (Peffers et al. 2007) and as this knowledge is moved to the smart city design level (Beckman & Barry, 2007) (Nunamaker et al. 2013), it may cause a need for new artifacts or an iteration of design in a previously designed artifact. At the smart city government design level, artifact interaction and integration can be assessed and can provide more information and knowledge that can be used to meet the goals of the smart city government or provide stakeholders with new public value through the offering of new or improved services. Over time, new business processes will be required due to new regulations or when new technologies become available. Therefore, new ICT systems will have to be designed into current or replacement artifacts and ICT system integrations will be necessary at the smart city level. As this happens, design iterations of existing artifacts should be undertaken, and with each design iteration, a rigorous evaluation (Nunamaker et al. 2013) should take place. Any new knowledge generated must then be fed back into the artifact design process, and to the smart city government system of artifacts level (Senge, 2006). Thus, the new knowledge can be fed into all system artifacts. This longitudinal process will document the system of systems approach to smart city government, keep knowledge consistent, and apply theory consistently throughout the entire system of systems at each level. This iterative process at the artifact level and the smart city government system of systems level follows the objective of a purposeful system described by Ackoff (1971). Smart city government system of systems artifacts is an example of a purposeful, ideal-seeking system because a smart city government has goals and/or objectives that can lead to an ideal set of government operations and services. Over time, a smart city government system of systems can also adapt to changes in goals as stakeholder requirements or other inputs change. DSR ensures that the pursuit of the ideal smart city government artifact system state is done systematically and that each artifact ADR/DSR iteration considers the requirements and knowledge of the other artifacts via the evaluation and knowledge feedback processes both within the artifact and within the system of systems (Ackoff, 1971., Peffers et al. 2007., Nunamaker et al. 2013).

Analysis and Evaluation

Analysis and evaluation are a critical component of the ADR/DSR process (Hevner et al. 2004) (Peffers et al. 2007) (Nunamaker et al. 2013). Analysis in the framework shown in Figure 2 occurs at two levels. First, at the smart city level the city the analysis will consist of data to make decisions, use data to monitor business processes, and provide transparent reporting to internal and external stakeholders and other levels of government. Second, at the individual artifact level, data is generated, used, and formatted for use at the smart city level, the performance of the individual artifact should be monitored, and the artifacts' operation must be monitored and reported.

The artifact's performance and effects need to be analyzed via case studies, empirical studies, and longitudinal studies to ensure the validity of the component artifacts, and the smart city government process holistically (Senge, 2006) (Simon, 1996). Each artifact will generate knowledge that will need to be captured and synthesized so it can inform both theory and practice to be used to improve the artifacts that have already been generated and inform the design of new artifacts within the system of systems (Gregor & Jones,2007).

Pries-Heje, Baskerville and Venable (2008) argue that an *ex-ante* evaluation of artifacts can be done stating that an *ex-ante* evaluation in its simplest form is a cost-benefit analysis. However, government projects are not always undertaken because there is a direct benefit when compared to costs: projects can be political in nature or undertaken because of citizen pressure (Janssen & Estevez 2013). The value of an investment in a smart city government model is not always in dollars and cents (Mc Knight & Chervany 2001).

An *ex-post* framework can utilize real production artifacts, allowing for evaluations of the individual artifacts via Peffers et al. (2007) DSR process model or the ADR BIE process. A smart city government system is too complex to be describable in one artifact; therefore, we must make use of the multilevel evaluation process shown in Figure 2 to evaluate an artifact in conjunction with its interactions with other smart city artifacts. This way, the behavior of each artifact can be improved to ensure the greatest utility to the smart city government. The utilization of theories, including Economic Transaction Cost, Stakeholder Theory, Agency Theory, Stewardship Theory, and Resource Dependency Theory, coupled with systems thinking and Organizational learning, ensure designed artifacts meet the needs of the smart city government while also maintaining a focus on available resources and cost during the design process. This dichotomy in ADR.DSR artifact design theory input allows goals to be stated for the smart city government. For example,

1) *Smart city government will be able to produce the same outputs as currently possible at less cost. (Resource dependency Theory) (Economic Transaction Cost Theory)*
2) *Smart City government will be able to produce more outputs than currently possible at the same cost. (Stakeholder Theory) (Stewardship Theory) (Agency Theory)*

Future Research and Limitations

The validation and empirical observation of instantiated smart city government artifacts will ensure IS community discussions about the suitability of the design principles used and the approaches to artifact design we propose.

Until this model is fully instantiated, the effects of using the economic transaction cost theory and stakeholder theory cannot be fully verified. Future research must therefore include instantiations of artifacts using the proposed smart city multilevel model, and the results of these instantiation must be recorded in case studies, empirical studies, and other valid scientific methodologies. By doing this, we also have the opportunity for further iterative improvements to the model presented within this paper.

Conclusions

Given the lack of research into smart city government design and its comprising systems from the IS community, many government related papers have adopted business processes and applied them to government systems. Smart city government needs its own set of unique models, frameworks, and theories and the work described in this paper indicates that ADR/DSR is the ideal tool to do this. As an organization, smart city government's operations and responses to its environment and stakeholders are very different from those of business.

A government has many complex business processes and a strict regulatory system that is difficult and slow to change. Building a smart city government ecosystem will require a more flexible regulatory framework that can quickly adapt policy to new digital processes or ICT innovations. This flexibility must come with a strong audit and risk management process to ensure government processes cannot benefit any one group of stakeholders over another (digital equity). The artifacts generated by ADR/DSR allow for complexity and flexibility, providing a strong design foundation. Through the design iteration process these artifacts can adapt to new ICT innovations or changes in the regulatory environment.

Within a smart city government with so many systems accessing the Internet, cybersecurity must be a focus. Therefore, during the construction of each ADR/DSR artifact, and during the evaluation process at both the artifact level and the Smart city government level, there must be a focus on cybersecurity. Each instantiation of an artifact within different smart city governments will require a separate cybersecurity review process associated with it. ADR/DSR allows for a generic construction process to ensure that security designs are specific to each instantiation of an artifact. Without these security considerations the smart city government will be open to data loss, data corruption, and digital business process errors.

Using ADR/DSR to design ICT artifacts will provide knowledge to aid in the building of fully integrated smart city government systems that can securely share data. Smart city government systems will allow customers to access all government services digitally and track the status of their individual transactions. While doing all this, smart city government will also be able to provide more responsive public safety and dynamically adjust all smart city systems automatically to ensure the optimal use of city infrastructure.

ADR/DSR and system thinking in this paper has given rise to a multilevel artifact evaluation process that fills a research gap in the design and analysis of smart city government systems. We view the smart city government as a system of systems (Ackoff, 1971) and we view the system of systems level in terms of a set of integrated ADR artifacts with control feedback used at the artifact and system of systems levels. The ADR methodology provides us with a way of simplifying the whole system into manageable ADR/DSR design artifacts and instantiations, while retaining a view of the entire smart city system of systems and their effect upon each other and how the environment effects the smart city systems of systems.

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Smart City: Applying Systems Thinking, Theory, and Action Design Research to operationalize a smart city.

It has been said that the path to hell is paved with good intentions. Cities are complex open systems that have many stakeholders who through their demands for action pull city management in many directions and make many demands on limited city resources (Gharajedaghi & Ackoff, 1984). Demands for service in a city can come from a diverse and sometimes hostile and antagonistic set of stakeholders (Freeman, 1951). The stakeholders of a city are anyone or any organization investing in, involved in, or affected by the city government. For a smart city, the stakeholder theory view of a city states that success lies in satisfying all stakeholders (Bowie, 2012). The complexity that is a city government makes successful project selection difficult and its results difficult to predict. Guidance through a cohesive smart city system can help support stakeholder satisfaction through appropriate action.

Ackoff (1971) posits that open systems have an environment. As open system, a city has an environment upon which it can act, react to, and respond to. An act is where the city as a system adds something new or does something new. A reaction is a city system event that is caused by an event in the environment. A response is a city event that is optional but is caused by a change in the environment. How city leaders decide to act, react, or respond should be a decision based on the goals of the city, the strategic plan, the resources available to the city at that time (Ackoff, 1967., Conner & Prahalad, 1996., Lyytinen & Grover, 2017), and empirical data concerning the city environment. The resources that are available to city managers include physical resources, such as budget, staff, and internal capabilities, but must also include an understanding of the city's environment and the situation at hand.

A smart city as implemented through its government should be able to allow city managers and stakeholders to identify a lack of knowledge, recognize an information need, and provide background information from other city systems so that city management can learn and make better decisions. In the resource-based view of an organization, it is argued that an organization should look internally to find resources or sources of innovation (Conner & Prahalad, 1996). However, all cities, smart or not, require partnerships with business, universities, and other actors to be successful (Dirks & Keeling, 2009., Nam & Pardo, 2011., Janowski, 2015., Neumann et al., 2019). For a smart city, relationships are arguably even more important and therefore making the right decisions is paramount.

The effect of stakeholders demands on the development of a smart city is a relatively unexplored area of research on smart cities. In the citizen centric smart city paradigm, the focus is on outcomes and how they meet the needs of stakeholders, but there is little research in the smart city space on how these decisions are made. This leads to the research question:

> *How does a city manage its resources and choose between projects demanded by stakeholders to create the most public value given scarce or limited resources?*

Taking public value as the point of departure, the purpose of this research is to help explain how to implement a smart city through the framework shown in figure 2 such that the city is able to make well informed decisions. Focus must therefore be on a smart city's (1) strategic behavior, (2) the institutional structures that are required to monitor the relationship between stakeholders and city managers, and (3) development of smart city business processes and governance to define and manage the generation of public value.

Smart city frameworks generally assume that all stakeholders agree, and that every smart city implementation and project is required. The multilevel ADR/DSR framework in figure 2 allows for dissension amongst stakeholders and choice on the part of decision makers as to how smartness will be represented in the smart projects undertaken. This research operationalizes the ADR/DSR-based process developed in Paper 1 of this dissertation (see figure 2.)

Literature Review

Action Design Research

Action Design Research is a design science research process that focuses on organizational processes rather than just on information systems processes (Sein et al., 2011). However, ADR as a design process offers no solution to as to how a smart city should choose between competing stakeholders. Other theories must be used to provide the business processes (in systems terms

(Ackoff, 1967), the environment) in which the ADR ensemble artifact (Sein et al., 2011) will function (Orlikowski & Lacono, 2001).

The ADR ensemble artifact (Sein et al., 2011) offers a single point of entry at the problem formulation stage. The framework developed in Paper 1 also follows this guideline, as I argue that smart cities cannot, and should not authorize the expenditure of resources on solutions without a problem. The outcome in a smart city, and of the ADR design process, is an artifact that generates public value (Moore, 1995., Geuijen et al., 2017). Orlikowski and Lacono (2001) offer four perspectives through which one can view an ensemble artifact; all perspectives focus on the interaction between people and technology. A smart city perspective should, in general, focus on how technology can aid people, whether in decision making or through interaction to add to the quality of life throughout the city environment (Janowski, 2015., Pereira et al., 2017). The embedded system view considers how the artifact is used within a social context. The citizen centric view of a smart city (Lee & Lee, 2014) focuses on how citizens engage with the smart city artifact; how different socio- groups derive value from using the artifact is of paramount importance. The development project view considers the social design, development, and implantation aspect of artifact creation (Vanolo, 2016). This is significant for a smart city as each smart city project authorized has a socio-context that is at the heart of the design process (Yin et al., 2015). The product network view of an ensemble artifact considers the multidimensionality of the artifact and how it fits with other artifacts within the city system as a whole (Ackoff, 1973) (Churchman, 1979) (Simon, 1996). The technology as structure view asks questions concerning how the artifact is used, and in what way it is altered based on societal rules. This view also focuses on the learning that can take place through the design and use of the artifact (Elbasha & Wright, 2017).

Systems View of the ADR Ensemble Artifact

Work Systems are the application of human and technical resources to produce products and services for internal and/or external customers (Alter, 2002). Alter (2002) argues that a work system is defined within the context of the problem at hand. Therefore, the framework will contain, people, data, ICT, and business processes that come together to produce products and services that customers (e.g., citizens) use. ADR (Sein et al., 2011) requires that we do not assume that technology is the system, or that technology is a magic bullet that makes a system successful (Simon, 1996). ADR requires that a designed artifact considers the operational context such as the business processes within which the artifact is used and the outcomes associated with using the artifact (Gharajedaghi, 2011) and because of ADR's relationship with Action Research, and environmental context in which the artifact was designed must also be considered (de Vries & Berger, 2017). This indicates that one must consider each artifact as a system or sub-system within a larger system, and ultimately as a subsystem within Smart City (Ackoff, 1971). ADR also allows for the designed artifacts to be changed over time (Orlikowski & Lacono, 2001), particularly as a result of learning. Orlikowski & Lacono (2001) and Sein et al (2011) both place emphasis on learning and theorizing throughout the design and use of ensemble artifacts. This learning can be at the organizational, management, or analysis levels (Project Management Institute, 2017). Organizational learning often leads to new ADR cycles to change the artifact operation.

Smart City

For a city to be recognized as smarter, one must first find a definition for what a Smart City is. MIT (2015) describes smart cities as "…systems of systems, and that there are emerging opportunities to introduce digital nervous systems, intelligent responsiveness, and optimization at every level of system integration". This definition is limited to information and communication technologies (ICTs), and their uses. However, a more rounded definition for a smart city is provided by Hall et al. as "…a City that integrates science and technology through information systems, integrating the conditions of their critical infrastructures, to better optimize, plan and monitor resource utilization, and enhance the city management's decision-making processes" (Hall, Bowerman, Taylor, Todosow, & von Wimmersperg, 2000).

There is significant disagreement and concerns among different academic disciplines within the academic community concerning the implementation of "Smart City" including, the strategies, the business processes, and the technologies. Technology companies are marketing and selling the "Internet of Things" as a system that can monitor every movement within a city and analyze all videos in real time (Taylor et al, 2015). This level of mass surveillance has been criticized by many public policy researchers as technocratic governance with too much potential for abuse (Ahmad & Dethy, 2019). In public administration disciplines, concern over personal privacy is generally seen to take precedence over saving and storing any personal information for long term usage. This includes, for example, CCTV footage that includes personal identifying features or vehicle tag information (Shelton, Zook, & Wiig, 2015). In terms of technology, cities must adhere to federal, regional, and local privacy laws and must have the appropriate governance and processes in place to ensure their information systems are in compliance.

It has been argued for many years that IT projects in the public sector require larger budgets, tend to be over budget, and produce fewer benefits than expected (Cats-Baril & Thompson, 1995). Therefore, it is incumbent on the smart city to include stakeholders in the planning, authorization, and review process to ensure limited budgets and resources are used to gain the greatest public value.

Stakeholder Theory

The term stakeholder as defined by Freeman (1984) as “any group or individual who can affect or is affected by the achievement of the organization's objectives.” Stakeholder theory is used to explain relationships between an organization and people, groups, and other organizations in the environment in which the organization operates. There is no literature and few specific recommendations in scholarly literature applying stakeholder theory to city governments. Smart city practitioners however, following best practices of the TOGAF Enterprise Architecture (The Open Group, 2018) and the Project Management Institute (Project Management Institute, 2017), have created both internal and external, or joint stakeholder committees to help guide smart city strategy and project selection. I therefore consider smart city endeavors as political ones requiring support from many stakeholders. Stakeholder theory provides a methodology to explain how smart city managers think about managing resources and projects to satisfy the objectives of stakeholders, how elected city council members think about their constituencies, and how executive city management (Mayor’s and/or city managers) manage smart city operations (Freeman, 1984).

Agency Theory

Agency theory has generally been utilized to understand and explain corporate governance management phenomena. This academic research is generally based in economics and focused on private enterprise. The recognition of other principal-agent relationships appearing in society, such as politicians/voters, brokers/investors, and lawyers/clients, or other theoretical perspectives have emerged to explain variations of the principal-agent relationship. In the context of a smart city, stewardship theory is an alternative theory that expands on basic assumptions of the classic Agency theory to extend understanding of important relationships and mechanisms in a governmental context (Hill & Jones, 1992).

In a government setting, the city-employee takes on the role of principal agent from agency theory. Studies have shown that the distribution of information favors the agent (Kassim & Menon, 2003). This has caused principals/stakeholders to control their agents by creating democratic decision-making processes. In a city working to gain or increase smartness, this would likely take the form of a smart city committee with citizen participation (Musa, 2018).

Stewardship Theory

Stewardship theory refines the stakeholder-agent relationship based on other behavioral traits than agency theory (Davis et al., 1997). Stewardship theory helps explain situations where smart city managers/project managers are considered stewards with motives in agreement with the mission and strategy of the smart city stakeholders. The stewardship theory is based on a steward whose behavior is ordered such that pro-organizational, collectivist behaviors have higher utility than individualistic, self-serving behaviors. According to stewardship theory, the behavior of the steward or management employee is collectivist in nature because the steward’s actions are based on meeting the goals or objectives of the city (Huovila et al., 2019). These actions benefit stakeholders such as citizens (e.g., via an increase in perceived quality of life) and through upper levels of city management as their objectives are met by the project managers.

Stewardship theorists assume a strong correlation between the success of the organization (smart city) and the stakeholder's satisfaction (Cardullo & Kitchin, 2019). A steward is said to maximize stakeholders’ objectives through mission-based performance measures, because, by doing this, the steward's utility functions are maximized (Fox & Hamilton, 1994). Smart city management must assume that stakeholders can have different objectives (Freeman, 1984); a steward's behavior can be considered organizationally centered by making decisions that the steward perceives as being best for the entire group of stakeholders (Mora et al., 2019).

Resource Dependency Theory (RDT)

There is little government or smart city research that uses a resource dependency perspective. In general, Pfeffer & Salancik (2003) identified three main tenets of RDT, 1) social context in which the organization matters, 2) organizations must develop strategies to provide for autonomy and pursue their own interests, and 3) power is important for understanding the internal and external actions and organization takes.

A city’s leadership and strategy are dependent upon the environment for its legitimacy in democratic societies, as power is derived from a mandate to govern via the electoral process. Therefore, a smart city strategy requires input from citizens, city leadership, and city employees (Vanolo, 2016) (Meijer & Bolívar, 2016).

The topic of “created environment” supports the following assumptions. First, that political action correlates with the degree of environmental dependency the city faces. Second, that a city government is dependent upon its environment for its features, its culture, and its economic status. Smart city characteristics provide a way to measure the environment (Nam & Pardo, 2011). Organizations facing similar environments are likely to choose similar behaviors, policies, and smart city projects to manage it (Mora et al., 2019). Smart city projects provide data that maximizes performance and create linkages with other organizations active in the environment (Leydesdorff & Deakin, 2011) (Rodrigues & Melo, 2013).

Economic Transaction Cost Theory

Literature on smart cities shows that smart city governments generally adopt technology or smart city projects to attain efficiency. As the technology is embedded in administrative processes, the data produced will increase efficiency and therefore, citizen satisfaction (Kim et al., 2017). Smart city projects tend to carry out control and monitoring roles in cities, thereby enabling the design of efficient urban systems (Jin et al., 2014). The ICT infrastructure is built to enhance efficiency and allows cities not only to address problems associated with population growth, but also achieve economic and social development (ISO, 2016).

An ADR artifact approach to Economic Transaction Cost requires a set of policies that monitor the cost of smart city systems versus the public value derived from system use and operations (Geuijen et al., 2017). This must be done through a management system that is capable of monitoring individual systems in use, but that also recognizes integrations and their value (See Figure 2.) (Ackoff, 1971). Moore (2013) offers practical guidance on constructing a public value account for all governmental operations. This public value account can be used to base line current systems, and then compare the public value of new smart city systems. Ultimately, the economic transaction cost of a new system should be less that the old system or generate more public value than the old system through the offering of more services at the same cost.

Authorization Artifact Design

Project Background

As is often the case, the City of Opelika approached smart city initiatives believing that all such projects are worthwhile. However, it soon became obvious that this is not the case, and that smart city projects needed to be evaluated on a case-by-case basis as to their feasibility. While feasibility analysis is embedded in the initial business process, it did not consider stakeholders' opinions or disagreements amongst stakeholders concerning the public value of a smart city project. Accordingly, a new set of business processes that enabled a more consultative approach to the smart city project was designed.

Applying ADR

Following the ADR process laid out by Sein et al. (2011) I designed a set of business processes that have been implemented in Opelika, and from this work I have generalized an authorization framework for the generalized smart city framework shown in figure 2. The steps completed during the design and implementation are outlined below.

1) Problem Formulation

There are three major issues with project authorization that will use limited resources and must align with the city's strategic vision. First, the city must be able to receive input from its stakeholders regarding the project. Second, the public value of the project must be as close to accurate as possible. Third, there must be a venue for results of the project to be reported to stakeholders so that assessment of the benefits can be made by city management and the citizens at large.

The research opportunity here is twofold. 1) Smart city projects are reviewed by both academic and practitioners from a perspective that all projects provide public value and are worth the investment. Cities, with limited budgets, cannot invest in every project, and must therefore make sometimes difficult choices. To my knowledge, this is an area that has been overlooked in current smart city literature. Design and implementation of a process for authorization helps ensure that chosen projects support the needs of the public while promoting city smartness. An authorization process based on this will provide a city with a methodology for making good decision regarding competing projects. 2) This authorization business process can lead to a theory-ingrained generalized framework of authorization that can be implemented in other cities, with different strategies, political organization, and resources.

The researcher and the city management worked through the MIS department to build the necessary business processes and monitor their operation. An agreement was reached on how the new business processes would be reviewed and implemented through the ADR research cycle. The start of the design process for the authorization process would utilize the same theories used to govern the smart city framework adopted by the city (see figure 2.).

2) Building, Intervention, and Evaluation (BIE)

This ADR cycle focuses on business processes and therefore utilized the organization-dominant BIE process outlines by Sein et al. (2011).

Before the BIE process could begin, analysis of the current authorization process was undertaken. This is shown in Figure 3. The initial smart city project used the existing city

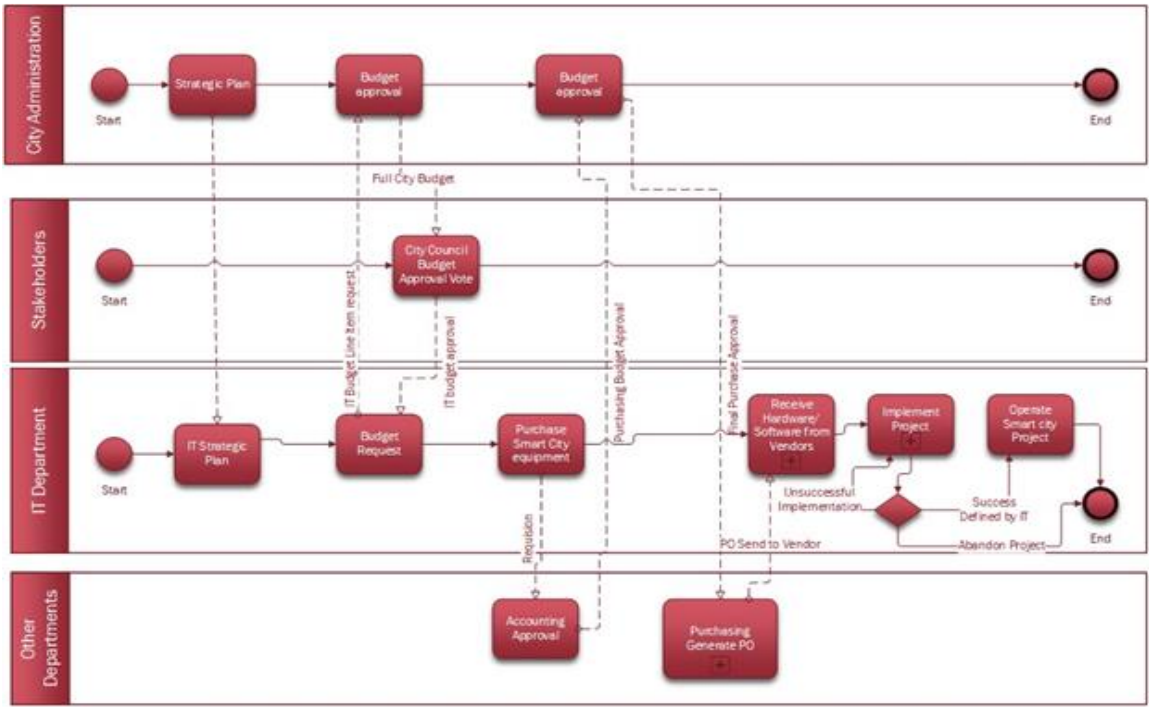

Figure 3. BPNM version of Initial Smart City Authorization Business Process.

purchasing process that was limited regarding both initial input from stakeholders and feedback of results to stakeholders. Results were shared with city employees that required the data produced by the project.

The city has a mission statement and a strategic plan outlining the goals of the city. The IT department aligns its own strategic plan based on those organization-wide goals. Smart city projects are not differentiated from any other IT project (e.g., replacing a firewall). First, a potential project is added to the city budget for a specific year. When the budget is approved by city administration, it is then sent for final approval via a city council vote. Once the money is approved, hardware and software are purchased, then the project is implemented. If implementation is successful, the system is considered operational, and any maintenance costs are shifted into the yearly maintenance budget. The disadvantages of the process include little reporting to stakeholders is required, and smart city projects are implemented through the IT department in an ad hoc process where the IT department responds to the stakeholder or other departmental requests by requesting the project via a line item in the yearly budget.

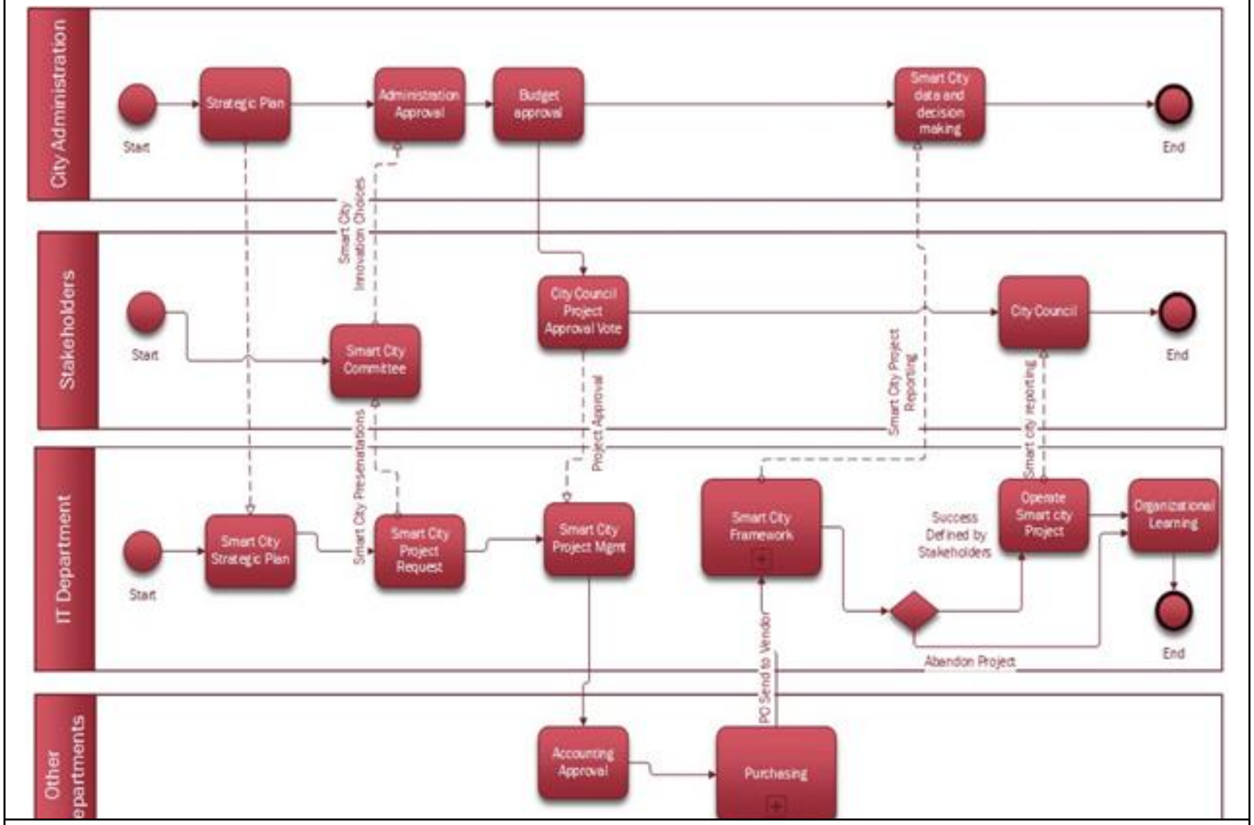

Figure 4. BPNM version of Intermediate Smart City Authorization Business Process.

Figure 4. shows how the smart city authorization process was initially designed and is an intermediate step in the ADR process. This design included the creation of a smart city project management system to control each smart city system and the formation of a smart city committee to help communicate smart city projects to citizens and to solicit feedback from citizen on current smart city projects. This communication includes the technologies involved as well as information regarding how data is collected and used. Citizens are also allowed to suggest project ideas within these smart city meetings, every idea is looked at and responded to. Once a project idea is deemed appropriate and feasible, the business process begins with the IT department taking the smart city project to the smart city committee and presenting the details of the project, how the data will be used, the projected public value(benefits) of the project, and with a project budget. Once the project is evaluated and approved by the smart city committee it goes to the mayor's office for approval. Once the mayor's office approves, the city council must vote to approve the project, project financing, and any contracts that are required.

Once the council has voted to approve the project, the smart city framework (figure 2.) is initiated to control and manage project implementation and integration into the city's systems architecture. Feedback is done at the request of a stakeholder group (e.g., the mayor's office or the smart city committee).

The city, after using this process for two years, recognized deficiencies in this process. First, the IT department no longer wanted to be the sole developer of IT smart city project ideas. Second, this process, while bringing stakeholders into the smart city process, did not allow enough for project comparison and choice because projects were developed and presented one at a time. While incorporating more stakeholders was an improvement, the city wanted a way for innovation and choice to be a part of smart city process. The city also wanted a way for stakeholders to be involved in the smart city project idea generation process.

Figure 5. shows the current business process (initiated for budget year 2019). Smart City ideas come from city departments, stakeholders, and/or other interested parties; these ideas are then evaluated for feasibility and strategic fit. The city IT department is furnished with a

smart city budget. Once approved, the IT department cooperates with the idea owner as a stakeholder to produce a project plan and a cost/benefit analysis for every idea deemed feasible. These projects are then presented to the smart city committee in an open (meaning open to the public) meeting for review and acceptance/rejection. The approved projects are then prioritized for implementation. Final approval comes from the mayor's office and ultimately via a council vote. Once approved the project management process and smart city framework process shown in figure 2 begin. This process is inclusive of all ideas and requests, while ensuring that the city maintains budgetary and technical control of the smart city project.

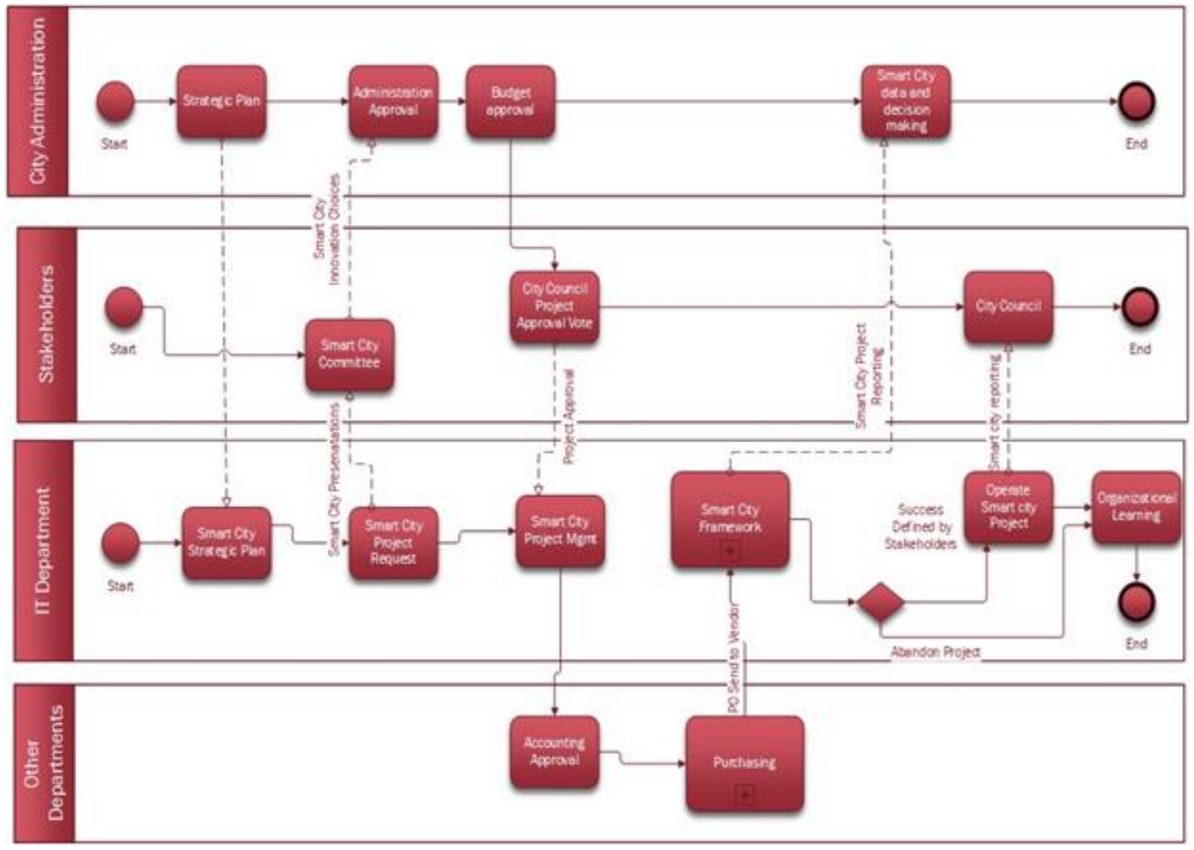

Figure 5. BPNM version of Current Smart City Authorization Business Process.

3) Reflection and Learning

The phase consists of two processes. The first is organizational learning for improving project, architecture, and systems practice within the city and the second is abstraction of what was learned during the ADR BIE phase for academic knowledge generation. This informs future system designers regarding the creation of systems belonging to the class of problems identified in the problem formulation phase. Following ADR design principles (Sein, et al., 2011), designers should utilize the theories identified in the problem formulation and implementation processes. Dissemination of ADR results is important and can be through academic and practitioner channels. This ensures that future projects can leverage the results of the smart city project.

4) Formulization of Learning (feedback loops (single and double) for system control and learning)

ADR Principles require the generalization of outcomes. In ADR, generalization is always challenging because of the highly situated nature of the created knowledge. DSR requires that researchers should show how the problems and solutions that are identified during the project should be generalized to a more abstract class of problems and solutions.

Operationalizing ADR and the Current Business Process

It should be remembered that this ADR project is not the focus of this paper, and therefore, summarized here. The focus is the authentication process.

ADR Stage 1: Formulating a problem and Research Questions.

Principle 1: Practice Inspired Research:

Stakeholders identify business problems and subsequently are focused on solving the business problem. Research questions and generalized outcomes are not a concern within city leadership. Therefore, within the smart city framework (figure 2) we focus on providing business solutions (the goal of ADR) and address any diverging priorities between researchers and city stakeholders in the learning and review processes within each solution development cycle.

The business problem in this case was that a quarry was proposed adjacent to the city limits. This quarry would have a direct negative affect on the city’s water supply and would affect many businesses in the area. The city had no baseline pollution data for air quality or water quality. Thus, a system to collect this information was requested by the Mayor’s office and several business owners so that any subsequent changes could be monitored. The solution is an ambitious city-wide air and water monitoring system.

ADR Research question: Can the Smart City Framework, operationalized via the business processes shown in Figure 5, be used to support a smart project design?

ADR Research question*: Is the systems of systems approach valid for smart city?*

Principle 2: Theory-Ingrained Artifact.

Utilizing systems thinking, the city had already invested in a citywide communications technology called LoRaWAN. This is a low bandwidth wireless technology that is capable of supporting 1000s of devices concurrently. The initial use case for this technology was to monitor noise from industrial parks that had generated citizen complaints across the city.

In following the idea of systems and system reuse, the IT department elected to use the LoRaWAN communications network rather than build, deploy, and manage another technology. The disadvantage of this is finding appropriate sensors that are compatible with the communications technology already deployed. Stakeholder Theory holds that stakeholders should demand artifacts and systems that meet the needs of the organization (in this case, an air and water monitoring system). Economic transaction cost theory requires that this system be built utilizing systems and ADR artifacts that already exist wherever possible. Agency theory coupled with Stewardship theory govern system designers so that the proposed solution is fit for the purpose, without any additional features that could be deemed unnecessary by stakeholders.

The project proposal was submitted though the authorization process shown in Figure 4. This project as per resource dependency theory was prioritized, and budget monies were moved from other IT projects to fund this sensor project. This reprioritization required adjustments of IT strategic planning and the movement of projects to accommodate this new project and its funding.

ADR Stage 2: Building, Intervention, and Evaluation

Principle 3: Reciprocal Shaping
Principle 4: Mutually Influential Roles
Principle 5: Authentic and Concurrent Evaluation

Principles 3-5 are part of the ADR BIE process and are concurrent processes that do not happen separately. In the smart city framework designed in figure 1, management of artifact creation is done at 2 levels. Level 1 is the project level; we must ensure the ADR artifact is designed and operational. At level 2, we consider all artifacts and how they can be integrated to provide better systems operation, better outcomes for stakeholders. Reciprocal shaping governs how the artifact in question will affect both IT and the organization. In the artifact proposal, a design decision was taken to utilize an existing IT artifact as the communications backbone for this project. The remaining design decisions to be made included sensor operation, sensor types, and how the data should be collected and stored.

In principle 4, Sein et al (2011) remark that researchers bring knowledge of technological advances. I have found in my research with the city of Opelika that the practitioners value learning and are always looking to incorporate new technologies in all the IT artifacts the city uses. The roles of researcher and practitioner in this area are somewhat blurred. This has been a benefit to the ADR process as when reflecting on the design and implementation process, and the results of artifact testing, it has led to quicker design cycles and less friction between researchers and practitioners. In the authentic and concurrent evaluation of the authentication process value was evident in evaluating how each project was brought to review and the city managers felt that the process, including question and answer sessions between the stakeholders and the designers, increased the public value of each project chosen.

Evaluation of the results of this project revealed issues that resulted in design changes. As the design cycles moved forward, single sensors were replaced with sensor suites and sensor placement issues from power requirements were solved via the addition of an inexpensive solar panel to the sensor suite. The choice of sensors evolved over time as the transmitter IoT computer (Raspberry Pi) limited each location to six (6) sensors. The sensors chosen were based on the indicators listed in ISO 37120 (2018). Next the issue of the number of sensor readings to make the data useful was considered. During the evenings, the battery could power the IoT computer, the sensors and transmit approximately 50 readings. This limited the number of readings to 4 an hour. This 15-minute cycle was acceptable to stakeholders given the design costs to ensure real-time readings. Appendix 3 shows a sensor suite attached to the pole and a set of readings for July 2020 for a single sensor.

Generalization of Business Processes for Managing Stakeholders

ADR Stage 3: Reflection and Learning

Principle 6: Guided Emergence

In this stage of the ADR process, evaluation of adherence to the ADR principles takes place. In building the IT artifact to sense and transmit data to provide baseline pollution values for the city, we built a simple model of the city's systems to ensure that, as we designed parts of the system, we were following the principles of ADR. Figure 6 shows the city's technology stack, where the business processes map within the stack, and where the ADR stages are fed by the results from the smart city technology stack. The problem formulation stage (ADR Stage 1) is missing as implemented systems by definition must be built.

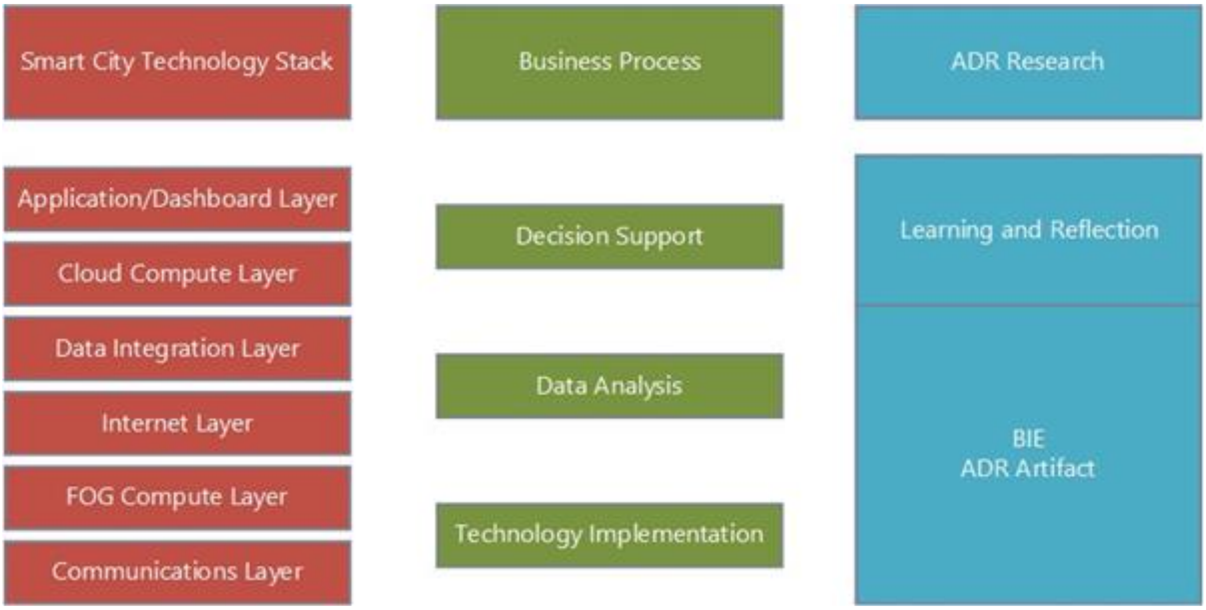

Figure 6. Smart City Technology model, business processes, and ADR Stages

Guided emergence also requires the analysis of the intervention results according to stated goals. In this case the project was to provide a city-wide baseline of pollution data if a quarry was constructed just outside of the city's planning district. While merely measuring near to the quarry would meet the objects stated by the stakeholders, the smart city review committee recommended to the stakeholders that the entire city be covered, as every citizen and neighborhood should have this data available. This recommendation was added to ensure the digital equity goals of the city be met by this project. The stakeholders agreed with this recommendation. This indicates the flexibility of the authorization business process to allow modifications as necessary, such as adherence to a mission statement that previously may have been considered beyond the scope of the project.

ADR Stage 4: Formalization of Learning

Principle 7: Generalized Outcomes

This action design research process was designed to allow a city to use its bureaucratic nature to allow stakeholder inclusion, resource management, and maintain control of smart city projects through the budgetary and authorization processes required by State law. The authorization process balanced the competing interests of the organizational stakeholders, acknowledged the research team and the benefits research provides to the city shown in figure 7. Secondly, in this sensor project, the generalized problem instance is providing a measurement of a city's baseline pollution levels. Generalization of the solution instance comes through the systems thinking nature of viewing city systems, their malleability, and envisioning how IT artifacts can be reused in different ways to enable new features or services. In this case, the existing city-wide LoRaWAN IoT communications network was sourced to enable a new service for stakeholders.

The multilevel ADR model for smart city shown in figure 2 requires a generalized authorization process shown in figure 7.

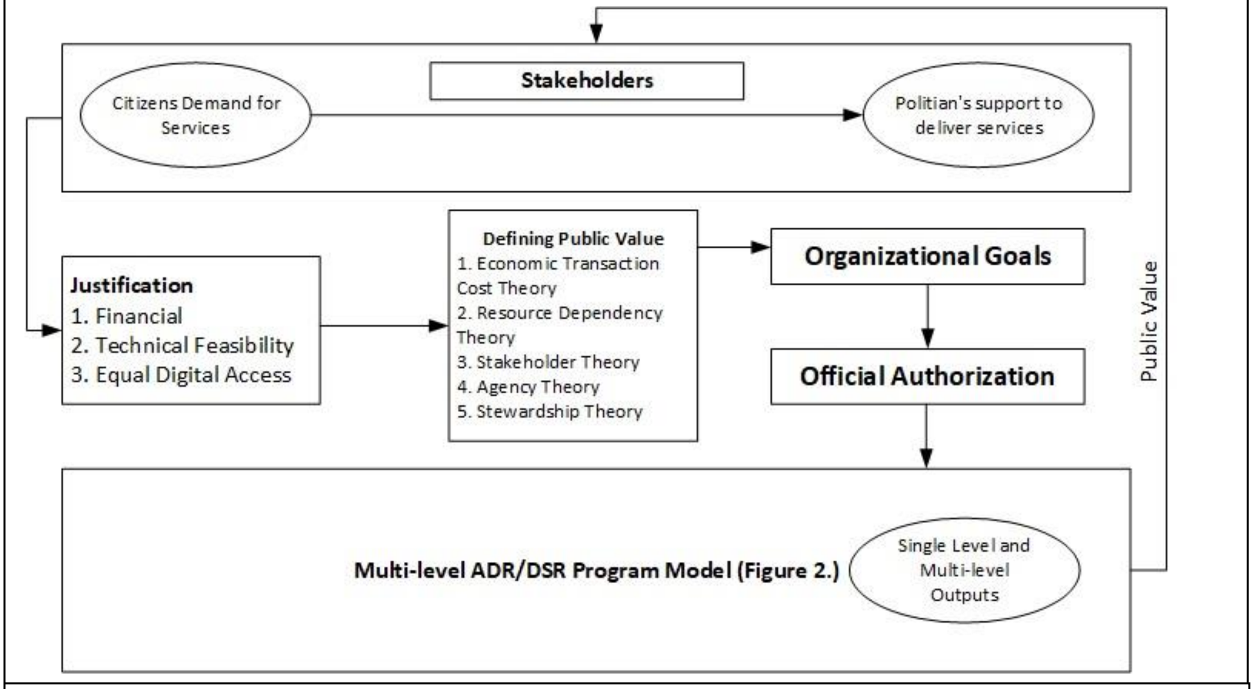

Figure 7. Framework for authorizing a smart city project adapted from Moore's framework for creating public value.

Discussion

After reviewing several smart projects Opelika has conducted, both from before and after the introduction of ADR, it became apparent that the relative success of the project was attributable to whether certain design questions had been answered. The ADR principles brought this into better focus.

Each smart city project should start with a “why”, and then focus on the outcomes. The why answers the question, why is this a project, and why is it needed. From the “why”, in ADR stage 1, we can identify high thematic outcomes for each project. The theme of a project is the story that sells the project to the smart city review board. Any outcomes should always be measurable.

Transformation into a smart city is done through frequent and sometimes small additions to public value, linking together a series of smaller changes to make a bigger difference. The road to smartness is a journey, not a destination. Each city must design and navigate its own journey. The smart city transformation is continuous without an end date. It is a constant process of learning, reflection, experimentation, and improvement. Progress must be tracked via measures that are in line with the city strategic plan. For a city, the goal is to improve the processes by which it improves itself; ADR in stage 4 and the smart city framework (figure 2) encourages cities to become learning organizations (Senge, 2006). Smart city projects must have the support of all stakeholders to be successful. The data derived from smart city projects must be institutionalized to foster a data driven mind set among city leaders.

Conclusions

The resources available to a city do not confer any advantage for a city if it is not organized to capture the public value from them. ADR allows a city to organize its resources and to strategically manage them to ensure public value is gained from their use. A smart city with theory at the center of its business process design is more capable of exploiting the public value of limited resources thus achieving sustained quality of life increases for its citizens; however, it must have the ability to do so. Implementing smart city projects with advanced technologies increases complexity and risk (Nam and Pardo, 2011); therefore, when authorizing a project, the capabilities of the city to manage the project and integrate it into city’s systems must be available. The proposal to the smart city review board must also include a management plan and skills analysis. Keeping the focus on the outcomes, particularly with respect to public value and strategic alignment, has greatly increased understanding of what a good project must accomplish. The resources available to a city are valuable only if they help to increase the public value offered to the stakeholders. This study suggests that, while complex, taking time to design projects with the end value in mind is not only possible, but it has also been successful in Opelika.

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A Systems Approach to Operationalizing a Smart City Infrastructure: Utilizing an ADR based smart city framework: A systems Thinking perspective.

There have been many efforts to describe how cities should be designed and how people should interact with city infrastructure to make cities appealing to citizens. The concept extends for over 2000 years from Plato's theoretical Utopia (Plato, Ferrari, & Griffith, 2000) to hub and spoke city designs to the industrial age and the Octagon city in Kansas, designed for vegetarians and built in 1856. In 1924 Le Corbusier presented Ville Radieuse (Radiant City), the machine city where daily life was controlled by machines (Merin, 2016). However, the advent of the Internet, ubiquitous computing power, and fast communications networks, only now makes it possible to build city infrastructure that will sense what is happening and be able to report that in real time. Integration of technology, particularly information communication technology (ICT) forms the basis of this ability to monitor and report concurrent activity.

A smart city has been described by many authors, thus there is little agreement in both the academic and practitioner communities concerning the definition of a Smart city or what makes a smart city "smart" (Albino et al. 2015). In the academic community, smart city has been described in terms of technology and its effects on human capital, education, social interactions, or by measuring environmental or sustainability impacts of technology implementations (Lombardi et al. 2012). Whereas businesses are mainly focused on how smart city technology implementations provide for the implementation of technology; usually their own, with their definition of smart city focused on the technologies they are selling, and how this technology, means the definition they have focused on. For example, Cisco Systems defines a smart city as: -

> *"A smart city uses digital technology to connect, protect, and enhance the lives of citizens. IoT sensors, video cameras, social media, and other inputs act as a nervous system, providing the city operator and citizens with constant feedback so they can make informed decisions."* (Cisco, 2021)

Bakici et al. (2017) define a smart city as "a high-tech intensive and advanced city that connects people, information and city elements using new technologies in order to create a sustainable, greener city, competitive and innovative commerce, and an increased life quality". These two definitions focus on different categories of city improvement and emphasize technology over everything else. This lack of agreement or focus on a specific set of technologies inhibits the ability of cities to design and build cities that fully leverage technology, as each municipality must go through a process of defining and designing all the smart city components anew with each new implementation. The current focus of smart city planners and academics today is on the citizen, in a citizen centric based smart city concept (Sepasgozar et al., 2019).

Using the Multilevel ADR/DSR framework developed in Figure 2. I elucidate and evaluate designed artifacts within a smart city system. Rather than establish another definition of *smart* city, I provide a broad and robust digital framework that operates in the context of the overall goals of a small city, its stakeholders, and culture. My position is that a city can be considered "smart" if it uses technology to achieve its goals, not that "smartness" is defined by incorporating a "smart" technology into the city's infrastructure. While many papers identify technologies that can be used to build smart cities, none identify how the project is chosen, whether the resources are available for the project, and what requirements and measures are needed to assess the success of a smart city technology project by relating the outcomes of the smart city project to the stated goals of the city and its stakeholders. The authorization artifact designed and shown in figure 7. requires that stakeholders themselves define the public value of a project based on its usefulness, how it meets its design goals, and the goals of the city. It is my contention that while smart city projects have had a specific benefit, this has been by accident because these smart city projects have been conducted in a vacuum with the assumption that each project is best for the city and without focus on any city-wide goals or strategic planning process beyond that of the technology implementation. By changing the focus of smart city development from a technology focus to an outcome focus based on the city's mission and stakeholder needs, I provide a measurable link between the smart city projects undertaken by the city and the city's goals.

In this paper, I focus on cities with fewer than 100,000 in population. Most smart city research has been conducted in large cities, leaving the much larger number of smaller cities left with trying to decide what parts of the larger city projects can be done with the more limited resources that smaller cities have available. I consider the limited budget and technical resources in these smaller cities, filling a gap in the literature. Further, in 2015 there were 19,235 cities with less than 100,000 in population (National League of Cities, 2015) in the United States, making this work immediately relevant on a wide scale.

Literature Review

Smart City

Cities have become larger and more important as urban populations have increased during the 21st century (Nam and Pardo 2011). The academic community has worked to define a smart city and which cities are smart by utilizing many definitions of smart city (Chourabi et al. 2012) (Gil-Garcia et al. 2015) and providing many examples of city technology (Bowerman et al. 2000) (Hollands. 2008). However, there is scant academic literature that links the smart city concept to an overall city-wide strategic plan or literature that focuses on measurement that is linked to the city-wide strategic plan. While ISO 37120 (2019) provides many indicators for measuring a city, it does not link the measures to strategic planning goals or provide baseline values that cities could meet. Unfortunately, companies and academics have focused on technology projects with an ever-increasing array of ICT devices for cities to use (Anttiroiko 2013). It is only recently that wireless network technology has provided ubiquitous bandwidth, “always –on” connections for these ICT devices (Lee et al. 2013), and again the focus has been on the network technologies rather than city wide outcomes.

Many smart city reference models have been promulgated (Cisco, 2012) (Zygiaris 2013) as examples, and they all focus on ICTs or technological outcomes. Projects that are based on these models also have technology outcomes as their goals. Many “Smart City” projects have been documented in academic research, and the results of these projects are generally seen as providing a social benefit. A question that has not yet been answered is why do these projects provide a benefit, and for whom? To examine this, I focus on the outcomes of projects as identified by cities themselves. By focusing on self-defined outcomes rather than specific technologies this framework can be applied to any smart city project. The rational view of organizations and the rational theory of management state that all members of the organization will collaborate to meet the goals of the organization (Markus, 1983). Cities are bureaucratic in nature as they are created via the explicit legal authority of the State government (Adler and Borys, 1996) and therefore function according to their structure (Meyer and Rowan, 1977) (Weber, 1921). The basis of legitimacy becomes whether the city has attained its purpose that is reflected in the rules of states and society (Meyer and Rowan, 1977). Any measurable outcome should be related to the goals of the city as its stated purpose so that citizens, city employees, and other stakeholders will support the project (Markus, 1983).

There is a recognized need for integration of city systems (Dirks and Keeling 2010). The linking of city systems occurs at two levels. First there is the city organization level, such as the road system linking with the storm drain system creating a system of systems (Ackoff, 1971) at the city level. The second level is at the information system level, where linkages between systems facilitate the sharing of information between systems (Dodgson and Gann 2011). The framework shown in figure 2 allows for the data an information system may generate to be considered at the individual system level and at the city system of systems (Ackoff, 1971) level. Given this requirement, a city's systems need to be integrated or converged to gain the maximum benefit of each system. This system convergence is defined as the process where two information systems share a common knowledge and technological base (Suh and Sohn 2015). In this paper, I focus on information systems within a city and integration of those systems.

In the United States, the decentralization of decision-making power away from central governments gives cities the ability to adapt ICTs and the associated measurement criterion and give both the ICT systems and the measurements a local context (Touati et al., 2019). This localization of smart city development, measurement, and implementation can be guided by the designed frameworks promulgated in paper 1. However, the nature of these integrated ICT systems causes each implementation and each iteration of the smart city framework to be guidable, but unpredictable.

Complex Adaptable Systems (CAS) and Smart city

In their review of complex adaptable systems research, Onix et al. (2017) identify seven (7) concepts: -

- Co-Evolution – Each system influences all the other systems.
- Emergence – System interaction give rise to emergent properties.
- Self-Organization – The ability of systems to constrain people, and for people to constrain the system.
- Fitness-Landscape – A complex system may appear to be ordered and predictable; however, hindsight does not lead to foresight because the environment and smart city systems constantly change in response to its environment.
- The Edge of Chaos – A smart city's systems never settle into a static state, but also never become uncontrollable.
- Dynamism and non-linearity – These are examples of the system of systems concept (Ackoff, 1971) where the whole smart city system provider greater public value that the sum of its parts.

- Adaption – Each city has a history, the past feeds with the present, and smart city artifacts evolve and are added over time in response to the city's environment.

The CAS nature of a smart city system requires a more experimental mode of management and system governance. The unpredictable nature of smart city system responses and the non-linear interactions between system artifacts means that minor change anywhere in the smart city system can produce large consequences elsewhere in the smart city system (Simon, 1996) (Sinha et al., 2018). The management framework in figure 1 provides a way to control and provide mitigation via feedback loops for each system change; however, tolerance of change and failure will be necessary for management to maintain smart city set of systems and the continuous change the outputs of the technology may require (Tompson, 2017).

In terms of design, ADR (Sein et al., 2011) allows a smart city project to have an experimental nature by providing a scientific method to understand the results of the smart city project implementation. Figure 2 provides for the authorization (Figure 7) of projects and the evaluation of the projects' effects from both a stand-alone project and as part of a smart city system perspective. This is possible through a robust evaluation of the knowledge gained from both the project implementation and through a review of the results produced as measured against the goals of the city.

Outcomes and Public Value

When developing metrics to measure the success of a smart city technology project, one must know the criterion for success. An analysis of city mission statements in the United States showed three specific criteria that can be used to measure the outcomes of a project against (see Table 4.). Many researchers of smart city concepts have used the triple helix model or a variant thereof to measure the smartness of a city (Leydesdorff and Deakin 2011) (Lombardi, et al., 2012). The Triple helix model identifies the University, Industry, and Government categories of metrics that can be used (Leydesdorff and Etzkowitz, 1996) (ISO, 2018). Unfortunately, these measures do not relate back to the goals of the city which are what defines public value to the city. The triple Helix model of innovation has been modified by Lombardi et al. (2012) to include a fourth helix, civil society. This fourth helix is included to measure citizen behavior within the city context. These measurements exist, to measure the value of each smart city project and to evaluate the project in terms of the city goals.

A smart city is a modern way of creating public value for the citizens of a city. Moore (1995) suggested that authorizing, operating, and task environments help determine public value but did not provide metrics for measuring these environments. The International Standards Organization has given us metrics by which a baseline may be measured for a city (ISO, 2018) (ISO, 2019). Any improvement to these baseline measures as a result of smart city projects are the expression of the creation of public value. Figure 8 shows the relationship between the themes identified by the ISO and public value.

The outcomes of smart city projects created and authorized through the framework shown in Figure 2 should create public value by improving measurements within one or more of the themes identified in Figure 8.

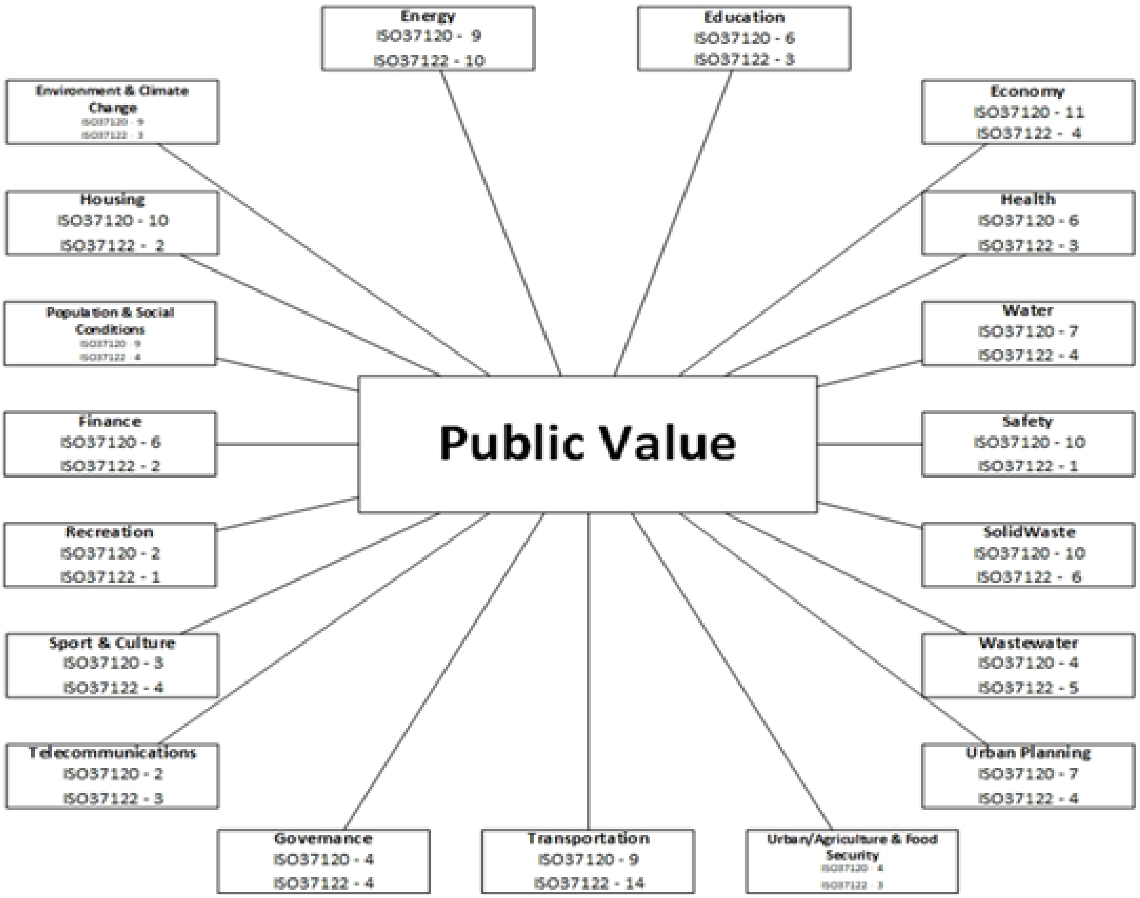


Figure 8. ISO themes (Number of metrics by ISO Standard) and the creation of public value.

Using the four helices identified by Lombardi et al. (2012), we provide a set of measures (ISO, 2018., ISO, 2019) and relate them to city goals (see Appendix 2, Table 11.).

It must be noted that for a metric to be used, the city must have the capacity to reliably measure and store the metric data. Once in place, this knowledge generation will provide data to be used by the city for informed decision making.

Quality of Life

An analysis of city mission statements in the United States has shown that quality of life is an overwhelming guide for city leaders (See Table 10). The World Health organization defines quality of life as an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards, and concerns (World Health Organization, 1997). Quality of life, per se, has not been a widely studied topic in information systems research. Mason (1986) noted in his examination of ethical issues that "at stake with the increased use of information technology is the quality of our lives…" When studied in the information systems research literature, quality of life issues are most commonly seen in the context of work issues. Igbaria et al. (1994) define quality of work life as an "individual's affective reactions to both objective and experienced characteristics of the work organization" (p. 176). While smart city projects may affect the quality of work life for employees, and this may provide public value benefit to the city, we generally think of smart city projects as benefiting the lives of citizens and stakeholders.

The effect of information technology on quality of life continues to evolve and breach the work-life boundary. Koch et al. (2012) have studied how social network systems acclimate new IT hires into an organization while Karanasios and Allen (2014) studied how mobile technology leads to new patterns of work. By its very nature, quality of life is systemic in nature (Simon, 1996), A city is an artificial phenomenon, therefore, to meet the goals of the city, a smart city project must continually respond to its environment while maintaining an invariant relationship with the goals of the city (Gharajedaghi & Ackoff, 1984) (Simon, 1996). This study continues the progression of research into the impact of information technology on the general quality of life of a city's citizenry.

Economic Development

Economic development is defined as the level of business activity in a community (Wassmer, 1994). Cities must therefore attract business and offer economic opportunities to its citizens. Today, the opportunities must be in the finance or technology sectors for young people to either stay in a city or to choose to migrate to a city (Bartley, 2006). Economists generally focus on income levels, urbanization, and education levels as indicators of economic development (Thompson and Lanier, 1987), while there is an argument for also measuring economic diversity and providing inter-industry linkages (Thompson and Lanier, 1987) (Wagner and Deller, 1998). See Appendix 2 for a list of economic metrics, their helix, ISO Theme, and their city goal category.

Sustainability

Sustainability relates to the conservation of natural resources, sustainable usage of land through urban planning policy, and the control and monitoring of pollution (Ramaswami, et al. 2016) (de Jong, et al. 2015). The European Union has the view that a Smart City's main aim is environmental sustainability (Ahvenniemi et al. 2017). While environmental sustainability is a worthy goal, I believe that is too narrowly defined for use in a city context and that sustainability should also include economic development factors, environmental innovation, and the governmental regulations that can also guide corporate environmental strategy (Tsai and Liao 2017). A link has been recognized between quality of life and environmental concerns, therefore sustainable economic development, through the planned use of land. Monitoring and mitigation of the effects of economic growth will allow for a city to meet its goal of sustainability. (Teodorescu, 2015) (Inglehart 2000). Sustainability indicators for cities are discussed in the International Standards Organization in ISO 37120:2018 (ISO, 2018).

Action Design Research and Design Science Research

Design Science enables research via the creation and evaluation of an IT artifact designed to solve an identified organizational problem or business need (Hevner, et al.,2004). The created artifact should be relevant and deemed valid by the relevant scientific community based on the arguments and assumptions used when designing the artifact coupled with empirical proof of artifact utility based on an observed implementation. (Ostrowski et al. 2014). A city, like any organization, is an artificial phenomenon (Simon, 1996), meaning that it is a man-made construct; therefore, ADR and DSR can be used to develop knowledge for the design and realization of artifacts that allow for the improvement of existing systems or the design and implementation of new systems (van Aken, 2004). The goal of ADR/DSR is to provide a robust scientific basis for a practitioner to build or improve a system using the designed artifact as the template for the practitioner’s instance of the system (van Aken, 2005). ADR/DSR provides for the understanding of a specific problem domain so that solutions may consistently be successfully implemented. However, understanding a problem is not enough, and a goal of ADR/DSR is to develop knowledge so this knowledge can be applied to the solution domain (Gregor and Hevner, 2013).

The question that must follow from the above is, when building a solution to a specific problem, is the process valid research or simple consultancy work? Can an ADR/DSR approach to improving or implementing new smart city information system be considered scientific method? According to Kuhn’s scientific paradigms, this depends on the current scientific context (Kuhn, 1970). Kuhn defines paradigms as a set of beliefs about how problems are understood that are shared by scientists. Buckminster Fuller & Kuromiya (1992) define design science as “The function of what I call design science is to solve problems by introducing into the environment new artifacts, the availability of which will induce their spontaneous employment by humans and thus, coincidentally, cause humans to abandon their previous problem-producing behaviors and devices. For example, when humans have a vital need to cross the roaring rapids of a river, as a design scientist I would design them a bridge, causing them, I am sure, to abandon spontaneously and forever the risking of their lives by trying to swim to the other shore".

Design science is therefore concerned with the creation of an artifact that can solve a problem, whereas science involves the observation of the artifact and its effects. Systems thinking enables the placement of an individual artifact, within a collection of artifacts, processes, and their environment, to define how the artifact should operate in conjunction with its companion artifacts, businesses processes and the environment in which the artifacts operate.

Sein et al. (2011) identify action design research as appropriate when there are complex interactions among sub-systems and that an inherent flexibility to change design processes as well as design artifacts is required. They developed ADR to allow for the creation of artifacts that include ICT, people, and processes. In this paper I use the multilevel design process shown in Figure 2 to show how to create an ADR artifact that is integrated into a larger set of systems. In information systems research numerous articles note that many scientific findings from traditional empirical research are irrelevant for or inaccessible to practitioners (Kitchin et al., 2017). I use a case study to show how bridge that ‘last mile’ so that smart city practitioners and

IS researchers can look at city-based technology differently, allowing them to solve relevant problems while defining success in a way that is meaningful to the city in question (March and Smith, 1995). The smart city framework (Figure 2) ensures through theory that the ad hoc methods previously followed to choose smart city projects can be abandoned and that the city remains in control of its smart city efforts and its ICT systems through the authorization process (Figure 7) and the governance processes built into Figure 2.

A goal of ADR/DSR is to produce artifacts that enable the attainment of human defined goals (Simon, 1996). Building the artifact and evaluating the artifact are the main issues in design research (March and Smith, 1995) who identify four types of artifacts: - constructs, models, methods, and instantiations.

Construct artifacts provide a city with a vocabulary and lexicon with which problems and solutions can be defined (March and Smith, 1995). This is required by the city to understand and frame the problem identification in stage 1 of ADR. Stage 2 of ADR requires building system models that are sets of propositions or statements expressing a relationship among constructs. Methods are then a set of instructions that can be used to perform a task. Instantiations are then the implementation of an artifact in a specific environment. This is the BIE process stages of ADR. By taking a systems approach to building an artifact that is designed to perform a specific task and be integrate into a set of city systems, I show how the artifact can be built within the context of a city and then serve as the proof of concept. Through the reflection and learning processes (ADR Stage 3) I demonstrate the public value of the artifact (Moore, 2013) (Geuijen et al., 2017).

In ADR Stage 3, refection and learning will contribute to and provide 1) classification of smart city system outputs, and 2) definition of measurements of system performance based on the defined system outputs. Continuing to ADR Stage 4, a practical generalized model for smart city design emerges. I will build and test an instantiation of the model (Hevner et al. 2004) (Sein et al., 2011). This fills yet another gap in the extant research as system design and integration at the city level has received little attention. Therefore, the artifact designed in this paper solves a wicked problem (Buchanan, 1992) (Hevner et al., 2004) and, following Gregor and Hevner’s (2013) knowledge contribution framework, we are developing a new solution for a known problem.

While the process described in this paper follows the ADR schema defined by Sein et al. (2011) for its general format, I also overlay the ICT design activities required by Hever et al. (2004) where appropriate. This combination is powerful because ADR offers a pragmatic research approach to the development of systems artifacts that that affect action, while Hevner's DSR process guides the creation of IS system artifacts that fit with business processes, socio-technical system outputs, and smart city business outcomes, resulting in engaged scholarship (Hirschheim, 2019).

Sein et al. (2011) describe how to define the knowledge contribution ADR, but they offer little guidance on the practical process of constructing the artifact. The six activities provided by Peffers et al. (2007) overlap with Gregor and Hevner and provide a firm methodology for artifact building. In general terms, Peffer's process is to: focus on problem identification, the prior knowledge base, and the value of this solution, define the outputs of the system with respect to the problem definition, define a generalized artifact that can guide a smart city implementation by defining the inputs required and a set of generalized goals, and document a field study of an instance of the artifact developed. These activities provide a practical framework that a city can follow to produce the identified measurable outcomes. Evaluating an instance of the developed system is Activity 5 (Gregor and Hevner, 2013) while the last activity focuses on the results of the framework and any required changes. The last two activities are described in this paper.

Multilevel Smart City Process

ADR Stage 1. Defining the problem

The term Smart City has been in general use for two decades (Doran & Daniel, 2014) (Lombardi, et al. 2012) and in recent times the concept has also been communicated under other monikers such as digital city, intelligent city, cognitive city, and knowledge city. Unfortunately, many definitions of smart city have been promulgated. Albino, Berardi, & Dangelico (2015) identified a large list of definitions for smart city used in research papers over the last ten years. These definitions of Smart City can be categorized in ways that capture the focus of each definition (Table 3). Some definitions have a secondary focus, so I identify a secondary category. The identified categories are:

- Technology – The focus of the definition is on how Information and Communications Technology (ICT) can be used to affect an artifact within the city, or the focus could be on a specific technology implementation.
- Sustainability – The focus of the definition is on sustainability using ICT. Sustainability can refer to resource use, financial responsibility, or environmental control.
- Economic Development – The focus of the definition is on how ICT can improve the growth and economic output of a city.
- Quality of Life – The focus of the definition is on how ICT can improve the quality of life to citizens living within the city. Quality of Life includes public safety, education, and facilities.

Most smart city definitions focus on ICT (Table 4). This focus on technology is partly because of overwhelming majority of smart city papers are case studies or a description of specific implementations of ICT to meet a narrowly defined goal of a single smart city sub-system. I believe this focus on single sub-systems is restricting research and implementation of smart city technologies on a large scale. Emphasis must be put on the overall goals of city leaders. Moving the focus from technology to goals provides a unique solution to the problem of defining what a smart city or digital city is and by focusing on the actual benefits of the smart project researchers will provide a more salient view of project success and the goals of the designed artifacts (Sein et al., 2011) (Hevner, et al. 2004).

Table 3. Categories from Smart City Definitions Review

	Category 1 Count	Category 2 Count
Technology(ICT)	18	1
Sustainability	2	3
Economic Development	0	3
Quality of Life	1	3

The overall goals of a city are usually found in a city mission statement or strategic vision document much as business goals are promulgated through mission statements or strategic vision statements. When considering the focus of city mission statements, I believe the overwhelming focus on ICT in the smart city definitions is unfortunate. Table 10 in Appendix 2 shows a review of city mission statements from cities in North America. Table 4 summarizes the data from Table 10. Using the same categories as the smart city definition focus, it becomes evident that technology per se is not a focus of city leaders and city planners who overwhelmingly focus on quality of life for the citizens.

Table 4. Summary of Identified Categories from City Mission Statements

	Category 1 Count	Category 2 Count
Technology(ICT)	0	0
Sustainability	5	3
Economic Development	0	5
Quality of Life	18	1

This disconnect between what the city needs, and the focus used in many development projects may inhibit the development of municipal technology infrastructure to build smart cities because the purpose of the technology does not appear to be at all aligned with the purpose of the city. Stakeholder theory states that organizational success (i.e., the city's success) is dependent on how well the organization manages the relationships with key groups (Freeman, 1984) so to affect the overall purpose of the organization (Freeman and Phillips 2002). By narrowly defining smart city projects in terms of technology and, in many cases, a specific technology, city leaders may not be able to identify how a specific project enables them to be seen to be supporting projects that meet the defined goals of the city, and ultimately the citizens or stakeholders themselves.

Rather than propose yet another definition of smart city, I focus on the action of being smart. Failure to align the city technology plan with the overall strategic plan of the city results in failed technology projects and wasted resources (Gerow, et al. 2014) just as it does for an business organization. Following the frameworks, theories, and methodologies set out above, I capture the smartness of the system with respect to the goals of the city, rather than focus on "smart" initiatives and technology. This links the system task to the strategic vision of the city. This concept is missing in the extant literature, even those that discuss city systems or collections of systems (MIT. 2015) (IBM, 2015).

The in-field problem addressed by this current research is whether a smart city system of systems can create public value utilizing the artifacts designed in Figures 2 and 7. ADR requires that the problem be framed an instance of a class of problems. Pereira et al. (2017) identify that smart city solutions must create public value (Moore, 1994) and provide benefits equally across the entire city. Because quality of life appears in most city mission statements; therefore, I use this as a guiding factor in developing the systems artifact and the measures (ISO, 2018) that can define success for this research.

ADR Stage 2: Building, Intervention, and Evaluation

In government information systems, the information and applications tend to exist in silos, with little information sharing because of the hierarchical nature of government organizations (Bigdeli, et al. 2013). For a smart city to be successful, an operational set of systems needs to be developed that ensures ICT systems are integrated as required by Figure 2. In this case study, municipal information systems and governance is defined as a collective set of systems and processes that work together in a purposeful manner to increase the quality of life of citizens, increase the economic opportunity of citizens, and provide for resource sustainability. By taking a resource-based view of the city, the goal of this smart city project is to optimize the integrated systems utilized by the city to maximize these three identified system outputs (Mata et al. 1995). Each systems connection and sub-system in Figure 14 represents a set of information flows between the integrated sub-systems and must be shown to service the system outputs, otherwise it is not critical to the municipal organization’s success. For this to be successful, the city’s mission statement and stakeholder needs should be aligned. If this is not the case, then project success will not be possible, as either stakeholder needs will not be met, or the project will not meet the mission statement of the city. The project authorization process in Figure 6 ensures this alignment of mission and stakeholders takes place.

Smart city definitions focus on the whole city including government agencies, non-governmental organizations, schools, private business, and citizens. However, a municipal government cannot affect the systems and processes of non-municipal entities. The system we propose will be for a municipal government and its agencies (Stratigea et al., 2015). Thus, all integrations within the framework must contribute to an identified focus of city leaders (Figure 8) and qualitative indicators must be defined to measure the effects of a city project or initiative based on the categories identified in Table 10 and Table 11 in Appendix 2. Measuring the success of a project in terms of the city's mission statement relates the public value of a project back to the mission of the city. Lombardi, et al. (2012) propose a modified Triple Helix model with indicators for measuring smart city initiatives. The four-helix model can be operationalized by being linked to the three foci identified in Table 11 and then summarized in Table 4, thus providing a classification of the smart city indicators in the terms of the city mission statements. Table 11 in Appendix 2 shows the city focus category, the associated helix, the ISO theme, and example indicators to measure each smart city projects success. Every city can choose from measures identified by Lombardi, et al. (2012) or the ISO (2018) based on the project it is implementing and the chosen definition of project success.

A Generalized Systems Model for Smart City Implementations

A generalizable framework needs to be designed for smart city projects. To design this model, I use a systems thinking approach, utilizing the comprehensive framework of Management Information Systems (Nolan and Wetherbe, 1980). This system/sub-system approach allows cities to design their own specific instances of systems and integrations while following a generalized model to ensure city technology projects are focused on delivering improvements to the cities identified goals.

Given the categories of importance as indicated by city mission statements, each smart city project should be measured on how it improves a citizen's quality of life, the economic development opportunities offered to citizens and how it provides for more sustainable use of resources by the city. Cities are complex entities that are managed through via complex system of systems (MIT, 2015). This complexity is in part because of federal regulation, state regulation, local culture, local regulation, and geographical location. For example, Coastal cities have different systems designs and requirements than high altitude cities. Cities are greatly affected by their regulatory system, size, and environment (Grimm et al., 2008) and therefore municipal systems will differ significantly from one city to the next despite the common goals evident in mission statements.

A Smart City Systems Model Instance

A smart city must build a collection of infrastructure solutions that include an integrated data center, integrated applications, integrated data, and an advanced communications network capable of collecting data from a myriad of locations, particularly Internet of Things (IoT) sensors (Dirks & Keeling, 2009). The systems integration model should show each city system and the links between systems should be identified with indicators showing the data flow direction. Figure 9 shows the actual system design for the prototype living lab.

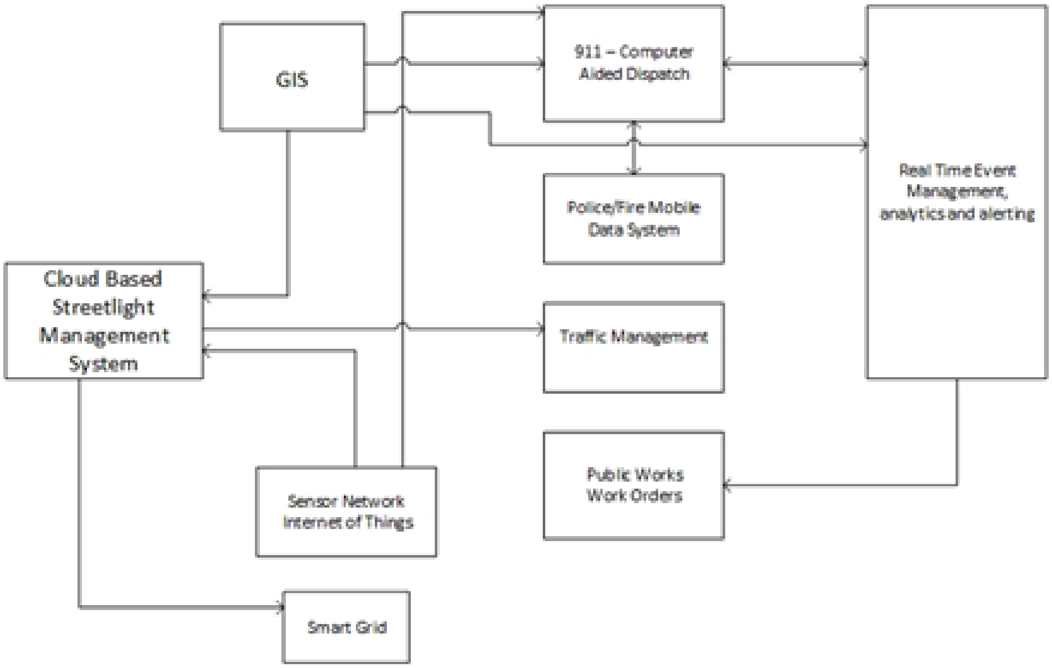


Figure 9. Neighborhood Streetlight Systems Framework

Utilizing Figure 2, the authorization process for this project was based on cost savings. The initial iteration cycle for developing this system focused on creating a smart streetlight system that initially focused on reducing the cost of managing the over 7800 streetlights within the city. However, after looking at the features and options with such a system, subsequent iterations occurred to design a system capable of ingesting data from additional sensors and utilizing system integrations to provide greater benefits beyond those of the individual project. The BIE process had many implementation challenges, beginning with information silos that exist within a city. These needed to be eliminated so that the required infrastructure could be built, and the data shared between all departments (Bergh and Viaene, 2016). Many studies seek to identify the core components that make a city smart (Gil-Garcia, et al. 2015) (Stratigea, et al. 2015). Evaluation that occurs throughout the BIE process helps ensure that the designed systems model provides a city with a road map to build a systems infrastructure that maybe followed in any order using any technology available. Cities can choose projects and implement this model partially and in any order the city sees fit. The value of this model is in the flexibility it gives a city as it moves forward with its smart projects and initiatives. At times, use of the model may encourage other projects. In this city project, for example, a need for full integration of all city systems became apparent and the work was also undertaken. Appendix 3 provides additional detail on this.

Implementation

A small city in the southeastern United States is following the Systems Framework elucidated in Figure 2 and the systems model from Figure 9. The city has previously implemented fiber to the home (FTTH) and now wishes to build on that investment with smart city initiatives. The city has undertaken a smart streetlight project to begin its smart city journey. This project will require access to the fiber network already installed within the city and will overlay a wireless network capable of supporting a large IoT infrastructure. The city covers approximately 150Km2 and has over 7800 streetlights. The current electric bill for those streetlights is approximately $978,000. The City of Opelika wishes to reduce this expense and provide brighter, smarter lighting across the city. The expected benefits of this project are to significantly reduce the power bill to the city and to increase the perceived safety of citizens (Haans and de Kort. 2012). By reducing the expense of operating the streetlights, the cost passed on to citizens in their electric bill will be reduced, thus increasing quality of life. Also, the amount of power consumed by the new LED based dynamic lighting system will be less than that of the current high pressure sodium streetlights, thereby increasing sustainability (ISO, 2018). Brighter, responsive lighting will also improve a citizen's perception of safety in that area, another quality-of-life issue.

The city has chosen a neighborhood as a prototype living lab to ensure the technology performs as expected. Figure 10 shows the neighborhood location on GIS parcel map. This neighborhood was chosen because the city wished to view the technology in a residential area with several lights. This neighborhood contains 180 streetlights. As an older area, it also has a considerable amount of foliage. This allowed the city to challenge the viability of a wireless network in such an environment as it replicates many treed neighborhoods that will eventually be covered by the new lighting system. The wireless network is required because, although the city has fiber network cables available, connecting all streetlights via fiber is not economically feasible. The city conducted a 900MHz wireless survey and could guarantee available bandwidth to all streetlights.

Initially the city utilized cost savings anticipated from installing LED lighting as the original justification for authorizing the project. Table 5 shows the current cost of operating the streetlights within the chosen area and Table 6 shows the predicted cost of a new dynamic streetlight system used in the authorization process.

Figure 10. Prototype Neighborhood GIS Street Map

In Figure 10, each small circle at the center of the larger circle represents the location of a streetlight with a motion sensor. The small circle with three inner circles (blue circle with yellow interior) represents a streetlight with a motion sensor and cameras. The camera streetlight will host two 720p 1 Mega Pixel high-definition cameras pointing in each direction on the road. The camera will provide metadata that includes traffic counts with directional information, pedestrian counts with directional information, and can recognize flooding water on the streets. The camera streetlight requires a total network bandwidth of 6Mbps to stream the video to monitor stations within the city. The video from the streetlight will be stored on the streetlight itself, giving up to six days of video available for manual download to the city's video management system. Two wireless gateways are used in this project to ensure the mesh wireless solution chosen will self-heal and report network down issues back to the city for remediation.

Table 5: Current Cost of operating streetlight in chosen neighborhood

Description	**Unit Cost**	**Total Cost (12 year life)**
Lighting arm and Light shell (400W)	$449 x 179 lights	$80,371
Bulbs and replacements (Bulbs changed every 3 years)	$89 x 179 x 3	$47,793
Labor costs for light installation and replacement	$550 x 179 x 4	$393,800
Operating Cost based on 8-hour average daily usage @6.3 cents per kilowatt hour	((400W x 179)/1000) = 71.6KWh x 8hours x 365 days = 209,072 KWh per year	
Operational Power Cost	209,072 * 0.063 = $938.20 per year * 12 years	$158,058.43
Total System Cost		**$680,022.43**

Table 6: Projected cost of Dynamic Streetlights and their operation in chosen neighborhood

Description	**Unit Cost**	**Total Cost (12 year life)**
Lighting arm and LED 150W (LED Light is replaced every 12 years)	$109 x 179	$19,511
Dynamic Lighting System Cost (12 years)	$13,998.00 + (software maintenance $24.95 per light, per year) 179 x $24.95 x 12	$67,590.60
Labor for installation	$550 x 179	$98,450

Light operational Cost (estimated) 2 hours at 80% power and 6 hours at 20% power	(((0.8*150)*179)/1000) = 21.48KWh * 2 hours * 365 Days = 15,680.4KWh per year (((0.2*150)*179)/1000) = 5.73KWh * 6 hours * 365 Days = 11,760.3KWh per year	
Operational Power Cost	(15,680.4+11,760.3)* 0.063 = $1,728.77 per year * 12 years	$20,745.17
Total System Cost		**$206,296.77**

The savings to the city by switching from traditional streetlights to dimmable smart streetlights is 69.66%.

Systems thinking requires that I now look at other benefits this system may offer, as this system fundamentally expands how streetlights work within a city.

The dynamic nature of the streetlights means that after 10pm the streetlights are dimmed, unless a sensor, in the form of a camera or Lidar radar, detects the movement of a person or vehicle and thus reverts the LED’s to its 80% mode.

By utilizing machine learning and artificial intelligence, these cameras can detect vehicle license plates listed on the BOLO (Be on looked out for) list by the local police department as well as detect collisions, road conditions, and provide general monitoring. Figure 15 shows how the data is fed to various systems via an event driven technology artifact.

The following data shows an analysis of the crime statistics for this neighborhood covering the months of February to July over the years 2014 - 2020. The system was operational in February, 2019 and data was collected in August, 2020. This time period includes COVID related lockdowns throughout the city .

Table 7. shows the total number of crimes committed over the period of investigation.

Table 7: Total Number of crimes by type of crime 2014 - 2020

Crime Type	**Total Number of Crimes**	**Percentage**	**Cumulative Percentage**
Juvenile Involved	85	4.8	4.8
Drug	104	5.9	10.7
Escape	3	0.2	10.9
Property	727	41.3	52.2
Sex	10	0.6	52.7
Traffic	15	0.9	53.6
Violent	818	46.4	100
Totals	**1762**	**100.0**	

Table 8. shows the total number of crimes for each year covered by the study (2014 – 2020).

Table 8. Total Number of Crimes Per Year

Year	**Total number of Crimes**
2014	284
2015	286
2016	215
2017	270
2018	286
2019	214
2020	207
Total	**1762**

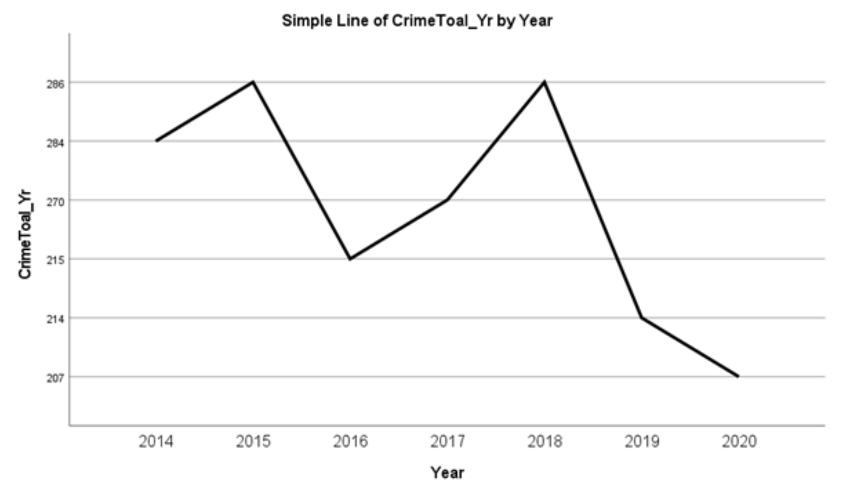
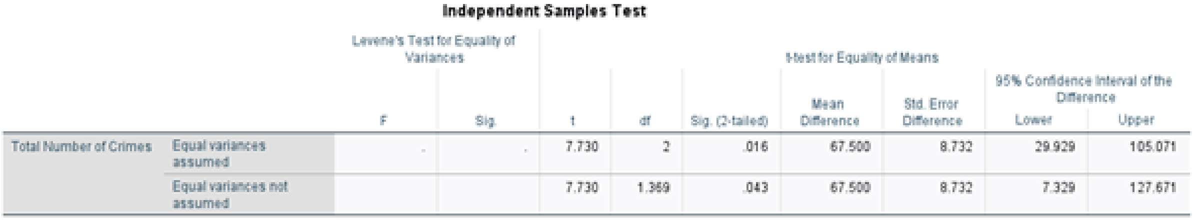


Figure 11. Line Graph of total crimes per year

Figure 11. Shows a decrease in crime across the neighborhood studied for the years of 2019 and 2020.

There is a drop in total crimes during 2016. This results from a large construction project in the main park in this area and a continuous security presence to protect the construction site and equipment. This disrupts our data slightly, but 2017 and 2018 numbers reflect the pre-2016 levels of reported incidences. A decrease in 2019 appears to be related to this project as no other explanation has been found. The further drop in 2020 may be COVID related; however, the consistency in the numbers in 2019 and 2020 indicate that it the pandemic did little to deter criminal behavior (as is evident throughout many cities in the United States) but the streetlights are continuing to do so.

However, if take the 2 years prior to the streetlight project implementation and the 2 years of data since the project implementation 2017-2018 and 2019-2020 as our groups.

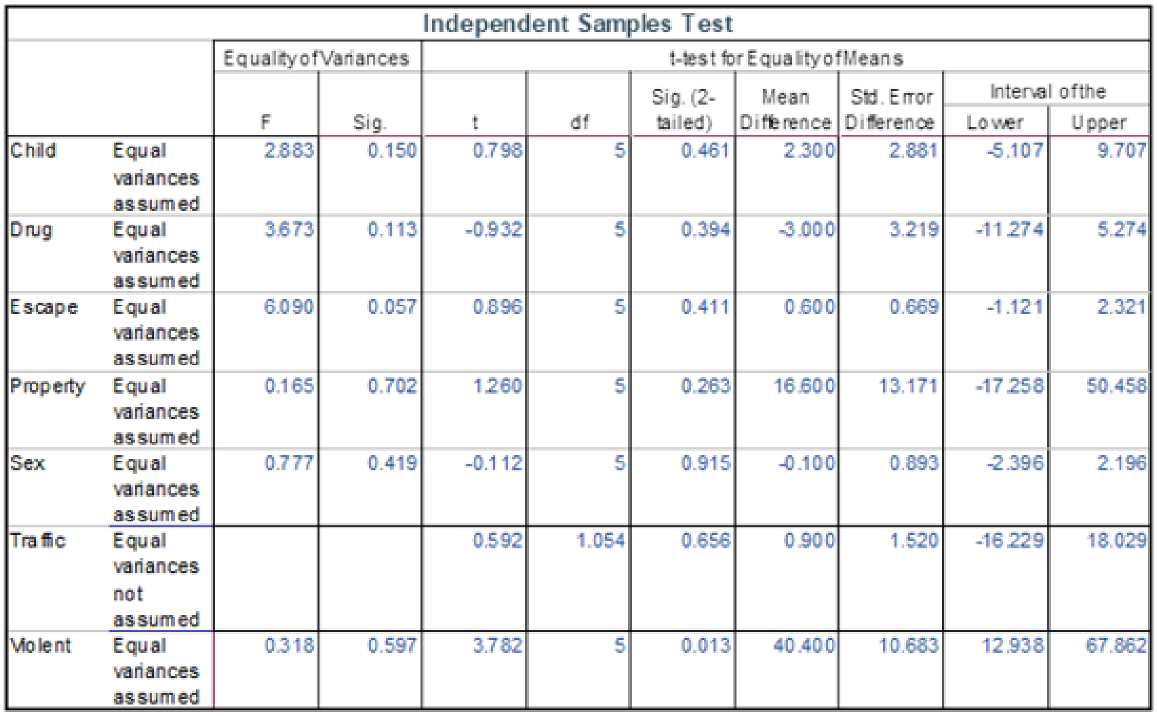


Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Total Number of Crimes	Equal variances assumed	.	.	7.730	2	.016	67.500	8.732	29.929	105.071
	Equal variances not assumed			7.730	1.369	.043	67.500	8.732	7.329	127.671

Figure 12. Results of Independent T-tests for total crimes using groups years 2017-2018 and 2019-2020

When running an independent t- test comparing the years of 2017-2018 with the years 2019-2020 Figure 12. when the project had been implemented demonstrated a statistically significant difference for the total number of crimes crime, t(2) = 7.73, p = .016.



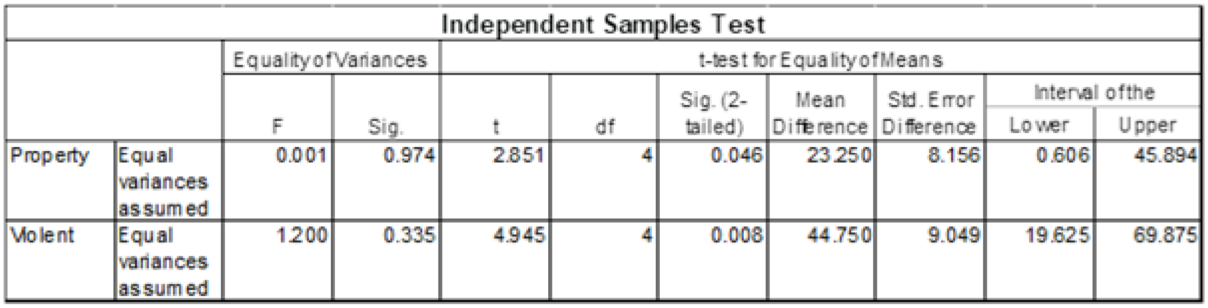
Independent Samples Test

		Equality of Variances		t-test for Equality of Means						
									Interval of the	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Child	Equal variances assumed	2.883	0.150	0.798	5	0.461	2.300	2.881	-5.107	9.707
Drug	Equal variances assumed	3.673	0.113	-0.932	5	0.394	-3.000	3.219	-11.274	5.274
Escape	Equal variances assumed	6.090	0.057	0.896	5	0.411	0.600	0.669	-1.121	2.321
Property	Equal variances assumed	0.165	0.702	1.260	5	0.263	16.600	13.171	-17.258	50.458
Sex	Equal variances assumed	0.777	0.419	-0.112	5	0.915	-0.100	0.893	-2.396	2.196
Traffic	Equal variances not assumed			0.592	1.054	0.656	0.900	1.520	-16.229	18.029
Violent	Equal variances assumed	0.318	0.597	3.782	5	0.013	40.400	10.683	12.938	67.862

Figure 13. Results of Independent T-tests for each crime type using groups years 2014-2018 and 2019-2020

Figure 13 shows the results on independent t tests for the averages of 2 groups. Group 1 is the years 2014 to 2018 and Group 2 is the years 2019 and 2020 where the streetlight system was installed. The 5 years (2014-2018) compared to the 2 years only demonstrated a statistically significant difference for violent crime, t(5) = 3.78, p = .013. There was no significant change for all the other crime types. There was also no statistically significant difference between Group 1 and Group 2 totals for the years studied.

Figure 14 shows the results of independent t tests for the averages of 2 groups with 2016 removed because of the anomaly of the park project influence on the numbers. Group 1 is the years 2014, 2015, 2017, and 2018 and Group 2 is the years 2019 and 2020 when the streetlight system was installed. Group 1 compared to group 2 years demonstrated a statistically significant difference for violent crime, t(4) = 4.945, p = .008. there was also a statistically significant drop for property crime t(4) = 2.851, p = .046. There were no significant differences for all the other crime types

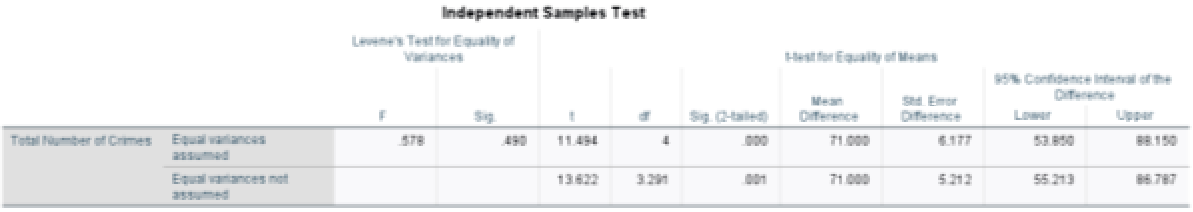


Independent Samples Test

		Equality of Variances		t-test for Equality of Means					Interval of the	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Property	Equal variances assumed	0.001	0.974	2.851	4	0.046	23.250	8.156	0.606	45.894
Violent	Equal variances assumed	1.200	0.335	4.945	4	0.008	44.750	9.049	19.625	69.875

Figure 14. Results of Independent T-tests for each crime type using groups years 2014, 2015, 2017, and 2018 in group 1 and 2019-2020 in group 2.

Figure 15 shows the results of independent t-tests for the averages of group with 2016 removed for the total number of crimes. Group 1 contains the crime totals for years 2014, 2015, 2017, and 2018 whereas group 2 is years 2019 and 2020.



Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Total Number of Crimes	Equal variances assumed	.578	.490	11.494	4	.000	71.000	6.177	53.850	88.150
	Equal variances not assumed			13.622	3.291	.001	71.000	5.212	55.213	86.787

Figure 15. Results of Independent t-test for Crimes total excluding 2016.

In the independent T-test, Group 1 compared to Group 2 demonstrated a statistically significant difference for total crime, t(4) = 11.494, p = .000. between Group 1 and Group 2 with the crime in the years 2019 and 2020 been statistically significantly lower.

Figure 16. shows a monthly break down of the crime data for each crime type for each year of the study. This data is overlayed with a trend line. The smart city administration found this report to be the most useful when reporting this data to city stakeholders.

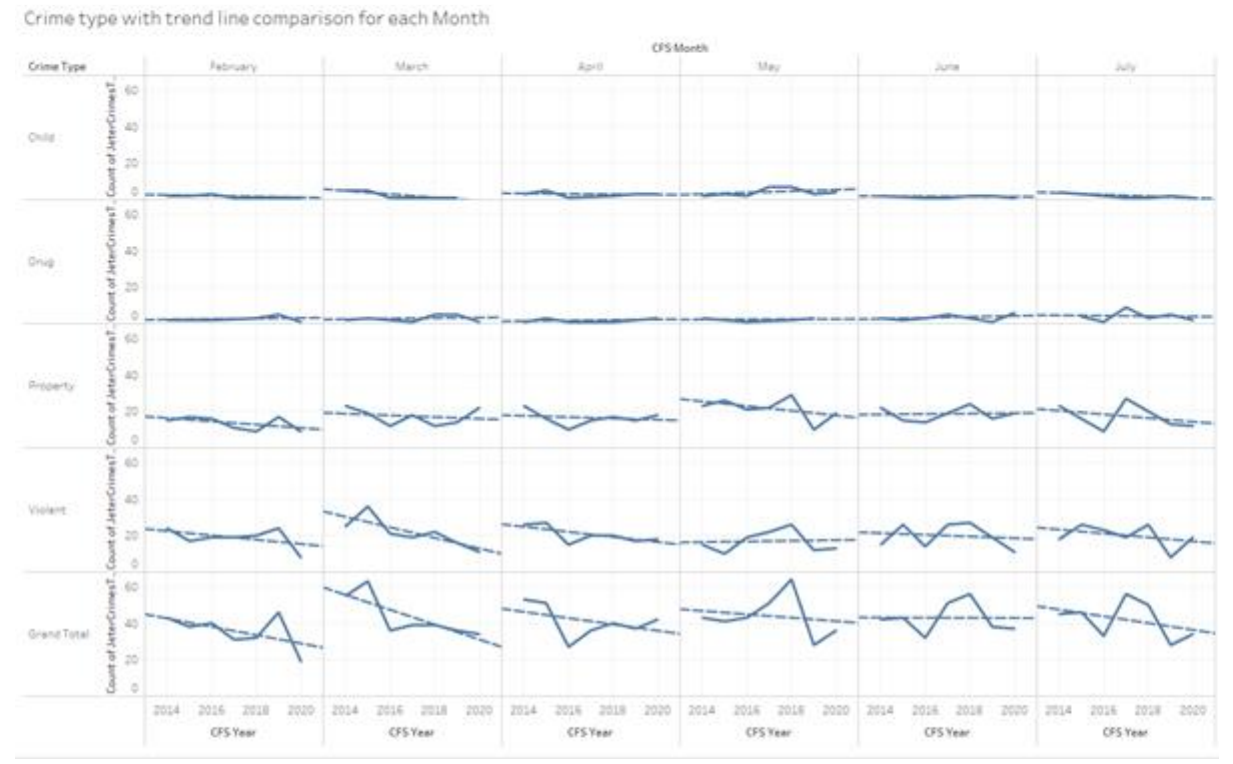


Figure 16. Analysis of crimes by type, month by month comparison for each year.

Figure 16. shows a declining trend in property and violent crimes, with the downward trend being most pronounced for violent crimes in the month of March. It is notable that in the second year of this project we saw increases in crime in April through July of 2020. Unfortunately, I cannot make any conclusions on this because this change in data maybe COVID pandemic related as the 2020 lockdown covers these months.

ADR Stage 3: BIE Process - Reflection and Learning

The Streetlight system started as a simple cost-saving project to convert older streetlights to LED. Tables 5 and 6 show the costs of a legacy streetlight system and the projected costs of a smart streetlight system. However, a second design iteration was implemented when it was realized that using smart LED controllers allowed control over the streetlights from a central location. Preferring automated control over manual control, a system was designed (Figure 14) to allow for automated rule-based control.

This reflection on the design allowed each iteration to extend the functionality of the initial system design. The features and integrations in the final artifact represent a continuous adaptation according to the systems analysis and evaluations that took place. The guided emergence of the streetlight system took place as the system designers looked at how the control of the streetlight system could be integrated at the city level into other systems, thus taking this from a single system to an integrated part of the entire smart city system. Through the designed data flows and links to public safety and work order systems, this allowed the city to derive more public value from the streetlight system than originally predicted in the authorization process. Once the technology artifact is designed and operation, subsequent design iterations can be ideated, and implemented, utilizing the smart city framework and basic technology design principals such as "agile" via the project management processes built into the smart city framework. These are not possible to see prior to observing the artifact in action.

Figure 9 shows the simplified systems framework required for the prototype streetlight project. The IoT network will integrate the sensors on the streetlights to various city systems. The city's streetlights are currently unmetered, making light or group of lights cost data difficult. Using an IoT sensor to meter each streetlight and passing that information to the smart grid system will enable the city to know exactly how much power is used by the streetlight system as a whole and will be able to group lights into neighborhoods or other groupings for reporting purposes. This information will also allow the city to quantify power lost within the distribution grid and make the grid more efficient and reliable if necessary. The video metadata provided by the camera nodes on the streetlights will be fed into the traffic management system to provide better traffic signal timing as the number of cars enter the main highway can be counted in real time. The video system can also identify potholes and standing water, thus enabling the automatic generation of work orders to unblock storm drains or fix the roads. In the event of crime, the camera nodes can send the video to the city's evidence management system for review.

The GIS system provides the mapping information to allow the city to report system usage and information based on location data. System troubleshooting is also map based, as device failures are reported by the real time engine to a map-based system monitoring solution that will automatically generate work orders in the trouble-ticket system in the event of a fault. The dimming solution aimed at saving power when no motion is detected is managed by the cloud-based Streetlight Management System.

Figure 17. shows how the streetlight project matches with the city missions of quality of life and sustainability goals. Matching the project to these goals ensures that the project helps the city fulfill its mission and that there is a direct and measurable benefit to the citizens of the city.

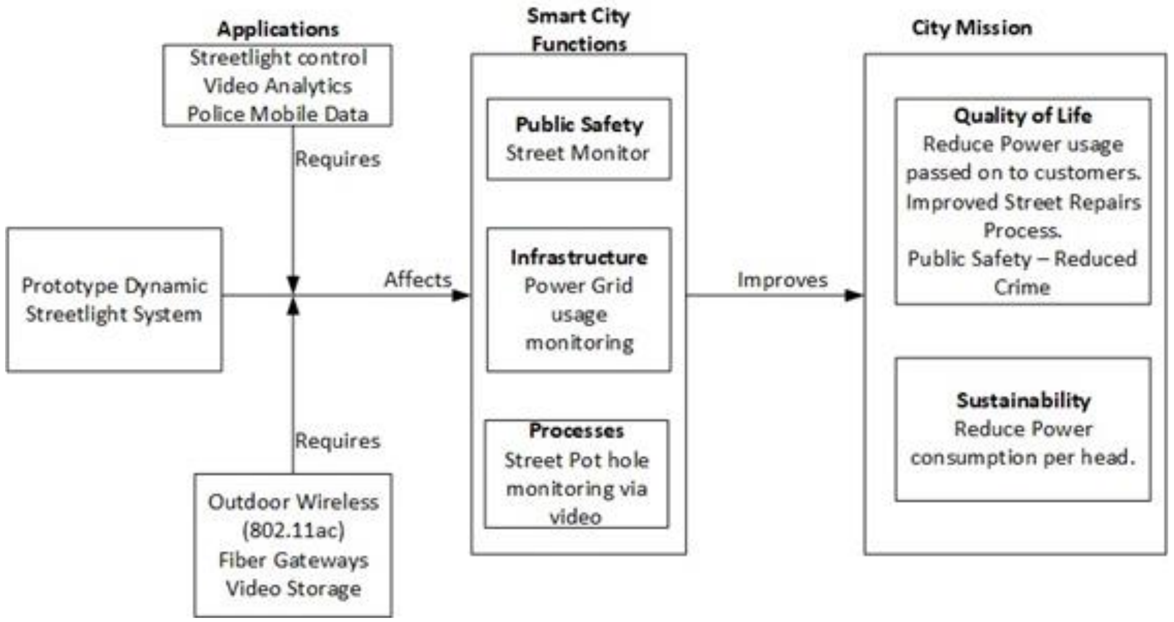


Figure 17. Smart City Project Framework for Dynamic Streetlight project

This project meets the smart city criterion by reducing the power utilized (sustainability metrics) in the city for streetlighting. This directly reduces the power consumption per head measurement, identified in the sustainability metric listed in Table 13. Quality of life is increased through the sustained drop in crime since the systems implementation.

ADR Stage 4: Formulization of Learning

Figure 18 represents a generalizable model that shows what a project undertaken by a city should require for inputs, the general functional operations of a city that could be affected and, based on our analysis of city mission statements, the goals that direct how the designed smart city sub-system outputs should be measured. The feedback is provided to ensure system control and to allow for internal system or policy changes that are needed to ensure internal efficiency and effectiveness. All city systems must respond to changes in the environment, which could include regulatory changes, citizen demands, and city leadership changes.

At this moment, smart city projects are being implemented and studied based on a specific technology of interest. This bottom-up approach to implementation will lead to smart city implementations that lack direction and cohesion. This ad-hoc approach to project initiation will frustrate city leaders and will lead to a disconnect between the missions and strategic goals of the city and the goals of the technology projects implemented under a technology driven smart city plan (Chatfield and Reddick 2016). Focusing on the identified outcomes and their associated metrics listed in Table 13 ensures a citizen focused approach to smart city projects or initiatives. A primary duty is that the city provide a safe environment for its citizens, infrastructure for economic development and growth, and defined governance.

These duties fall into three main categories. They are public safety, which includes police, fire, emergency medical response and emergency management; infrastructure, which includes streets, signage, engineering, grounds, environmental management, and building maintenance; and governance and processes, which are the ordinances and management processes of the city defining how citizens and businesses interact with their city government. To support these processes, a smart city, requires a sensor network (IoT), to measure and control smart city projects coupled with a set of applications, databases, and analytics to provide system functionality to users. Smart projects will add fidelity to these databases and applications.

The system model proposed in this paper expands on the work of Gil-Garcia et al. (2015) who identified smart city components and provided necessary integrations and system outcome measurement criterion to provide a framework for selecting and authorizing smart city projects based on optimizing increases in the identified outcomes as preferred by city stakeholders.

The focus of this paper is on the systems and sub-system integrations necessary for smart city projects to be successful. Public Safety applications provide tools for public safety personal to access data, for example, vehicle ownership information and vehicle tax payment history, in the field. A second example would include fire response plans for large commercial building being available with address location information to fire departments and rescue personnel. Infrastructure is the collection of applications and systems required to run the city, including ERP systems, revenue/taxation systems, billing, work orders, trouble tickets, and communications systems. Examples of data usage within the infrastructure include city infrastructure, its geographical location, and service information. Other examples of infrastructure application and data are business license bills, and permit inspection calendars, permit inspection reports and certificates. Governance and process include the applicable federal, state, and local laws and applicable regulations, for the operation of the municipal government, and all business processes in use within the municipal government.

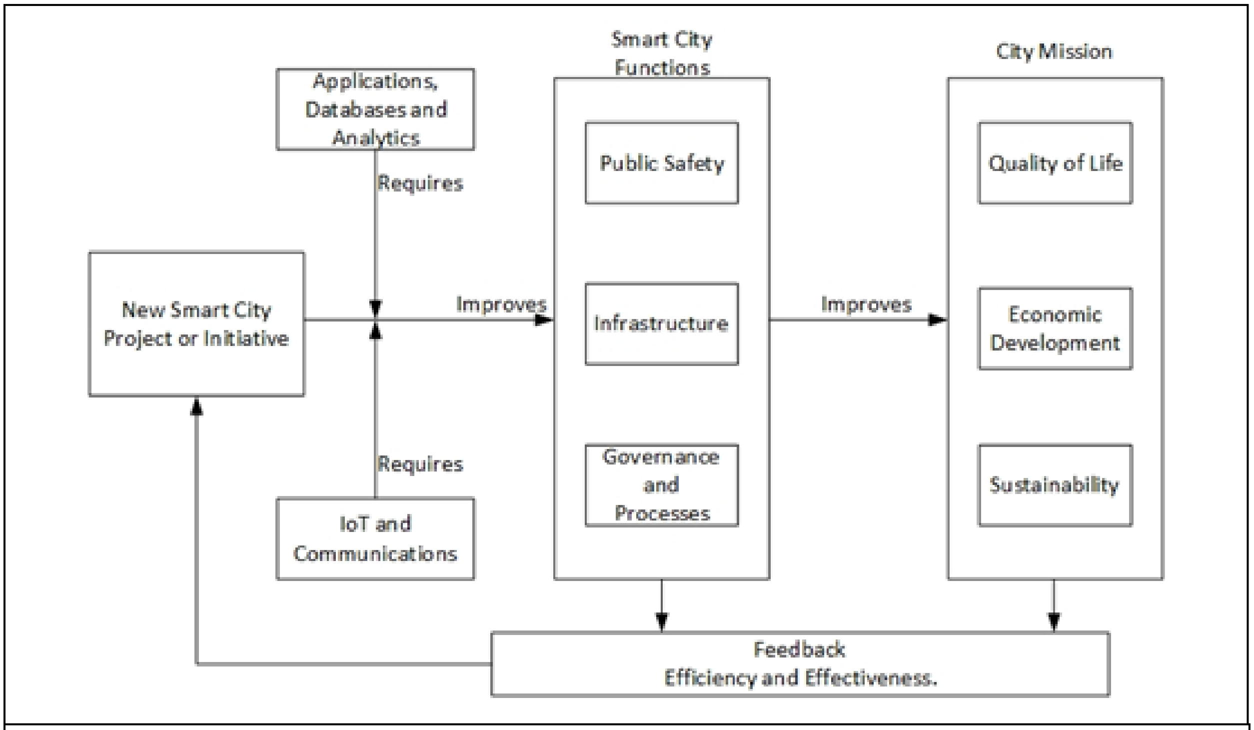


Figure 18. Generalized Smart City System of Systems based Framework.

Framework Usage

The generalized framework developed herein can be used to identify the outcomes a smart city project should have. By identifying outcomes, stakeholder support will be more likely as the smart city project can be mapped to city goals. The measurements required to directly measure system implementation success can be identified and reported, thus allowing the city to claim success and provide public value to citizens with reports showing how citizens have directly benefited from the project. The outputs of the new smart city systems must be fed into current systems to integrate new data and events into existing applications. Figure 2 shows that this will create new development cycles in affected artifacts through the city level design processes. The generalized systems framework developed in Figure 19 will allow for malleable sub-system design and data flows as well as freedom of choice in project and an implementation order that is completely flexible.

Discussion

The designs in this paper focus on the missions of the city rather than a technological definition of smart city. This allows a city to prioritize projects through its authorization process in a way that meets the overall strategic goals of the city and the city can measure success in terms of the city goals. This allows city leaders to have good predictive data on project outcomes that focus on their objectives, and project authorization can be undertaken by stakeholders with a clear picture of smart city projects, goals, and projected outcomes.

For a city project to be successful, the silos built between departments need to be broken down so the project can be implemented across departments and so that the data generated, and subsequent analytic results can be used to by all departments to drive further improvements and automation. Maintaining the focus of strategic city-based outcomes rather than on technology means improvements can be measured and focused on the citizen to define success.

Project Lessons Learned

The analysis of this project showed that is difficult to get disparate departments within a city organization to co-ordinate their efforts. Initial project ownership and maintenance responsibilities had to be negotiated to ensure individual department responsibilities were understood and agreed upon. Within the living lab, the IT department and Power Utility department specifically had to agree on light and sensor maintenance and upon access rights to the real-time data provided by the lighting sensors.

Real-time alerts to other software systems needed to be configured and integrated. This is an ongoing project within the city because each system in the city has its own APIs and information requirements. To pass data from one system to another requires a unique integration for each system. It should be noted that this is likely to be the case with every city, and thus a common system language or city operating system should include a data schema and ontology that all city-based systems can understand, thus making the passing of data or data flows between systems less onerous for cities to implement.

More generally, we expect the cities will have to require that system vendors spend more time explaining and defining how information can be added to and exported from their systems. Also, there is no standard method to generate and parse city specific data, thus making it difficult for cities to get data into and out of disparate systems. Cities will have to acquire more skills and capacity in data management and system integration to ensure such questions and details are fully understood. It is my contention that a set of vendor agnostic best practices models that include data flows and data formats would be significantly more useful to practitioners that the current focus on individual systems and vendor specific technologies.

Conclusions

The multilevel implementation of ADR has proved to be a feasible framework for building a smart city. Via the use of ADR, I have been able to structure this study in a meaningful way the provided a focus upon the knowledge generated and how the learning derived from a smart city project can be formalized.

ADR requires comparing the situation before and then after an artifact’s implementation, rather than using control groups for comparison. The overarching problem with smart city is the lack of design knowledge. I have developed a generalized system model for smart city designers to ensure system integration and a focus on city strategic outcomes. In the dynamic streetlight system testbed, the city thought that applying ADR in a multilevel way was very successful. The integrations between the streetlight system and the public safety system allowed data to be shared and showed a public value benefit beyond that expressed when the streetlight system was proposed.

Future Research

Cities are implementing smart city projects in an ad hoc fashion based either in a research need or some form of budget availability. The Multilevel ADR framework developed herein allows for a stakeholder driven approach to smart city development, allowing cities to focus on aligning these projects with their mission statements. Future researchers should use this framework to conduct future case studies in cities of different sizes, in different locations, and perhaps with emphases on other mission-related goals.

The significant number of systems in use in cities and governments will eventually require the use of a single language. A smart city schema or ontology that describes the data, and the data flows, allowing systems to easily communicate and share data and events with each other. Future researchers may want to model such an endeavor in the public safety realm, wherein the NCIC (National Crime Information Center) has defined how crime data is to be stored and communicated with state and federal government agencies.

The generalized systems framework developed in the paper is done so from a limited case study. Case studies such as this should be expanded in the future to cover a whole city.

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Dissertation Conclusions

Systems design, smart city goals and associated social indicators, the smart city model, the current concerns with environmental quality and with the qualities of urban life, and the increasing attractiveness of the strategic planning idea are driven by a common quest. In their own way each asks for a clarification of purpose, for a redefinition of problems facing a city, and for a re-ordering of strategic priorities to meet stated goals. This requires the design of new kinds of goal-directed actions for smart city operations that calls for a redistribution of the outputs of city governments programs and processes through different channels to the various competing public interests.

Systems thinking requires that we continue to measure the effect of each smart city intervention, such that as Jevon's paradox predicts, creating or expanding systems has not solved resource use problems as it may encourage the increased use of the system in question (Newman, 1991). Thus, Jevons' Paradox has important implications for smart city implementations. As Polimeni et al. (2008) noted, a reduction in resource consumption through increased system efficiency is good for complex systems such as a city, because less resources are used, or less waste is produced. Increases in system efficiency lowers the consumption of input resources for the city, which in turn lowers the cost-of-service delivery. As the price of service delivery reduces, basic economic theory tells us that demand and, therefore, service or system use will increase, thus increasing the cost to deliver the service at the same level of quality. Thus, improvements in efficiency can be turned into new and more complex behavior outside the system, causing further a need for smart city system adaption or change as new demands from stakeholders are recognized and authorized. This requires a framework that allows for flexibility and complexity that are inherent in city systems.

Our Smart city systems framework based on systems thinking allows a smart city to build a digital strategic planning model of the city with longitudinal data from the physical city via multiple smart city systems (e.g., corporate data, school system data, sensors, etc.) and allows for feedback via the smart city investment program, authorized via the smart city framework. The information systems framework artifact will utilize business need as defined by the city stakeholders as its driving input. For small cities, the business need is generally defined by the mission statement of the city. The smart city framework also offers a further benefit to the city, as each technology artifact becomes part of a dynamic system model of the city that is created and includes all city assets, with real-time input concerning those assets derived from the physical assets via dataflows from the developed smart city system artifacts that following that smart city framework allow for feedback into the physical systems through data-based decision making and automated real-time rule-based controls (Figure 21, Appendix 3).

As a contribution, this dissertation designs a generalized framework that removes the problem of multiple smart city definitions by defining project success and focusing on metrics that are related to the goals of the city. By doing this, researchers and practitioners need not define what they think a smart city is but can define a project or set of projects in terms of the strategic goals of the city. The framework is usable for any size city or project focusing on any type of output. Such flexibility is missing in the literature.

Through a citizen's perspective the ADR multilevel city process can be used to model future smart city service delivery while leveraging stakeholder requirements. This is done by mapping and analyzing the smart city system of systems, to ensure service operationalization generates public value through a digital business model created for each service.

Moore (2013), places strategic management at the center of the public value strategic triangle, however, based on the research and learning from the multilevel ADR process, I have expanded this to include the processes discussed in this thesis. Figure 22 shows this expanded public value strategic triangle, including the Multilevel ADR artifact creation process and other management processes required to build the smart city.

Throughout this dissertation it has been argued that the creation of a smart city must produce public value for the undertaking to be of use to both the city government and its stakeholders. Applying ADR was successful in that the participants thought that the intervention led to much better outcomes than that which they would normally reach using other methods of dealing with similar problems. It was encouraging that the multi-level ADR method worked well, but from these interventions we cannot draw the conclusion that the developed ADR method is the best method for creating a smart city. I can merely conclude that it is one possible solution and that it appears to have significant merit. I would recommend to cities looking for a smart city management framework to define the situation in which interventions are to be made and the wider organizational context at the start of the ADR work. The city should then tentatively define how to measure the success or failure based on the outcomes define for each artifact. For instance, in the case of the present project, is it a question of the ADR concept generation, generating a higher quantity of ideas than previous strategies, or question of the participants merely considering the method to be a better and more useful way of working.

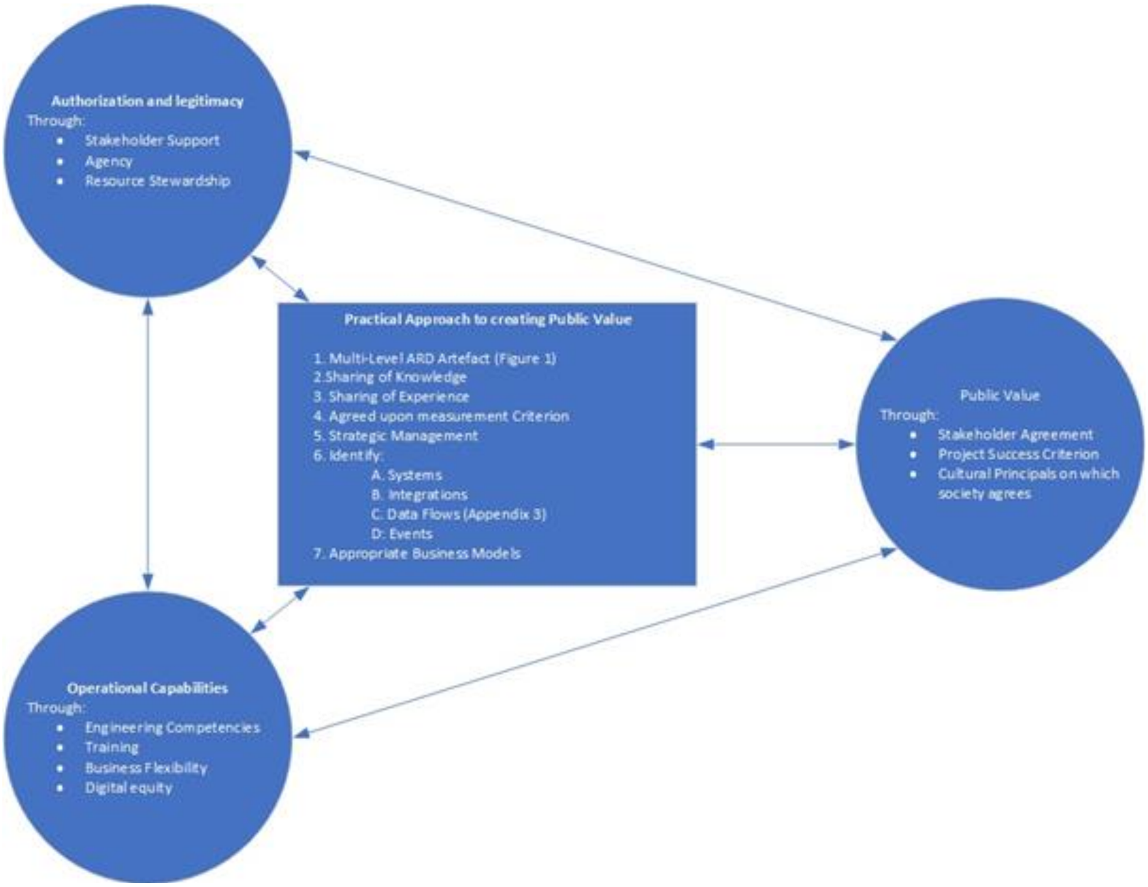

Figure 19. Practical Implementation of Moore’s (2013) Public Value Strategic Triangle

Figure 19. allows for strategic planning and smart city project choice by individual cities as each city will have its own goals and strategic priorities. The generalization of the Multilevel ADR process allows for its use in many scenarios and is adaptable across cultures. In this implementation I have made no judgements on how projects are chosen or on the types of projects chosen; the multilevel ADR framework allows for the data from each project to be shared system by system. How that data is used is for city leaders to decide.

Appendix 3 shows the full set of systems and integrations design for the smart city used in this dissertation. Systems thinking allows us to break city systems until their functions and parts, however, we found that at the city level, utilization of data, and the creation and processing of events became the focal point for practitioners, as they sort to make sense of the data and the knowledge generated. By evolving from pure systems thinking to an event-thinking system, the city created automation processes for warnings and alerts, so that real time decision making is possible, whether it be human, or AI based.

Smart city creation is about a city government solving problems by integrating technology through a the city's business processes to provide citizens with a more responsive, a more transparent, and more efficient government. Figure 20. shows an overview of the smart city process from the citizen's perspective.

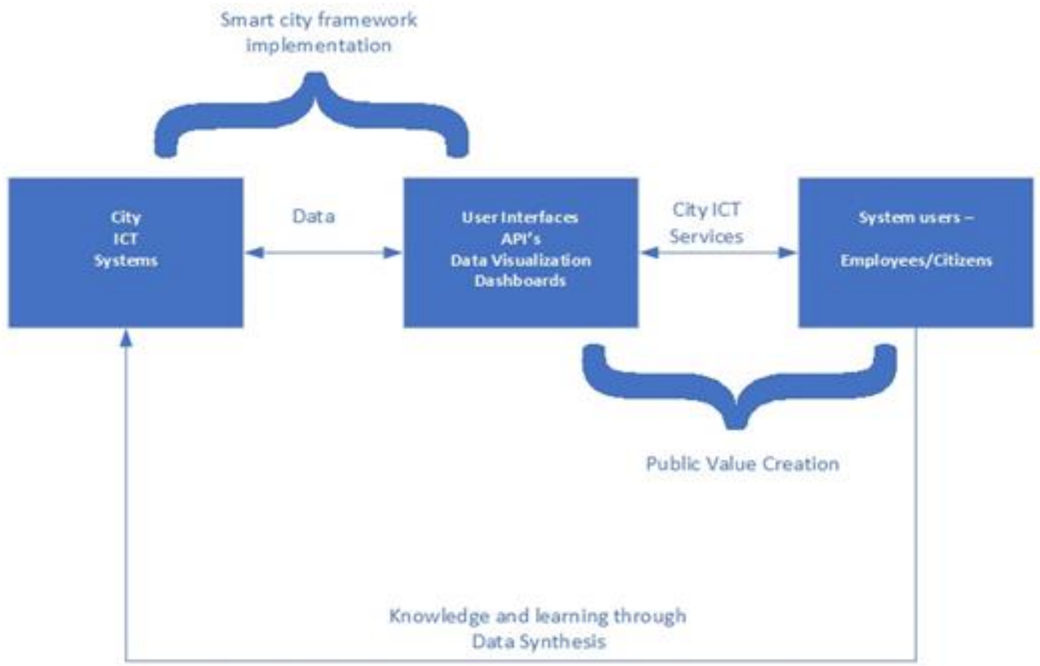

Figure 20. Overview of Employee/Citizen view of knowledge creation through use of smart city framework.

By synthesizing data citizens or employees can create public value and provide knowledge that contributes to future smart city project creation thus providing positive feedback allowing additional system changes. Thus, the goal of the smart city framework is achieved, ensuring the city council or board has control over the smart city processes while allowing city managers and employees the freedom to use the business process frameworks of their own choosing to operate their department functions. The smart city framework also provides an information flow that ensures project results are reported and that management decisions are made with as much information as possible. The smart city framework also ensures that learning is recognized and incorporated into future smart city projects.

Practitioner Conclusions

Smart City is about people. The provision of public value in the smart city concept is concerned with how people relate to one another, their environment, and how they learn when doing so. By having a focus on the mission statement of the city, the outcomes of authorized smart city projects put people first and knowledge generation second. Utilizing ADR allows the city to accept change and learning as sources of innovation for future smart city projects. The multilevel ADR framework provides techniques to help monitor and evaluate the performance of individual smart city projects, which ensuring each project contributes where possible to a larger city wide system. The Multi-level ADR framework ensures each project and system participates in the collection and systematic review of quantitative indicators, while also allowing for qualitative reviews from the field concerning who did what, when, why, and the reasons the event was/is important to ensure organization learning is comprehensive.

The Learning from each project is the key to smart city success. Knowledge should be continuously enriched, through internal ADR processes and from external sources, for this to happen, it is necessary to build systems and processes that support the city, its employees, knowledge storage, knowledge sharing, and is accepting of new ideas and technologies. Additional conditions for the success of a smart city program include the participation of all stakeholders and the creation of transparent and democratic business processes couple with the creation of diverse steering committees including citizens, with access to and the ability to use information created via the smart city systems.

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Appendix 1 – Case Study – Smart City Wi-Fi System Design and Reporting using the Smart City Framework.

Smart City Analytics

Developing a comprehensive analytics models for a smart city poses several challenges. Evaluating the effectiveness of any specific system or system of systems but particularly a city-based analytics system is difficult because of the complexity in developing appropriate criteria for measurement (Grimsley & Meehan, 2007). This complexity is in part because of the number of stakeholders a municipal government has, including citizens, businesses, educational institutions, non-profit agencies, elected officials, and government employees (Janowski, 2015). Also, the relationships between the stakeholders and their municipal government, may be controlled via statute, regulation, or in a client – service provider relationship thus adding an addition layers of complexity (Grimsley & Meehan, 2007). The major problem in any analytics system within a city is the lack of a suitably realistic model or a complete set of city data to make predictions against (Bostrom & Heinen, 1977). This is further complicated by the open nature of the system itself (Ackoff, 1971). This presents an epistemological issue, in that gaining knowledge from a city-based analysis system under uncertainty will make decision making using the data subject to error caused by variation in the environment of the system (Elsbach & Stigliani, 2018). Thus, the results of the system must be fed back into the system as an input, so that new knowledge gained through the analytics can change how the analytics result is interpreted in the future as in Figure 1 (Senge, 2006) (Churchman, 1979).

This is a sample analysis of system usage as an example of a smart city project, designed using the smart city framework developed in Figure 1. The city is broken into smaller parts (Gharajedaghi, 2011) to prove an economic development specific analysis that will show prospective businesses, using a smart city system, how people move in the downtown area, and how they respond to the various community events that are organized in the downtown area. However, our ADR/DSR artifact must consider analysis of data from the whole city as part of its design parameters (Gharajedaghi, 2011). Through the analysis on objects (cell phones) I build a longitudinal ontology of human movement in the downtown area of the city that will enable businesses to focus events and marketing at specific points to be more effective at reaching customers (Shamszaman & Ali, 2018). This aligns with Janowski (2015) who suggested that an important component of digital government evolution is for digital transformation to be contextualized and to transform external relationships.

We collect data from the Wi-Fi and Bluetooth systems to develop analytics models for understanding the movement patterns, the analytics process used by the city, and the usage of the data to make decisions. The combination of evidence meets the requirements for a case study (Yin, 2014) in that we are creating a systems artifact.

The design of our artifact is for measuring the behavior of people in a specific environment over a specific period, considering different stimulus in the form of special downtown events. The data model produced after the case study should be able to predict the paths taken under normal conditions, and under categories of events that take place.

Artifact evaluation can take place after the instantiation phase, so we can test the design hypothesis:

Can a systems artifact collect data and be used for the prediction of behavior based on an event category, while ensuring the provision of this data to other systems?

This case study then allows for the evaluation of a Smart City framework (Figure 1.) system artifact in a real environment, so true ethnographic data can be utilized and analyzed, giving a phenomenological view of a downtown area (Pries-Heje & Baskerville, 2008).

The Smart city framework ensures we consider our ADR/DSR artifact as a designed system (Simon, 1996) that is part of a larger system (Ackoff, 1971). Each system, within a city, is considered part of a larger environment which i, just a larger system (Churchman, 1979).

In this case study we will show an improvement (Gregor & Hevner, 2013) in smart city design. By taking a system thinking approach using the smart city framework Figure 1 as our design process we will show that smart city projects should be integrated into the city, and that each project is both a cause and effect (Gharajedaghi, 2011) that should be measured. I implement the artifact using a single case study (Yin, 2014) to provide rigor.

Instantiation and physical Implementation – The Smart City Framework Process

Project Design

The first stage is problem formulation, guided by the principles of practice-inspired research and a theory-ingrained artifact; existing knowledge should be used to create an artifact that addresses a practical need interwoven with a context. Tasks in this stage are to identify and conceptualize the research opportunity and to formulate initial research questions, coupled with theory-based system benefits required in the smart city authorization process.

The trigger for this case study was the stakeholder demand for Wi-Fi across the city. Economic transaction theory provides support for the city to reduce the initial roll out of Wi-Fi to the downtown area, covering an initial eight (8) block area.

Specifically, I was interested in the conceptual design phase producing the Wi-Fi data, because it has an influence on other functions and systems within the city. The multilevel nature of this design is of research interest in the smart city space. By involving representatives from several city functions during the design phase, more viewpoints on the Wi-Fi system outcomes would be shared and thus a better system could be integrated into the smart city system. A way to address this issue is to use agency and stewardship theories to ensure project management at the city level asks for the correct data and that project managers at the individual system level use selection methods to structure the interaction between participants representing different functions.

The initial research question formulated was whether a systems artifact could collect data and be used for the prediction of behavior based on an event category, while ensuring the provision of this data to other systems? ADR requires that, during the problem definition stage, the problem should be cast as an instance of a class of problems, as this allows the researcher to generate knowledge that can be applied to the class of problems that the specific problem exemplifies (Sein et al. 2011). Smart city systems have not previously been developed utilizing a smart city multilevel design artifact that includes designers from cross-functional departments. Straus et al. (2011) note that there is little knowledge of what happens in interorganizational groups, as different people bring different cultures and agendas with them. Therefore, it was concluded that system design within a multilevel ADR process used in a smart city context would fill a gap in extant literature while supporting the city’s desire to implement Wi-Fi throughout the downtown area. As smart city projects have become increasingly common, the research of this part of the project was framed as addressing the following class of field problems: smart city design and systems learning.

Authorization involves securing long-term organizational commitment and budget for project implementation. The design participants were selected in consideration of their background, expertise, and function within the city, so that they could give a representative view of what would be useful outcomes for the Wi-Fi project. The benefits identified by the initial design team were: -

- A modern city has free Wi-Fi available.
- Usage data and location data could be used by business to decide location.
- City event decisions and usage patterns could improve events in the future.
- Planning decisions concerning downtown may be able to utilize location data.

This information was provided to city leadership so formal project authorization could be given to the project.

Project Authorization

Utilizing the generic authorization process shown in Figure 7 as instantiated in the business process show in Figure 2, the project description and proposed benefits were presented to the city council for project authorization and budget approval.

Building, Intervention, and Evaluation (BIE)

BIE is an iterative process in an environment. The BIE phase interweaves the building of the artifact, intervention in the organization, and evaluation, and the outcome of the BIE stage is the realized design of the artifact. This design must be evaluated so that the individual project work and that the project integrated with the rest of the city’s smart city systems. This stage is guided by the principles of reciprocal shaping, mutually influential roles, and authentic and concurrent evaluation. The principle of reciprocal shaping implies that increased understanding of the organizational context in which the new system will operate influences the design of the artifact, and the artifact influences the practices in the smart city context. In a smart city, the ADR principle of mutually influential roles emphasizes the different types of knowledge which the project participants as managed by the project manager, bring with them and the learning among the different participants. The principle of authentic and concurrent evaluation emphasizes that the evaluation should be on-going and part of the design and implementation through the entire BIE process.

The initial knowledge creation target for this Wi-Fi system is usage and location data that can be utilized within decision making processes within the city.

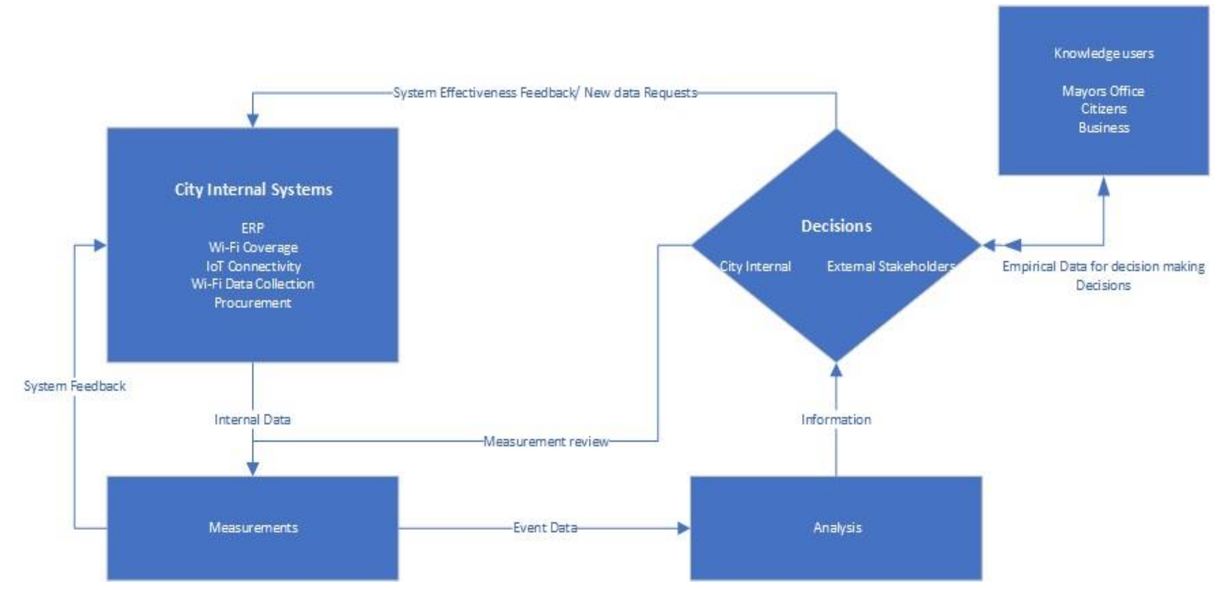

Figure 21: Conceptual Data Collection and Analytics Artifact designed to provide downtown Wi-Fi and data.

Figure 21. shows the ADR designed artifact that describes the ICT systems and business processes required to provide analytics of citizen movement patterns in the downtown area.

City Internal Systems: This represents all the information systems and their integrations used by the city. This includes IT management systems, employee data systems, and public safety information systems.

Measurements: This conceptual module, includes all city measurements that can generate events. Separating this from the specific ICT systems, allows the city to look at measurements and levels holistically, as well as part of the specific IS that generates the measurement data.

Analytics: This is the process of looking at all measurement data generated by the city, to identify patterns and relationships, or behavior models, that can be used for decision making in the city.

Decisions: In a smart city, the movement to automated decision making is slow, and where automation can take place, it will. If automation is not available or desirable, the analytics data is made available to city decision makers, who can then make decisions based on the data and analytic information they have.

The data flow arrows show information flows between the different systems within the whole artifact. Each element of the system artifact provides feedback into the elements providing data. This allows the system to adapt to its environment based on the policies and controls inherent within the system, or directly inserted by decision makers as demands on the system or priorities change.

Figure 22 shows the as built Wi-Fi map of the city. This is the Wi-Fi system used to collect the movement data. The Wi-Fi system was designed by conducting a Wi-Fi survey of the area, and then selecting, based on ease of installation and cost, the best location for each wireless access point.

Data Collection

By placing several geo-located Wi-Fi access points in the downtown area, it is possible using Wi-Fi and Bluetooth radios to triangulate the location of Wi-Fi or Bluetooth enabled phones as they move though the downtown area over time. The data chosen is people counts based on Wi-Fi enabled phones as they utilize businesses and move through the downtown area. By tracking this information and utilizing the city event calendar, the city can monitor the base use of the downtown area. The economic development agency has asked for this information so that new businesses can locate where people travel on their journey through town. Also, the success of events can be directly measured in terms of attendance, as can individual movement behavior during the event. Thus, events can be better arranged and planned in subsequent years after studying how individuals used the event.

Figure 22. Wireless Installation map of downtown area.

Data Analysis

Table 9 shows the analytics that will be produced using the data.

Table 9: Analytics and Data Used for downtown Wi-Fi	
Analytic	**Data Used**
Visualization (Heat Map of Wi-Wi Traffic)	Time of day, Day of Week, Season
Visualization (Above data + Dwell times)	Time of Day, Day of Week, Season
Visualization (Above Data + Event Calendar)	Event Calendar
Visualization (Above + ESRI GIS Data)	Integration of Businesses location and spatial data
Visualization (Above + Journey Analytics)	Identify individual journeys within geographic Wi-Fi zones
Visualization (Above + Repeat visitors)	Identification of repeat visitors across multiple days or multiple geographic zones.

Application for Generating Data

The BIE process for the artifact that will generate the data required is show in Figure 23. The design process for this artifact went through several iterations.

The project expanded the current Wi-Fi system into the downtown area. This was a constraint imposed by the city to ensure that system administrators had the expertise and capacity to implement the Wi-Fi system and manage its operation and maintenance.

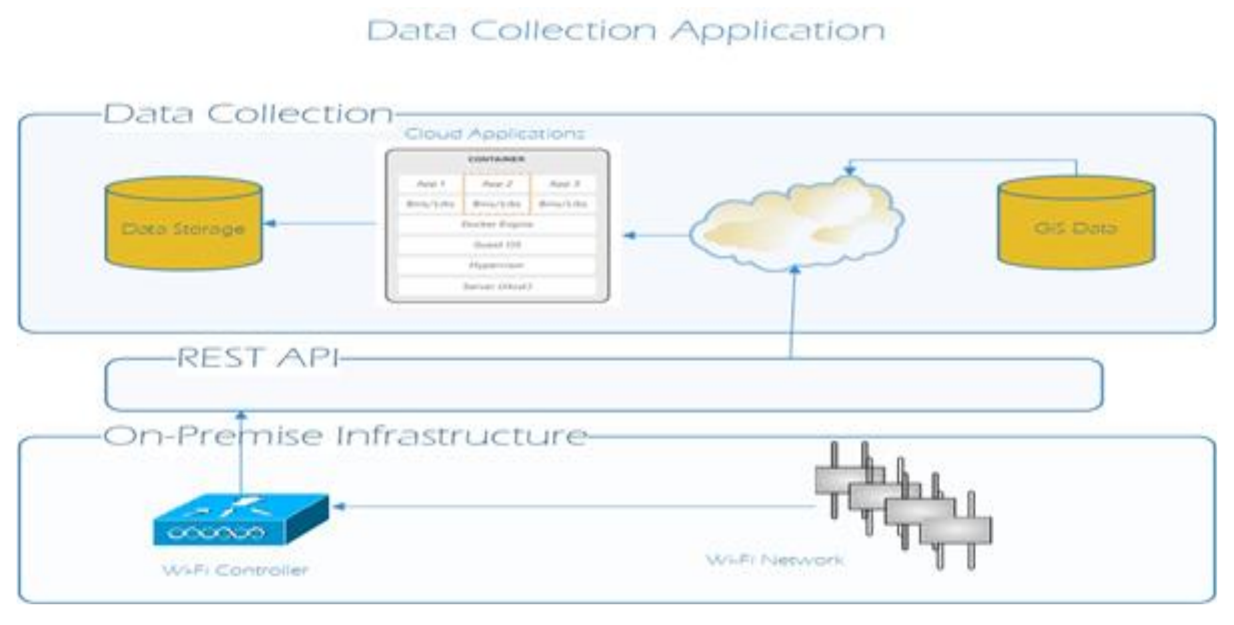

Figure 23. Wi-Fi Data Collection system architecture.

The Wi-Fi management system generates data that can be collected and organized within a database. This data then needs to be translated so it is relevant within the City’s GIS mapping system.

Stakeholders demanded that this data be anonymized. Only location data is pulled into the GIS system; no user or device information is pulled. Further, this information is deleted from the Wi-Fi system after seven (7) days, according to city policy.

Once the wi-fi location data is translated, each user can display displayed on a map using the time stamp information to provide maps at different times. The GIS system is also capable of animating this data to show the location data from set time ranges.

Several reports can be generated by this system.

Sample Data Produced by Case Study

Figure 24 shows the usage statistics for the downtown area and Figure 25 shows location information for people in the downtown area at 5:00pm on a Saturday in January.

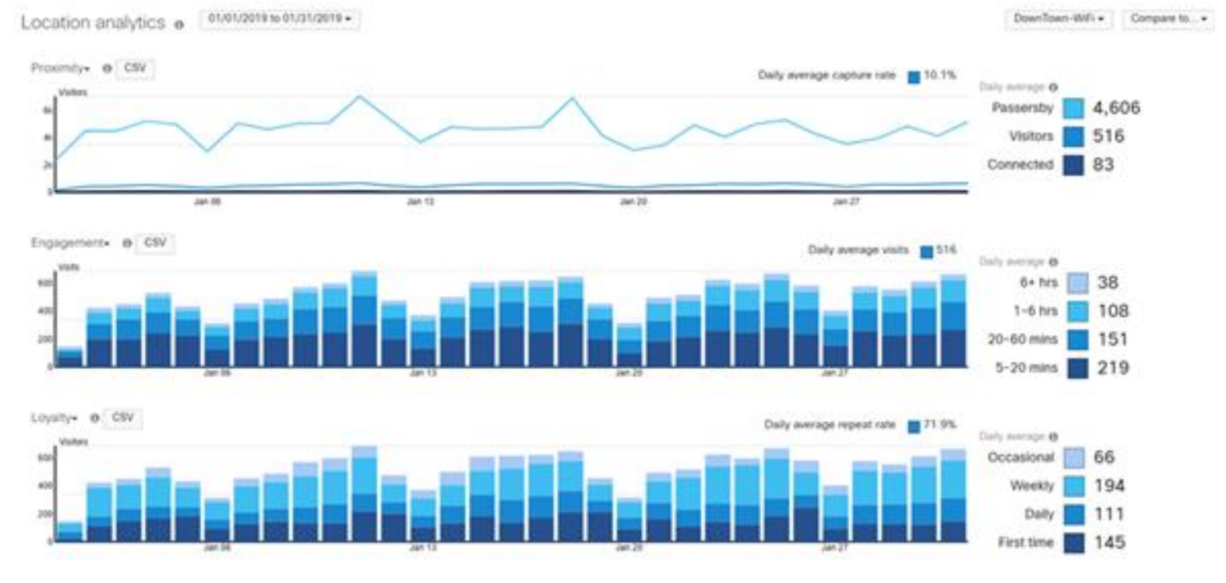

Figure 24. Downtown Wi-Fi utilization during January 2019.

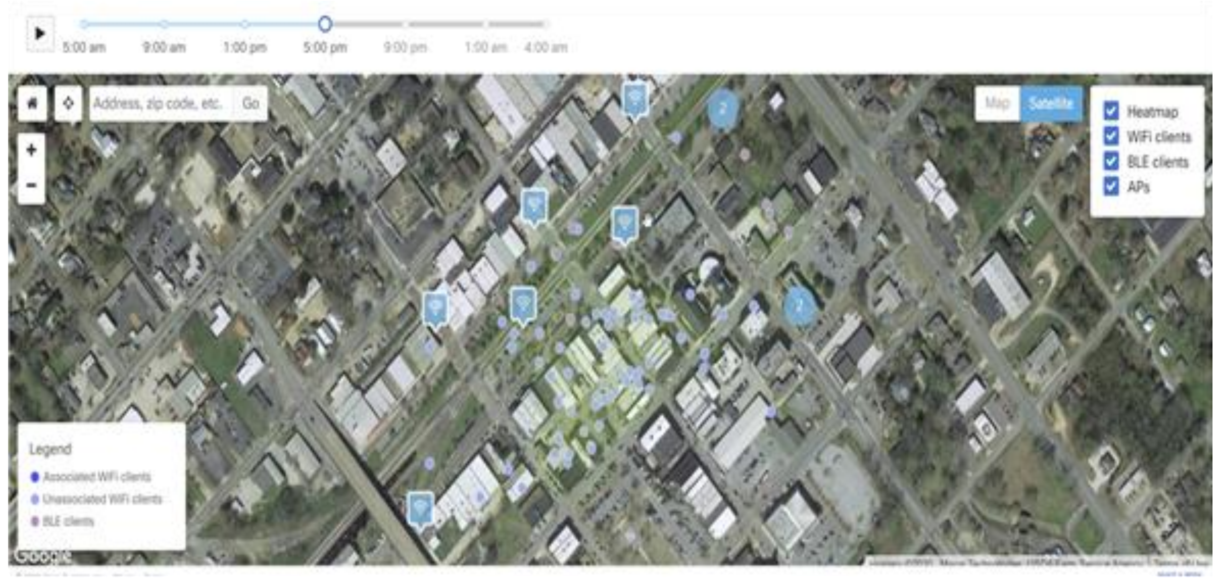

Figure 25: Visualized location information for downtown Wi-Fi APs

Multilevel Reflection and Learning

The ADR reflection and learning stage operates concurrently with the design and BIE stages at both the individual project level and at the city level. This is done to ensure the artifact is operating as expected and is not adversely affecting other smart city artifacts/systems. As the ADR artifact is implemented as a single case the learning process is concerned with applying the knowledge derived from the design and implementation process to a broader class of problems (Sein et al., 2011). Concurrent reflection also allows for the modification of the research process according as increased understanding of the systems and processes established by the artifact and its addition to the city systems. This ADR stage is governed by the principle of guided emergence, which emphasizes that the artifact will reflect not only the preliminary design created, in this case, by the researcher, but is also shaped by use in the city, the different perspectives of the stakeholders, and by the outcomes of authentic and concurrent evaluation. The reflection and learning stage emphasize the importance of incorporating the outcomes of addressing Principle 1-5 in the final artifact (See Figure 9).

During the reflection and learning stage, the design and redesign of the artifact during the project life cycle should be examined. The ICT systems and business processes developed in this case study were and are being continuously modified according to the evaluations and analyses of artifact performance and usefulness that take place. While the artifact project is complete, the smart city is ongoing and never complete, and each smart city artifact, system, and process is continuously reviewed to reflect the increased understanding of both the organizational context and the emerging smart city processes.

During evaluation, the adherence to the ADR principles must be reviewed and intervention results must be analyzed according to the original stated goals used in the authorization process. These two reflections and learning processes were performed throughout the course of the ADR project and at the end of the ADR project.

Formulization of Learning

The final stage of ADR involves the formalization of learning and the generalizing of learning outcomes, the generalization process is difficult because the artifact was developed address a specific need and organizational context. Generalization therefore is achieved by regarding the developed artifact as a solution that is a solution to a wicked problem, and then making a conceptual move from the specific, unique, and real artifact to a generic and abstract artifact at one of three levels (Sein et al., 2011): 1) generalization of the problem, 2) generalization of the solution, or 3) generic design principles from the design research outcome (methods for solving similar types of problems). Sein et al. (2011) articulate these tasks so that the first and third task of the formulization of the learning stage of ADR involves utilizing the learning by placing it into a class of in-field problems and expressing the artifact outcomes as design principles.

In this case study, the developed artifact provides two concepts - the generation of a systems framework for collecting citizen location data and the application design for storing and processing of the location data. This can be viewed as belonging to the class of smart city methods for creating a smart city. Taking the learning from the specific instance artifact to design principles for the class of solutions to which it belongs was done in the proposal for a new smart city design solution (Figure 1). The design principles were confirmed during the BIE cycles of this project; the smart city design framework emerged because of the ADR interventions.

The class of in-field problems for the smart city framework had to be framed. I realized during the project that the framework would be relevant for smart city project design in all cities. The design of the smart city framework will have an impact on the operational costs, which are paid for by taxes, and the indirect societal costs (e.g., privacy concerns). Therefore, the smart city framework should belong to the class of solutions that facilitate the selection of projects that are to contribute to the provision of public value in a smart city. The smart city framework was built for a class of solutions, emphasizing the importance of a cross-functional teams in the design, authorization, and BIE process.

The second task in the formulization of learning process involves sharing the outcomes and assessment with practitioners. ADR requires the specific instance be in an organization; therefore, practitioners are involved in the project and were continuously updated on its progress and the resulting outcomes. The outcome for this project was also shared with city decision makers through presentations, workshops, which generated further insights into how the data can be used by different departments.

Task four involves reviewing the learning in the light of the theories selected to build the smart city framework and to formalize the results for dissemination. The developed artifacts and the learning from the development process have been viewed in the light of the relevant literature identified during Stage 1. The project goals for data usage were also promulgated based on benefits predicted by the theories used in the design process.

Discussion

Modern society is more complex, and digitalization of business has driven city stakeholders to expect similar behaviors, services, and technology usage from their city governments. By providing city Wi-Fi networks across all municipal buildings and designated entertainment districts, the city is providing an integral part of the technology required to be considered a smart city (Musa, 2018).

The use of stakeholder theory allows the city to use an authorization process that identifies who should benefit from the project being authorized and the measurement indicator (ISO, 2018) that should predict the benefits of the project, and a guide for measuring the final impact of the project at both the project level and the city level. Analytics can be used throughout all city systems, to provide feedback into the decision-making process. However, while I have utilized city goals as a marker for how the analytics system can be evaluated, research must be done to evaluate city goals within a cultural context to ensure cities have feasible, measurable, and relevant goals (ISO, 2018).

ETC theory states that we should be trying to do more with less, or the same for less cost. Using Wi-Fi system that has a main goal of providing fast internet access to the users present near the system to provide a secondary set of data should show how people are navigating and using the services provided by the city meets the requirements of the ETC. By providing utilization rates and location data, the city now has access to how its facilities and services are being used.

As cities seek to make more data-based decisions, continuous usage of city facilities and spaces allows city planners and decision makers to make decisions with the added knowledge of how these spaces are currently used. Behavior changes can then be planned via policy and/or signage to provide for more efficient usage of space, or more profitable use of space.

It was noted that during this project that the data identifying the devices connected to the network could possible contain personally identifying information (PII) as defined by the GDPR. The governance structure for this project had to be revisited several times to ensure that the city did not inadvertently make this information available to the public. A strong and flexible data governance process should be in place as is added in Figure 1. This will allow a protocol to be developed and followed to ensure that privacy rights of individuals are always protected. A byproduct of this is that the city is considering an Institutional Review Board (IRB) process akin to a university human subject IRB process, before information can be collected and shared with third party organizations.

Conclusions

The focus by stakeholders on municipal government goals should therefore be a focus of smart city research. By providing smart city services, stakeholders, using data and data driven models, can utilize municipal space more effectively, while ensuring cost effective technology solutions for continuous monitoring of how city services are been used by citizens.

The case study in this appendix covers analysis of movement patterns of people in the downtown area of a small city. Analysis in this case is done via triangulation of people's Wi-Fi and Bluetooth connected devices in relation to the city Wi-Fi antennas in the downtown area coupled with Bluetooth discovery of the devices themselves. This information will also be useful for new businesses to select locations in the downtown area.

The citizen centric city concept should take the citizen as its main constituent part and should ensure the citizens that data collection process will not put personal information at risk. The authorization process (Figure 6) can be used to build trust and ensure transparency. Good governance of authorized projects and a strong citizen centric data usage policy should avoid turning the city into a "black box" where citizens and the city administration lose control of the collected data. The data, or insights made through data analysis, should be used to make data-driven, transparent decisions for the benefit of the citizens.

Appendix 2 – Tables

Table 10. Mission Statements Review (North American Cities)		
Mission Statement	**Main Focus**	**Secondary Focus**
The City of Concord partners with our community to deliver excellent service, and plans for the future while preserving, protecting, and enhancing the quality of life. (Concord, NC)	Quality of Life	
To ensure a safe, clean, healthy, productive city where neighborhoods are revitalized, history is preserved, the natural environment is respected, and where all people can reach their full potential through education, commerce, culture, recreation, and wellness (York, PA)	Sustainability	Quality of Life
Marion is a progressive city that provides high quality services which promote an active, safe, and healthy environment; it enables the community to realize the best standard of living possible through cost-effective governance. (Marion, IA)	Quality of Life	Sustainability
The economic, social, and environmental vitality of the city. The city strives to provide high quality and affordable services that respond to the needs of our communities and invests in infrastructure to support city building. The city is a leader in identifying issues of importance and in finding creative ways of responding to them (Toronto, Canada)	Sustainability	Economic Development
We respect the dignity and worth of our citizens and value the diversity of culture, heritage, and history within our community. We pledge to strive to improve the quality of life and opportunity for economic prosperity of all our residents by working to attract more visitors and industries and assuring all of our citizens a clean, safe, economically viable and progressive city that is responsive to changing needs (Mobile, AL)	Quality of Life	Economic Development
Strengthen Community Image and Sense of Place Support Economic Development Strengthen Safety & Security Promote Health & Wellness	Quality of Life	Economic Development

Foster Human Development Increase Cultural Unity Protect Environmental Resources Facilitate Community Problem Solving Provide Recreational Experiences (San Carlos, CA)		
A leading community in which to live, work, and thrive (Woodbury, MN)	Quality of Life	
Dedicated to consistently providing high quality services and quality of life to all who live, work, and visit the City of McAllen (McAllen, TX)	Quality of Life	
The City of Nampa staff and leadership shall serve citizens by being open and transparent. Nampa shall seek to facilitate economic opportunity by encouraging free-market principles, supporting the community by providing incentive for economic development and investing in our infrastructure and operating efficiencies (Nampa ,ID)		
The Mission of the City of Virginia Beach is to be Financially Sustainable, in order to provide Excellent Quality Services, and Infrastructure and Facilities, that are Responsive to Community needs, and protect the natural Environment giving Citizens Value for their tax Dollar (Virginia Beach, VA)	Sustainability	Economic Development
Effectively, efficiently, and equitably enhancing resident's quality of life; attracting private investment; stimulating growth city-wide; and delivering services with a commitment to excellence. (Camden, NJ)	Quality of Life	Economic Development
To provide outstanding services in an efficient, effective, and professional manner To be a local government which embraces the changing needs and expectations of our residents To protect, maintain, and enhance the City's public infrastructure by anticipating long-term needs and taking prudent steps to provide for those needs	Quality of Life	

To encourage, foster, develop, and utilize a strong volunteer corps in many facets of city government (Valparaiso, FL)		
Our team of professionals will provide our residents and business community with the highest quality services in a fiscally responsible manner through cooperation, strong ethical leadership with a lifelong commitment to enriching lives. (Haines City, FL)	Quality of Life	
To respond to the ever-changing needs of our community and its residents; and to ensure their financial and personal security through guided quality growth, innovation, and the efficient use of resources. (Mountain Iron, MN)	Quality of Life	Sustainability
The Mission of the City of Copperas Cove is to provide excellent public services using revenues effectively to meet the needs of our diverse community. ((Copperas Cove, TX)	Sustainability	
The City of South San Francisco's mission is to provide a safe, attractive, and well-maintained City through excellent customer service and superior programs and to have a work ethic that will enhance the Community's quality of life. (South San Francisco, CA)	Quality of Life	
The Mayor and City Council's mission is to protect and enhance the quality of life of our residents. While maintaining our strong sense of community and citizen involvement, we will continue to provide leadership for future development. We honor Westworth Village's strong diverse heritage - from the original ranchers to our military families. Our residents celebrate their collective diversity and enjoy a positive community spirit. (Westworth Village, TX)	Quality of Life	
The mission of the City of Prescott is to provide Superior Customer Service, to create a Financially Sustainable City, and to serve as the Leader of the Region. (Prescott, AZ)	Sustainability	
It is the mission of the City of Austell to provide advanced opportunities by meeting current and future needs of those living in, doing business with, and visiting the City. Our primary goal is to	Quality of Life	

provide an honest, effective, and open government; to protect life and property, and to provide professional, cost-efficient services; and excellent customer service to our citizens. (Austell, GA)		
The City of Glendale delivers exceptional customer service through precision execution and innovative leadership. Emphasis on: - Fiscal Responsibility, Exceptional Customer Service, Economic Vibrancy, Informed & Engaged Community, Safe & Healthy Community, Balanced Quality Housing, Community Services & Facilities, Infrastructure & Mobility, Arts & Culture, Sustainability (Glendale, CA)	Quality of Life	Sustainability
The mission of the City of Corpus Christi, Texas is to deliver municipal services which meet the vital health, safety and general welfare needs of the residents and which sustain and improve their quality of life. (Corpus Christi, TX)	Quality of Life	
The City of Richmond is dedicated to promoting a high quality of life for its residents by providing municipal services and addressing community issues in partnership with its citizens, businesses, and neighbors. (Richmond, MI)	Quality of Life	
Our mission is to enhance the quality of community life for those residing, doing business, and visiting in Kent. Kent CARES about honest and effective government service; protection of life and property; and ensuring that the City provides professional services to the citizens of Kent (Kent, WA)	Quality of Life	
To provide value added services in a customer friendly, cost efficient and effective manner resulting in a safe and prosperous community. (Henderson, NC)	Quality of Life	
The mission of the City of Auburn is to provide economical delivery of quality services created and designed in response to the needs of its citizens rather than by habit or tradition. (Auburn, AL)	Quality of Life	

Table 11. Operational Focus, helix, ISO Indicator			
City Focus	**Helix**	**Indicators**	**ISO Theme (Indicator)**
Quality of Life	University	Public expenditure on education - percentage of GDP per head of city population.	Education
		Percentage of population aged 15-64 with higher education living in Urban Area.	Education
		An assessment of the ambitiousness of CO2 emission reduction strategy.	Environment & Climate Change
	Government	Share of female city representatives	Governance
		Percentage of households with computers/mobile devices.	Telecommunications
		Number of public libraries.	Education
		Number of theaters and cinemas.	Sports and Culture
		Green space (m^2) to which the public has access, per capita.	Recreation
		Proportion of the area in City for recreational sports and leisure use.	
		Health care expenditure - percentage of GDP per capita	Health
		Crime Rate - percentage per capita for various types of crime.	Safety
		Law Enforcement Accountability Assessment	Safety
	Civil Society	Voter turnout in national, State and Local elections.	Governance
		Percentage of households with Internet access at home.	Telecommunications
		Total book loans and other media per resident.	Education

		Theater and cinema attendance per inhabitant.	Sports and Culture
	Industry	Employment rate in knowledge-intensive sectors.	Economy
Economic Development	University	No. of universities, colleges, and research centers in the city.	Education
	Government	e-Government on-line availability. Debt of municipal government per resident. Energy intensity of the economy - gross inland consumption of energy divided by GDP.	Governance Finance Energy
	Civil Society	GDP per head of city population. e-Government usage by individuals (percentage individuals aged 16-74 who have used the Internet, in the last 3 months, for interaction with public authorities). Foreign language skills. Fiber to Home and/or Business.	Governance Population &Social Condition Telecommunications
	Industry	No. of Annual Scholarships Employment rate in knowledge-intensive sectors. Proportion of people undertaking industry-based training.	Education Economy Education
Sustainability	University		
	Government	Unemployment rate. An assessment of the comprehensiveness of policies to contain urban sprawl and to improve and monitor environmental performance. Urban population exposure to air pollution by particulate matter - micrograms per cubic meter	Economy Urban Planning Environment and Climate Change

	Civil Society	Total annual water consumption, in cubic meters per head.	Water
		Total annual power consumption in Kilo Watts per Hour (KWph) per head.	Energy
		Efficient use of water (use per GDP)	Water
		Efficient use of power (use per GDP)	Energy
		The total percentage of the working population traveling to work on public transport, by bicycle and by foot.	Transportation
		An assessment of the extensiveness of efforts to increase the use of cleaner transport.	Transportation

Appendix 3 - Case Study - A Smart City Complex Adaptive Systems Framework Instance

A smart city must build a collection of ICT infrastructure solutions that include an integrated data center, integrated applications, and an advanced communications network capable of collecting data from a myriad of internet of things (IoT) sensors (Dirks & Keeling, 2009). The systems integration model should show each city system, and the links between systems should be identified with indicators.

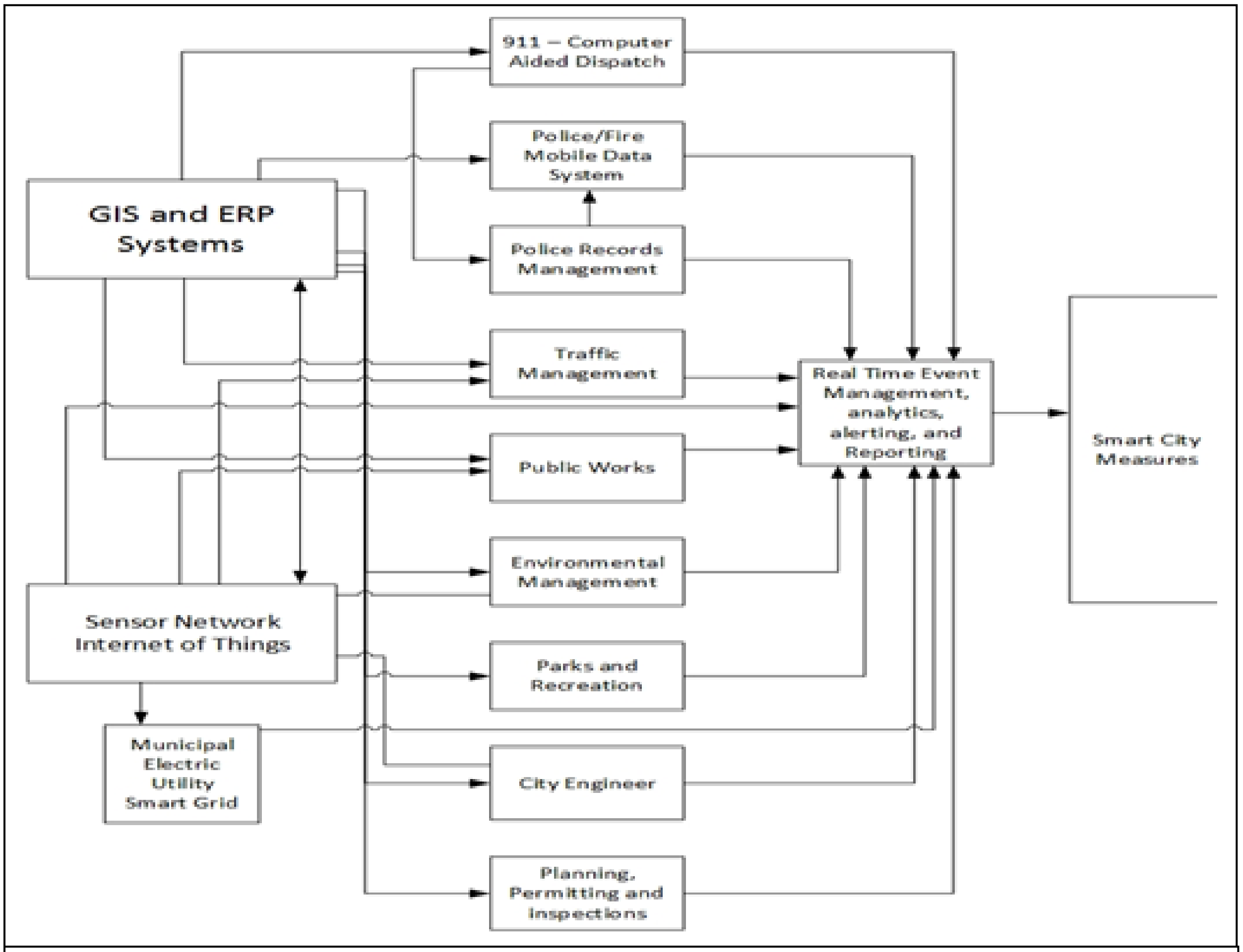

Figure 26. A Small City Systems Framework

Cities' structures usually contain sets of departments that manage the various tasks of the city (Figure 26). While the names of the departments vary from city to city, the functions they perform are similar. Cities may order their tasks differently; however, the model of the systems in use can be adjusted for individual instances to fit the local nomenclature. Systems integration across departments, agencies and/or business units is important because it will provide citizens with a better quality of life, more economic development and better resource utilization and sustainability. Table 12 gives a definition of each system, which department may use it, and its function within a city.

Table 12. System Definition, Main City Department User and Functions

System	Department(s)	Function
911 – Computer Aided Dispatch (CAD)	Public Safety	911 Calls Dispatch Police/Fire/EMS
Police/Fire Mobile Data	Police and Fire	Provide GPS co-ordinates to CAD, track historical vehicle behavior, and provide real time alerts to staff.
Police Records Management	Police	Crime reporting and documentation
Traffic Management	Engineering Public Works	Provide centralized traffic light control and intersection monitoring
Public Works	Public Works	Vehicle fleet management, infrastructure maintenance work orders, wastewater management, city building maintenance, street cleaning, street signs, cemetery, and grounds keeping.
Environmental Management	Environmental Management	Garbage pickup, recycling programs.
Parks and Recreation	Parks and Recreations	Manage municipal sports complexes, leisure programs, organized activities, and sports. Manage municipal event/conference space.
City Engineer	Engineering	Postal address creation. Infrastructure improvement and build plan review and inspections. Storm water management.
Planning Permitting and Inspections	Revenue (Permits) Code Enforcement Bldg Inspection Fire Inspection Planning Public Works	Business licensing, building occupation certificates, manage planning application process. Work orders to public works for street changes, code enforcement inspections, and citations.

This system of systems framework has many links. Each of these links must have a purpose and must be tied back to the categories identified in city mission statement focus listed in Table 9. Much research has been done on spatial analysis, utilizing Geographic Information System (GIS) (Theodoridis, Mylonas, & Chatzigiannakis, 2013); (Doran & Daniel, 2014). There are three sub-systems I feel are critical to the successful operation of a city as inputs to the infrastructure functions.

The first –sub-system, a GIS system, is required to locate all city assets, system endpoint locations, and sensor locations to track city all equipment and identified system events on a map. By providing spatially based recognition of events and city actions, city staff will be able to report usage by area, by planning zone type, or by voting districts. This spatial information is the base information that all city systems use. Mapping provides meaning to reported data that shows an effect on a citizen’s quality of life (crime heat maps, and school zone maps), for economic development (traffic counts and infrastructure investment), and for sustainability (pollution heat maps and recycling counts) for any given area. Map based city information provides an easy to understand, dynamic reporting that is visual, rather than tables of numbers (Chapin, 2003).

The second system essential to the building of a smart city is a network that can allow IoT sensors a way of sending data back to the city data center for processing. Each city’s topography, infrastructure, and capabilities differ, so we cannot prescribe a specific networking technology to achieve this goal. City infrastructure, pollution, fluid systems (water, wastewater, and storm water) and traffic data must be sent to the event management system located in a city data center or cloud data center. From the event management system, event data is transferred to the appropriate module for processing and action by city staff if required. The significance of being able to access the data in real time is that actions by the city can be proactively initiated as events are detected rather than the city passively waiting for them to be reported by citizens or city employees (Salim, 2012).

The third system is an ERP system that provides purchasing, human resource, inventory control, revenue, permitting, inspections, and web-based access for citizens to request services from the city. This system provides the governance and control required by governmental organizations to ensure, the city follows ethics laws, procurement laws, and other general regulations enacted by the Federal Government, State Government or even local ordinances enacted by the City itself. By providing rules and controls that are auditable, the city cannot act or spend money without following the correct procedures enforced by the ERP system. For example, a work order created automatically by the streetlight system to clear a storm drain based on the detection of pooled water must go through the same approval process a manually entered work order goes through based on a call from a citizen.

Table 13 shows each module within the framework and defines each link and which indices it should affect, according to the modified triple helix model and information in Table 11.

Table 13. Framework links and the affected output Indices

Module	Linked Module	Indices
911-CAD	Police/Fire Mobile Data System, Police Records Management, IoT, Event Management.	Crime Rate - percentage per capita for various types of crime. (Quality of Life) Law Enforcement Accountability Assessment (Quality of Life)
Traffic Management.	Event Management, IoT.	Accident Detection all traffic signal timing changes. (Quality of Life)
Public Works.	Event Management, IoT.	Automatic detection of Infrastructure problems allows fast response to maintenance issues (Economic Development and Quality of Life). Storm Water System monitoring and repair. (Sustainability). Wastewater System Monitoring. (Sustainability)
Environmental Management.	IoT and Event management.	Track recycling centers and customer counts. GPS location information showing pick up times. (Quality of Life) Manage citywide recycling programs (Sustainability)
Parks and Recreation.	IoT.	Provide Sports and leisure facilities, activity programs (Quality of Life) and conference and event centers (Economic Development)
Planning Permitting and Inspections.	ERP, City Engineer.	Provide e-Government processes to ensure a consistent approach to planning and permitting with the City. Allow inspection process to be monitored online (Economic Development)

City Engineer.	IoT.	Storm Water Control (Sustainability). Energy efficiency programs (Sustainability). Pollution monitoring (Quality of Life). City infrastructure planning and approval and inspection. (Economic Development)

While each information system within the city helps improve the stated goals, there are also other city government internal tasks that are not represented on this model. This model defines the systems integrations necessary to provide the ICT infrastructure that can support smart city projects. It can be seen from the following examples utilizing the model in Figure 2 that the collection and sharing of information between city departments through integrated information systems will allow the development of smart city applications shown in prior literature. Appendix 1 shows the implementation of a dynamic streetlighting system. This system requires the use of GIS to mark the location of each device, and an IoT infrastructure to link all the streetlights together to ensure they work together to dim and brighten as people and cars are detected. Video data will also be streamed back to the city's servers for analysis with traffic and pedestrian information to be fed into the traffic management system. This information will also be retained for use in maintenance decisions, for example on when road resurfacing and sidewalk maintenance needs to occur. This video can also be moved to the police evidence management system if a public safety related event has been captured.

It can also be seen from this design that an initial requirement for a smart city is an appropriate GIS system with the necessary information on city infrastructure collected (Venigalla & Baik, 2007). If a smaller city does not have the resources to complete a GIS project, then a partnership with a local university may be an option. This arrangement would supply the necessary expertise while also offering an educational opportunity to students (Dawe & Sankar, 2016).

System Connections

Each system has various connections to the other systems for integration purposes. The GIS system is connected to 911-Computer Aided Dispatch (CAD), Police/Fire Mobile Data System, Traffic Management, Public Works, Environmental Management, Parks and Recreations, Planning, Permitting and Inspections, City Engineer, Water Utility, Smart Grid, ERP system, and the Real Time Event management, analytics, and alerting system. All of these systems require spatial data and maps to operate. By utilizing maps, events can be placed in a specific location so personnel can be directed there and map-based reporting can be conducted based on the city's needs. The sensor network is connected to CAD, Traffic Management, Public Works, Parks and Recreation, City Engineer, Water Utility, and Smart Grid systems. These systems utilize sensor data to proactively maintain city infrastructure. For example, the Smart Grid utilizes electrical sensors to monitor equipment performance, and to monitor the grid for failures, allowing the system to self-heal if a failure is detected. The Smart Grid sensors also creates work orders for crews to fix problems or replace/repair equipment that is showing a predicted failure alert. Parks and Recreation utilize ground water sensors in the ball parks and soccer fields to enable water savings by only activating the water sprinklers if the amount of water in the ground reaches a specified level. The ERP system governs rules for purchasing, inventory usage, permitting, and billing. The City Finance department tracks all public expenditures and incoming payments via the ERP system. The ERP system also generates all work orders, so equipment usage and labor hours can be tracked, and linked to map locations via GIS.

The Real Time Event management, analytics and altering system provides connectivity between the applications and generates warnings that require a human response. This system also handles the analysis of video data to provide event warnings to either public works, in the case of identified city infrastructure failures, or to 911-CAD in the event the camera systems detect vehicles that have been flagged by the local law enforcement agencies. The Water Utility utilizes GIS to track all underground infrastructure and the Sensor Network to provide water flow information, meter reading and leak detection. The 911-CAD system utilizes GIS to provide mapping data and address information, to locate calls to 911. This system also, passes the 911 call center notes to the Police/Fire Mobile data systems, so the officers have the 911 location, directions, and transcripts of the call(s) in real time. The Police/Fire Mobile Data Systems also updates the 911-CAD center with the location of officers and public safety vehicles. Officers can see the locations of all other units and personnel responding to an incident. The Police/Fire records management system (RMS) take the data from 911-CAD and the Mobile data system to create the written reports for each event an officer responds to. This system is also responsible to reporting crime data to the relevant federal agencies for national statistical reporting.

Public Works and City Engineering utilize the Work Order system within the ERP system to respond to city building issues or to infrastructure issues reported by citizens or identified by the Real Time Event Management and Analytics System. Public works also operates the sewer system and uses the sensor network to ensure the sewer system is working correctly, by monitoring flow data at each pumping station and ensuring all the wastewater arrives at city treatment facilities. City Engineering also provides design reviews and inspections of new city infrastructure, including roads, bridges and city owned buildings and facilities. City Engineering is also responsible for monitoring storm drains; Traffic Management uses GIS to provide mapping and location information and the sensor network to import real-time traffic statistics to control traffic light hold and release times. Video analytics also provides intersection accident data to the 911-CAD system for dispatch of emergency services.

Environmental management uses GIS for route planning of trash pickup and for tracking recycling drops and the type of materials being recycled at different locations. GPS is also used to track each trash truck as it follows its route so citizens can see where the truck is if their trash has not been picked up.

Planning, Permitting, and Inspections uses GIS to management the planning process for land usage throughout the city. The permitting process utilized with the ERP system allows permits to be requested online, and then the citizen or business can track the permit and inspection process as it is completed. Permits are issued online via the ERP permitting web portal. The permit process includes inspections of retention ponds throughout the city. The Sensor Network IoT will be utilized to provide water quality information and foliage growth data.