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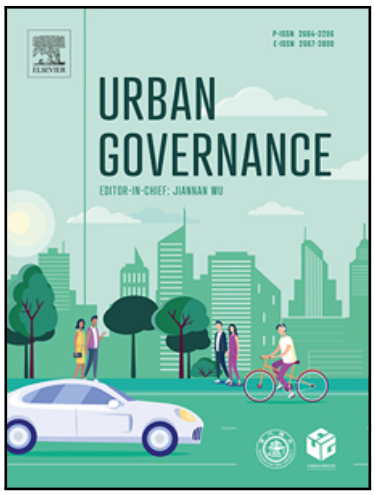

Governance Rules for Managing Smart City Information

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Governance Rules for Managing Smart City Information

Abstract

by

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Collecting, processing, and distributing information has always been a core function of government. This core function has evolved from the earliest ancient governments using clay

tablets to today's smart cities relying on integrated data exchanges (IDE). A smart city "uses information and information technology to make better decisions to improve the quality of life" [1]. The IDE framework builds upon the data platform literature [2] by incorporating governance systems to manage a smart city's activities. This conceptual paper takes existing research, synthesizes it, and creates a new framework to identify how cities can select the appropriate governance rules to facilitate the political, financial, and operational sustainability of their IDEs, and derivatively, their smart city efforts.

Keywords:

Smart Cities
Governance
Information Management
Data Platforms
Sustainability

1. Introduction

1.1 Managing information has always been a core function of government

Managing information has always been a core function of government. For example, one of the earliest civilizations in the world, the ancient city of Sumer in Mesopotamia (c. 4500 – c. 1900 BCE) [3] used cuneiform tablets [4] to record contracts and property transfers. In fact, most of the clay tablets that were unearthed, were used to support a public function. Some historians also believe that the expansion of these earliest empires critically depended on a code of law that could be communicated to the far-flung parts of the empire (e.g., the famous Hammurabi's Code, 1758 BCE) [5]. Since then, new technologies have developed to improve the collection and distribution information, generating new challenges and opportunities for civilization and also how government should provide data and information[1]: including the printing press [7] [8], the telegraph [9], the Internet [10], AI [11] and block-chain [12]. "Smart cities" are the latest conceptualization about how technology can improve government [13] [2]. Although by some accounts, the term has become a brand that businesses use to sell technologies [14], this study defines smart cities as those that "use information and information technology to make better decisions to improve the quality of life" [1].

[1] The remaining discussion in the paper will talk about both data and information. Data is, most primitively, a sensed perception, and a scalar, (i.e., nominal vs. ratio data), for example, 1 million people. Information is data in context, 1 million people live in the city in 1980 versus 1 million people who have died of Covid-19 since January 2020. Context provides meaning to "1 million people" [6]. To make the reading less awkward, we will not use the phrase "data and information". Rather, we use the terms interchangeably based upon the context of the discussion (e.g., where the discussion turns to the outcome of analysis), we will talk about information rather than data).

[2] Like the printing press, the telegraph, and the Internet, and block-chain, Smart Cities are built from many previous technologies. Smart Cities are different in that the Smart city technology also has a geographic referent.

1.2 Information is a Core Resource and It Requires Governance

Traditional theories of public administration have focused on the efficient operations of centralized bureaucratic government [15][16][17]. The reality, however, is that centralized government is no longer the only way to provide public goods and services. In an increasingly complicated world, there are now many more ways to achieve public outcomes (e.g., markets, networks, and bureaucracies) [18] and many more kinds of organizations working collaboratively across many jurisdictions [19]. With so many kinds of organizations now working collaboratively, [20] argues that "government networks" require new management skills as well as a renewed look at information technology as the "ties that bind" [20] [21]. The study of how to best achieve public goals and services has moved from a study of bureaucracy and government to a wider study of "governance" [22]. It is the process of "bringing together a multitude of actors of different types toward some collective goal" [23].

If information is foundational to Smart Cities, the governance of that information is necessary to its success. Looking at smart cities from a governance of information perspective, there are two important generic components in Smart Cities. First, there are the individual projects, for example, to improve health and well-being, further environmental sustainability, reduce crime, or encourage economic development. These projects require information to be successful and their success justifies to citizens, investors, and political leadership why local governments should use information better and continue to support Smart city efforts. The success of these projects is often the principal way to decide how "smart" that city is. Much less attention, however, is paid to the information, and its governance, that makes these projects possible.

The second component is the whole store of information that a city possesses and has access to. This whole store of information goes beyond the information of what individual projects need and includes all the information that cities use to become smarter. It is the information that can be shared among projects now and in the future. This component is central to the "enterprise view" [24] of information because the information is not owned by a project but is owned by a whole enterprise, in this case the smart city enterprise [23] [24]. This store of information is a smart city's core resource and is foundational to its success.

There is less visibility paid to the whole store of data as it does not have the same political support that stakeholders supporting a particular project like finding transportation for prenatal care for indigent mothers. Consequently, there is less political, financial, and managerial attention to encourage the "enterprise" management of information. Information is scattered among different projects making it difficult to leverage all the information that is necessary in working on complex problems. This study explains how governance rules should be chosen to sustain these efforts even while there are no stakeholders who generally care about information or meta-data.

1.3 The Integrated Data Environment Assumptions and Logic

Effectively managing information requires integration. Integrating information fully realizes the value of that information. Information needs to be integrated across the silos of government and its many projects. In thinking about how one manage and govern information it is important to remember that smart cities are socio-technical systems [26] [27] that integrate information technology capabilities with social needs and capacities. To do this, a smart city needs a

framework to integrate the work of many disciplines and professions to make a smart city work. For example, a framework is needed to provide guidance to system architects who need to know, the purposes of the information, the information flows showing how organizations should be managed (e.g., a traditional system analysis), the desired qualities of the information [28] [29], and ownership rules [30] before they can "codify" these values, rules, or laws in how these systems are supposed to work. In many cases, however, these activities are not explicitly considered, and system architects and software engineers are left to build in their own biases and assumptions into these systems.

The importance of making clear what the governance rules are is very visible now that we are understanding that racial biases can be "baked into technical systems" [31][32]. It should therefore come as no surprise that there are many more biases about how organizations should use information that are also baked into smart city systems. In fact, these software rules have the effect of law – that they effect for the indefinite future how things are governed or managed [33] but unlike law, are hidden within the technology and thus hard to see and to change.

This focus on governance rules is extremely important as we build tomorrow's information systems [34]. An IDE improves upon the data platform [35] [36] [37] because it moves beyond general principles laid out in the data platform concept [2] by formally addressing the integration of organizational and technical governance rules. Early in the design of data platforms it was recognized that simply providing data was not sufficient and there needed to be a focus on user's needs by using scenario-based design approaches [38] and by integrating other tools to facilitate use and communication [39] [40]. Making the governance rules explicit leads to more robust

technical solutions, but also technical solutions that have a better chance attending to the legal, political, managerial concerns of a city.

As important as the short-term success of an IDE is its long-term sustainability. Integration of short-term needs with building a longer-term capacity to sustain smart city efforts is most often overlooked. Given the immediate pressures to make projects show a return on investment and solidify public support, the equally important efforts at sustaining these efforts over the long run are often crowded out. It is easy to see why. Funding sources are often temporary, and the windows of opportunity are open for a short time because of the overlapping economic, management, leadership, political opportunities, and technical cycles that all affect whether and how systems are built.

Given all these pressures to act in the "now" it is no wonder that questions about long-term sustainability is put off to another day. Path dependency will probably set in [41]. As the smart city adds more projects each pursuing a new opportunity, a short-term culture is developed, and it becomes more and more difficult to coordinate these independent activities over time. An integrated framework allows for IT professionals to communicate and coordinate their work with managers, political leadership, and attorneys to provide for more sustainable smart city development. The coordination leads to better outcomes, continued public support and funding because they are specifically addressed in the governance rules chosen.

This study examines two questions important to IDEs: 1) What is an IDE? and 2) Given the central importance of IDEs to Smart Cities, how can these IDEs be sustained through appropriate governance?

1.4 Contributions of this Research

The contribution of this research is to underline that the IDE is a foundational feature of the smart city enterprise in the U.S.[3] and to clarify its many functions over and above what has been assigned to data platforms. Ad hoc, opportunistic strategies have generally characterized the growth in the early days of smart cities, but a nationwide survey revealed that many public managers are now realizing that the sustainability of smart city initiatives need to be addressed.

The value of this work is that people who work on smart cities now have a framework to think about governance systems and how they might design and manage a smart city. Municipal, regional, and PPP governance approaches have strengths and weaknesses in attending to certain problems that smart cities face. Public governance approaches will be better than public-private partnerships in some ways. Regional governance approaches have strengths and weaknesses as compared to the more common municipal governance approach. In part, these choices as to governance approach are influenced by what goals and values cities are pursuing and thus, they force the question of what the city plans to do. This paper allows both practitioners and academics to talk about these tradeoffs in an explicit and systematic way. In summary, being clear about the governance rules is necessary to good design, a good implementation, a management scheme, and ultimately its sustainability.

This work also contributes to research on smart cities and more generally on the large socio-technical systems we are building including smart cities, open data, and Big Data. Much of the

[3] The highly decentralized and fragmented federalist system in the U.S. is the backdrop of our study informed by interview data; however, our review of the literature included research and case studies on Smart Cities from around the world.

literature takes on a socio-technical theory of innovation but if that is true, the research must advance by addressing socio-technical issues, especially ones that involve governance. How much publicness [42] and public values are there in the design and implementation of public information systems?

The research also elaborates governance functions that more directly link values, problems, and organizations. This gives decision-makers a vocabulary and conceptual model to support their decision-making as they design and implement the informational foundations of their smart cities. This study also discusses three dimensions of IDE sustainability – political, financial, and operational – to show how attending to each of these different functions of the IDE contribute to the overall sustainability of smart cities. In turn, sustainability in all these dimensions really depends upon effective governance, and this study examines three dominant approaches to governance: municipal, regional cooperative, and public-private partnerships.

1.5 Outline of Paper

The next section explains more fully what an IDE is and how it works. Essentially, there are several functions that operate in three domains of an IDE: political, financial, and operational. Further, choosing an appropriate governance approach for the unique domains of the IDE contribute to the sustainability and success of smart city initiatives. The final section will discuss the implications and present emergent questions for future research.

2. Integrated Data Exchanges: The Foundation of Smart Cities

2.1 IDEs are Data Platforms with Governance Rules

One of the common features of smart cities is the integration of technology, data, and information to improve quality of life for those who live, work, learn, or play in the city [43]. In most cases, smart cities develop at the project-level, using a smart project to address a specific problem [44]. As smart cities become more complex over time and the scope of their projects increases, cities begin to see the benefit of integrating and standardizing the data of their smart city projects [45] [46]. For example, many of the projects will need to share the same demographic information about their citizens. In addition, public problems are complex, and so cities need data not only about health, but economics, and transportation to provide a coherent picture about the problem space they are dealing with. A recent study highlights this phenomenon, noting that most smart city initiatives (74%) now involve many departments within a city (cite).

Constructing IDEs begins with centralized and dynamic data repositories that could be a database, data lake, data warehouse, or a linked set of data. In its most basic form, the IDE contains data from more than one government unit, available through a common repository rather than in different agencies; in other cases, the data is collected by other non-governmental partners. Co-locating these data, uniquely collected by different units allow stakeholders across and outside city government to access and integrate these data with efficiencies resulting from managing only one interface and protocol for all the projects in the IDE. Moreover, the coordination process required for multiple stakeholders to share their data on interoperable

systems, facilitates the scaling up and long-term sustainability of individual smart city projects [43] [44].

But IDEs are more than the creation of interoperable systems. Creating information is not just collecting and aggregating data; rather, information is data in context. Without context that meets the needs of people, the data has little meaning and utility [38]. Thus, an IDE has more functions than that required of a data center as originally envisioned [2]. In some cases, these functions are essential, in other cases, they are functions carried out by cities that wish to exploit the different public benefits more fully from the information collected. Being clear about these functions and how to govern them are critical to the long-term growth and sustainability of smart cities.

Figure 1 illustrates a smart city from the perspective of managing data as a core function of government. At its core, this figure captures the core problem in interoperability [49] but is drawn in a way to emphasize the task of information management in a smart city. At this high-level, there are two generic components: 1) the projects which generate services but also generate data (e.g., "Roadways", "Health", "Mobility"), that sit upon the foundation of the Smart City 2) the Integrated Data Environment where all of the data is stored. Data could come into comes into the IDE from a project "Roadways", but it is an "data island" in that this roadway project accumulates and collects data (d) for just that project. There is also a "Health" project designed to improve the health of that city's citizens but here the data (d) flows from the health project to the IDE and back to the "health project" (two headed arrow). Finally, there is a "Mobility" project that is seeking to provide mobility services to mothers with high-risk pregnancies. This project also provides data (d) to the IDE and also receives data (d) from the

IDE including the health data just mentioned. The health project and the mobility project could share data (d) between themselves (hashed line), but it is far more efficient for them to share the information through the IDE using one common interface. IDEs may also include data from private sources, facilitating data to stakeholders both within government and outside of government.

Problems and opportunities with integrated repositories are not new and are discussed extensively in the "interoperability" literature (see [24] [45] [46] [47] [52]). This literature is cited because interoperability problems are usually encountered as governments become more sophisticated in their use of data. Unfortunately, governments can unknowingly back into these interoperability problems as they grow, creating significant negative path dependencies. A strategic view of IDEs would consider them early as part of a design process as smart city projects are implemented. Even more details about IDEs are provided as this paper identifies and explains the many different functions inside an IDE.

[Figure 1 near here]

2.2 Smart city Governance: Public and Private Models

Having provided a first definition of an IDE, the next logical question is to explain how an IDE is to be governed. The goal is not just collecting, organizing, and distributing the information, but providing the functionality to make sure that the data is useful and used. In the U.S., smart city projects are typically implemented using one of three governance approaches: municipal, regional cooperative, and public-private partnership. The municipal model is a conventional

public service mode of public provision characterized by a single-jurisdiction government responsible for the design and operation of smart city projects.

A regional cooperative is also a public governance model. It differs from the municipal model in that it also involves neighboring governments and may include universities, which are often cited as strategic partners when they work with smart city initiatives. Regionalizing smart city initiatives across a number of local governments is one way to address increasing demands on resources [53]. While economies of scale and efficiencies can be realized through regionalization, fragmentation and political territorialism remain strong disincentives among local governments in the U.S. [54]. There are a variety of configurations to regional cooperatives. One is a hub and spoke system where a large city, with resources and expertise, provides leadership, and then involves smaller local governments because of the regional advantages of doing so. Another is a clustered system of like governments in the same geographic region. A distinguishing factor is the regionalization of smart initiatives [54] with many governments in a cooperative role responsible for smart city success.

Public models (both municipal and regional cooperatives) may contract with vendors for technology solutions, as government has long relied on the private sector in this service area [55]. However, the distinguishing feature of public models is funding and governance of the project rests with the government. The PPP model is a cross-sector solution that engages industry as partner in the design and operation of smart city projects. While PPPs have been defined as loosely as any collaborative effort between the public and private sectors, this study shares Athias's [56] view that PPPs are "a commitment between parties that goes beyond traditional procurement—the private partner bears significant risk and shares management responsibility

with public partners." PPPs are a long-term commitment for "provisioning a public asset or service where the private sector bears significant risk and management responsibility" [57]. That is, PPPs are fundamentally different from other forms of government acquisition in that organizational and financial interdependencies constitute a distinct form of shared governance [58].

PPPs are commonly used for infrastructure projects as government resources to finance investment are constrained [57] [58] [59] [60] [61] [62]. Cities enter partnerships with private sector firms to create public and private benefits. In the case of smart city initiatives, cities benefit from technology investment, repurposing underutilized assets, and in some cases sharing in revenues generated from the new service, while private firms benefit from new revenue-generating opportunities. For example, LinkNYC utilized a PPP to replace payphones across New York City with WiFi enabled smart kiosks installed and managed by City Bridge Consortium in exchange for shared advertising revenue. Smart Columbus (Ohio) developed their smart transportation systems through a PPP with significant private sector funding in exchange for user fees for some partners and indirect benefits of economic development in the region for other partners [63].

Public and private approaches to governing smart city initiatives, illustrated by the municipal, regional cooperative and PPP models, are summarized in Table 1. Extant literature and practice informs the study's explication of the features, advantages, and challenges of each of the governance approaches. (See [64] for a comprehensive review of the PPPs and smart infrastructure.)

[Table 1 about here]

Table 1 summarizes the features, advantages, and challenges of each of the governance approaches drawing from extant literature. In this study's view, governance approaches utilized for smart city projects can be applied to an IDE. Choices about which governance model to utilize will affect the long-term sustainability of an IDE in various ways. For example, different governance approaches have varying capacities to engage with citizens, businesses, or ensuring that the IDE has the right set of skills to innovate. Municipal, Regional, or PPP governance approaches will also vary to the extent that they have stable and sufficient funding or can weather the shocks created by overlapping political, economic, and technology cycles that often plague long-term IT projects [65].

3. Applying Governance Approaches to Provisioning IDE Services

Different governance approaches can be applied to an IDE. Choices about which governance model to utilize will affect the long-term sustainability of an IDE in various ways. For example, each governance approach has varying capacities to engage with citizens, businesses, or ensuring that the IDE has the right set of skills to innovate. Governance approaches will also vary to the extent that they have stable and sufficient funding or can weather the shocks created by overlapping political, economic, and technology cycles that often plague long-term IT projects [65].

Figure 2 identifies the different functions of an IDE and are organized into the political, financial, and operational domains. Each of these different functions individually but also in how

they interact are all important to the long term sustainability of an IDE. Having discussed the major governance approaches in the U.S. and presented the various kinds of functions located with an IDE, the next section will more fully describe these functions and the strengths and weaknesses of these governance approaches in implementing those functions.

[Insert Figure 2 about here]

It is important to understand that the question of what governance approach should apply – municipal, regional cooperative, or PPP – could be asked of the whole IDE enterprise or for the different functions within an IDE. For example, the guidance and oversight function could be well-served by a public, municipal model, while the civic-tech participation function could be better governed by a PPP governance approach. By identifying the various functions that an IDE needs to perform, the appropriate set of governance rules can be applied to that function rather than the whole IDE.

A 'one-size-fits-all' approach where a PPP or a municipal government is responsible for managing all the IDE's functions does not allow for the appropriate governance approach for each unique function. This is an important design principal in ensuring the long-term sustainability of the IDE.

3.1 Political Domain: Guidance and Oversight

There must be a guidance and oversight function that is responsible for providing a long-term vision for the IDE, coordinates other IDE functions, and is ultimately accountable for its success.

The inherently public nature of the IDE means that it must operate in the political environment. The guidance and oversight function must also make sure that the functions supporting operational and financial sustainability of the IDE are implemented in a way that is cognizant of the values and "rules" in working in a political environment.

The different governance approaches bring different strengths and weaknesses in executing the guidance and oversight function. The municipal government model is geared toward a command-and-control relationship where its decisions are followed by other stakeholders. The regional cooperative introduces diffused responsibility and lateral relationship amongst neighboring governments creating shared responsibilities for guidance and oversight functions perhaps complicating oversight. At the same time, regional cooperative models also incorporate regional stakeholders into the governance system which may make it easier to coordinate the efforts of many local governments than a municipal government governance model. This is especially true if the geographic interest lies further than a city's boundaries. Finally, the regional governance approach could reduce risk and pool resources to enable stakeholders to do things that they individually might not be able to do. PPPs introduce complexities to the oversight and management function [66]. PPPs may have difficulty in understanding and working in the public sphere.

The neoliberal critique of the pervasiveness of capitalistic interests in monetizing access to public goods [67][68] [69] is a threat to a core function of government in ensuring access to information, a central assumption in this study. Private partners may also find it difficult to provide funding if they do not have input into the guidance and oversight function. Receiving funding from PPPs may make it possible to financially sustain the IDE but it comes with the

price tag that PPPs would have a stake in its guidance and oversight of the IDE. The question then becomes whether the PPP has the correct incentives and capacity to manage and provide oversight of an IDE that provides a core responsibility of government to insure access to public data.

3.2 Financial Domain: Acquiring a Sustainable Source of Funding

Many of the projects being pursued by smart cities have one-time streams of funding: a partnership with a company to work on a specific demonstration project, moneys from a foundation or governments grants to showcase a new innovative idea that can be adopted by other cities, or the use of small discretionary budgets that periodically become available through surplus revenues or through combining funding from other sources [43] [64]. While these funds are useful to go after small low-hanging fruit or to demonstrate the value of using data to deal with a problem, they are certainly not sufficient to sustain ongoing innovation or to effectuate a "transformation" of how government works. Long-term funding of these initiatives is now becoming a central concern among directors looking to sustain these projects and is another essential IDE function.

Sometimes there is a risk in the municipal government model where resources are scarce. Long-term, sustainable funding in the municipal government model is dependent on the degree to which the oversight and guidance function (political) is executed as well how well the operational dimension is in providing useful services. For example, a data breach caused by poor day-to-day operations or the failure to innovate, may destroy any goodwill thus far developed, and with it, the ability to ask for increased municipal funding. Municipal

governments are also sensitive to political and economic disruptions [65] [66]. The election cycle may not overlap with the economic cycle and funding could be subject to the various 'shocks' to the long-range planning and execution in larger its projects [65]. Larger municipalities may have the institutional resources required to invest to utilize capital budget to invest in IDE and pay for the ongoing operational costs [73]. Smaller governments may not have the slack and the resources to stand up an IDE on their own.

At the same time, relying on a PPP governance approach to supply funding has its own problems. As mentioned earlier, private funding may have a high price tag including having a strong voice in the direction that the IDE takes and what value is being extracted. Here, regional cooperatives are preferable to municipal government models in terms of reducing the transactions costs of innovation generation, sharing costs, and reducing the risk. Yet some local governments face increased funding constraints [74] and resources to develop and then sustain the IDE in the absence of private investment. Thus, ensuring the long-term funding of the IDE is a necessary function. The question then becomes whether a municipal, PPP, or regional cooperative model is best able to provide continued funding for that IDE? Is monetizing the collection and distribution of data a way viable way to raise revenues?

3.3 Operational Domain

The operational domain captures the purposes and work of the IDE. The functions within the operational domain include technological and social development and engagement, citizen and stakeholder participation, sense-making, day-to-day operations, and technological innovation. This is an illustrative rather than exhaustive list of purposes; that is, some cities may have

different objectives in mind for the operations of their IDE. Cities may emphasize some functions over others, for instance focusing more on technology innovation than citizen and stakeholder participation. Not unlike the political and financial domains, functions in the operational domain can vary in their success depending on the governance model chosen.

3.3.1 Operational Domain: Supporting Civic and Technology-Based Use of Data.

Many smart city initiatives are established to pursue technology-based economic development. Economic development occurs by attracting business to the municipality or region, as well as fostering an environment to encourage entrepreneurship [75]. Technology engagement focuses on stakeholders such as developers, hackers, and hobbyists, as well as established and new businesses [76]. The value of the IDE can be the development of new applications or data tools, and/or combining public and private data to use and/or sell. Civic entrepreneurs and nonprofits could focus only on the public value of the data, using data in new ways to provide services.

An IDE can introduce a competitive advantage for a municipality or region, which creates broader economic benefits for the community. IDEs also offer an opportunity to implement standards and interoperable systems that facilitates blending public and private sector data. Leveraging this feature of the IDE introduces new pathways for citizen and business to participate with government in the implementation of civic technologies [77]. Recognizing the increasingly foundational role that data has to the success of most companies [78], cities might also use IDEs to position the community as a technology leader to attract companies, talent, and other resources. This function would focus on making sure the data is accessible as possible and to ensuring that the IDE has data that meets its consumers' needs.

IDEs with greater reach, such as those in a regional cooperative or PPP may be more attractive for economic development. PPPs, in particular, have long been used to support economic development and efforts to drive entrepreneurship and growth [79]. In this governance approach, the value of the IDE for the private sector can be the development of new applications or data tools, and/or combining public and private data to use and/or sell. It may also be positioning the community as a technology leader to attract talent and other resources.

Similarly, a regional cooperative has a wider audience, scale, and scope of data to attract interest and investment in the community. Risks and benefits are shared among the partners and there is vested interested in the long-term success of an IDE—grounded in economic health—with a regional cooperative or a PPP. A municipal government model with its limited boundaries and scope, is less suited to fostering robust engagement with the tech community and likely more constrained than the other governance approaches in its ability to create new opportunities for regional economic growth by leveraging IDE resources.

3.3.2 Operational Domain: Citizen and stakeholder participation.

Improved citizen participation and engagement with government can also be an important function to insure the long-term sustainability of smart city initiatives [75]. Here, the focus is on democratic values and inclusion. Information is also central to transparency and to a government that is accountable and responsive to its citizen's needs [74] [75]. In this function, the IDE would have an interface that supports citizens rather than the tech community. The challenge is to create capabilities to support citizens who have a much more difficult time with the fast pace of innovation [82] [83]. These capabilities must not only align with citizens technical skills, but

also support the process of democratic deliberation through the enhancement of a qualified, informed, and thoughtful community [84]. However, these processes may work at a slower pace because of the need to deliberate and move to consensus. Attention to this value requires acknowledgement of this tradeoff and commitment to the multiple citizen perspectives and roles in the governance of the IDE [85].

When citizens are involved in the design and governance of smart initiatives, the likelihood increases that attention will be paid to issues of equity and inclusion. Citizen engagement in the process can also improve transparency, accountability, and ultimately, wellbeing. As Thompson [86] notes:

> "Virtually, all systems should be able to securely exchange and utilize available data to produce integrated answers for a more sustainable and resilient city where citizens have a better quality of life in more livable, efficient, and productive places. Overall, smart city agenda should be based upon long-term vision, people, and processes as the main drivers ([86], 369)."

Some governments have recognized smart city initiatives as a vehicle to improve wellbeing and to promote inclusion of underrepresented groups, at least in their formulation [85]. Ensuring that citizens have the information they need about government is central to implement a citizen-centric smart city initiative [87]. It is also important to understand citizens needs in both the design and implementation of specific projects [78]. Finally, effective engagement with citizens also develops social and political capital [1], thus ensuring that citizens see the value of the IDE and will support it politically and ultimately through continued public funding.

How important this function is and how much effort is given to support these values may vary to the degree that this function conflicts with other values and functions. These objectives can

conflict with other objectives, particularly when private sector partners are involved as PPPs may be more likely to minimize citizen engagement. In this governance model, government partners may need to convince or mandate engagement by PPPs to execute this function. Or they might hive off these functions to the public partner which is much better attuned to citizen concerns and needs.

Public governance models are better suited to citizen engagement, particularly around areas of equity and inclusion. Municipal government can leverage known assets in the community to provide design and implementation feedback on the IDE. The regional cooperative has similar attributes but extends the reach, which might also capture new stakeholders and approaches to engagement through shared best practices.

3.3.3 Operational Domain: Sense-Making

With the advent of open data, and now smart cities, the difficulty of obtaining data is no longer the biggest bottle neck in the use of data. The new bottle neck is in knowing how to use that data; thus, sense-making is becoming recognized as the next important function in IDEs. There are two notions of sense-making employed in the IDE. They differ in terms of the degree to which the public has a role in "making sense." One way to make sense of data is through the traditional tools that data analysts might employ - finding patterns in the data to either locate a problem or ways to deal with the problem. However, given the public nature of IDEs and the strident polarized disputes over what is a "fact", "sense-making" will become an increasingly important function in IDEs. "Sense-making" is an organic and dynamic process whereby different stakeholders bring their various frames of reference to understand what implications

information means for them [81] [82]. It is organic and dynamic because new information, new analysis, and provisional frames of reference are creatively developed to determine pragmatic ways of defining and solving problems. This kind of sense-making function needs explicit attention where the public needs help in interpreting for example, whether schools should receive a "failing grade" as defined by the data [83] [84] [85].

As a result, IDEs would need to make sure that this sense-making function has public spaces that allow for different publics to understand its meaning and negotiate a common understanding of what a "failing school" is. Cities may choose not to engage in these functions but that could be at the expense of reducing the public value of the data. Political sustainability will also be threatened because citizens will continually wonder what data is being collected and for what use. Limiting access to this data limits the exercise of 1st amendment rights by infringing on the "right to be informed" [86] [87].

The sense-making function could have three basic elements in a smart city IDE: 1) providing publicly available resources to analyze and visualize data; 2) providing education on how to use data; and 3) a public forum that takes advantage of these techniques to repeatedly ask questions, answer questions, and discuss the results in an iterative fashion. Iterative cycles might draw in new data, generate more refined questions, or result in the collection of new data. When a city is in the habit of asking and answering questions based upon data, according to this vision, it is on its way to becoming a smart city.

A public sector governance model should, in theory, be the best approach in executing the sense-making process; whether the municipal or regional cooperative model. Yet, the new sense-

making process will also include more sophisticated analytical techniques to garner full value of the information collected. It is this element of the "sense-making" process that argues that the public sector might not compete as well as the private sector or contractors in deploying these techniques. At the same time, a PPP approach might have more difficulty working with the "messy" political environment, especially if this sense-making process is closely linked to the policy process where analysis requires understanding and applying various frames of reference in analyzing information [83] [84] [85].

3.3.4 Operational Domain: Day-to-Day Operations

Smart city initiatives are pursued in part, to streamline internal operations, meet strategic priorities, and improve planning and coordination [75]. These daily operations include such activities as maintaining the hardware and software. Given the emphasis on use, data management would include such tasks as curating data, managing public records and open data requests, sourcing, and provisioning data, and protecting the security and privacy of the data.

When it comes to daily operations, efficiency is the watchword. Efficiency, however, is sometimes challenging to achieve in the public sector [95]. Efficiency, however, is not the only value that in the public domain and therefore not central to what public professionals think of as important [96]. The pursuit of democratic values is often at odds with efficiency goals [97].

Determining the appropriate governance approach to daily operations is less clear cut. PPPs could have an advantage because of their focus on efficiency. At the same time, while many of the day-to-day operations may seem strictly technical in nature they may, in fact, have a political

and democratic dimension that may not be executed in a way that a municipal governance system could accomplish [31]. A nuanced approach could take advantage of the PPPs ability to be more efficient but, at the same time, make sure that decision-makers continually ask what political choices are being made when a technical decision is made. For example, “efficiency” decisions about setting up access to data may in fact have significant consequences for those who do not think like systems engineers. The value of efficiency must be tempered with a realization that decisions are made in a public environment.

3.3.4 Technology Innovation

In addition to pursuing efficient day-to-day operations, IDEs must have a function that continues to pursue technological innovation. The incapacity to innovate results in outdated technologies, which lead to lower economy, efficiency, and effectiveness. The public sector was the most innovative sector in the early days of computing because of its size — it could afford risk in funding specialized areas. More recently, however, most governmental units are slow to innovate especially in those areas where public services must be provided without any disruption of services. There are a host of reasons why: 1) special interests that extract rent through the provision of legacy systems by creating dependencies and having strong political influence [68], [98]; 2) outdated procurement systems that make it difficult to innovate [99]; 3) the “goldfish bowl phenomenon” that abhors failure and risk [100]; 4) a personnel system that results in outdated skillsets [101]; and 5) a public service culture that is much more risk averse than their private sector counterparts.

PPPs can be an effective tool to foster technology innovation while at the same time, sharing risk and reward. PPPs have the benefit of the private sector's advantage in access to human capital and financial resources, which support a faster pace of innovation. Yet the challenges of PPPs in technology innovation can lie in ownership of the IDE (or its elements) and the types of innovation that are pursued. That is, PPPs would have a preference for projects that benefit the private partner perhaps at the expense of underrepresented citizens thus setting up a conflict between public and private values [102].

In summary, this section specified the political, financial, and operational domains of an IDE and how they contribute to the success of the IDE. For each of the domains, the appropriateness of different governance approaches was discussed, and strengths and weaknesses identified. The dimensions (and their subsequent functions) defined in this section are not inclusive of all those important to a useful IDE, but they are a serve as a baseline conceptual framework, leaving to future research the addition of other dimensions and functions. (See Table1).

4. Discussion: Governance and Sustainability of IDEs

In the previous section, each of the IDE functions were described and then examined as to the degree to which municipal, regional, or PPP governance approaches could support those functions. The examination included both the likelihood as to how well they could support those functions as well as some of the risks and opportunities these governance approaches offered.

This discussion of IDE functions and governance approaches were examined individually to provide a good description and a focused examination of that function. In real life, however, all

these functions and the governance approaches are interrelated, thus making it a complex problem. Cities may determine that they do not have a political constituency to fund IDEs and may turn to the private sector to bridge the budgetary gap, a common approach due to shrinking public funds [103] [104]. This may solve the financial sustainability problem, but it introduces other stresses and opportunities within the system. Public private partnerships are struck because both parties, public and private gain in some way. The private interest may fund a project to gain a chance to experiment with a new technology, but it also may seek financial benefits. It may seek to monetize access to data or services with the result that some public goods may be privatized. This would threaten a core reason for government to collect and distribute information even while it gains necessary funding.

It is also important to look at the complexity and tradeoffs that may come occur because of the governance approach itself, whichever governance system we are talking about. It may simply be the case that the private sector does not have the experience or expertise to deal with the public nature of many of these problems. They may be less understanding of the public's needs or how to work with the public. Even if the goals of the smart city are to increase efficiency or increase the rate of innovation, not attending to the public nature of these projects may catch up with the project when a PPP governance approach is taken. Unresponsiveness or the lack of transparency to the public may in the long run politically sabotage the PPP's long-term charter. This is even more likely if the public sector champion who helped develop the PPP leaves office. A catalyzing event like an information breach of the citizens' information may quickly put the PPP project in jeopardy although the real problem may be the long-term lack of attention to the public's needs. There will always be a public aspect to a private sector operation especially when

the private sector is involved in a public project. Recognizing this fundamental reality needs to be recognized in the governance rules that are developed.

Looking across these functions may also reveal tensions within a governance approach. A municipal governance approach may have some advantages over PPPs in understanding and working with the public, but the weaknesses of a public governance approach may also jeopardize the long-term sustainability of its IDE. Public governance rules will probably hinder how fast an IDE can innovate. The long political process to gain approvals, the pace at which the public sector workforce can adapt and retool or hire persons with specialized expertise also have an influence on the pace of innovation. When the public sees that an IDE just cannot do what others can do, there may be a loss of confidence in the IDE that then cascade to problems with the political and financial functions. How willing would citizens be to continue to fund an outmoded system, or even support increased funding in the future?

Finally, downplaying the importance of some functions may also cause stresses on the development of other functions in this system. Not paying attention to the sense-making function may result in an IDE collecting information, but for what purpose? Citizens might correctly ask, "if information is the way to improving government, why is all of this information being collected if it is not being used (or being used only by those who have the funding and technical skills to do something with the information)? "Why should we continue to fund this expensive operation?" How can we politically continue to support this?

Clearly, the IDE is a socio-technical system that needs to account for what technologies can offer to realize social interests. Some of the answers may lie in recognizing that different functions are

better suited to certain governance approaches. Rather than a strictly municipal approach to all of these functions, designing the governance system would systematically examine each of these functions for how they best fit for each function but also as to how they interconnect to the governance approach to the other functions.

4.1 Future Research on the Governance of Smart Cities

Research is now underway to empirically examine how different governance approaches perform in carrying out the various IDE functions identified. Anecdotes from public managers have revealed, although not empirically validated, that many are focused on short-term immediate needs but wish they had the time and resources to begin thinking about these longer-term issues. Many of these managers have also indicated through a nation-wide survey that there is a need for assistance in thinking through these questions.

Another important question only implicitly addressed in this study is role of public values in the smart city implementation [74] [89] [98]. Each of these governance approaches tends to advance certain sets of values over others and thus prominently figures in the question of what governance rules should apply, and by extension, how likely it is to be sustainable. For example, values are implicit in several issues now facing smart cities including the relative importance of collecting public and private information and, derivatively, public, and private claims on that information. When smart city efforts look to financial sustainability many of the solutions proposed include monetizing public information but how does that align with the ongoing efforts to increase transparency and advance the public's right to know?

Access to data is a critical public resource [106]. Those who have access to data can affect the power distribution in agenda-setting and decision-making [107]. Future research should consider empirically testing power differentials among the varying governance models of IDEs. To what extent are citizens gaining power and voice as data becomes more readily available?

5.2 Conclusion

If good public management is good decision-making [15], then information is the lifeblood of government. Creating, storing, and analyzing information is not only a core government function, but it is also foundational to the rest of society. As for government, evidence-based or data driven decision-making is key to be recognized as a "smart" city. Foundational to smart city efforts is an IDE to manage vast and disparate sources of information. One of the contributions of this study is defining an IDE and its role in curating, managing, and disseminating information.

In constructing a conceptual framework for an IDE, dimensions of political sustainability, operational sustainability, and financial sustainability emerged. This study makes the argument that IDE sustainability may be dependent on different governance models: municipal, regional cooperative, and PPP. If an important goal is to use up-to-date technology to make sure that the city stays innovative, it makes more sense to have this function governed by public-private governance systems and their accompanying rules than to keep that within a municipal governance system. If, however, the strategic goal is to make sure that the public is actively involved in smart city efforts or to be transparent and accountable, a public governance system is more appropriate for those functions.

The kinds of questions raised and analyzed in this study are precisely the kinds of questions that architects ask when they begin designing smart city data solutions. In a very real sense, this study helps to frame the conversations stakeholders from various interests should have when developing the architecture of politically, financially, and operationally sustainable smart cities.

Figures and Tables

Figure 1: Smart City IDE

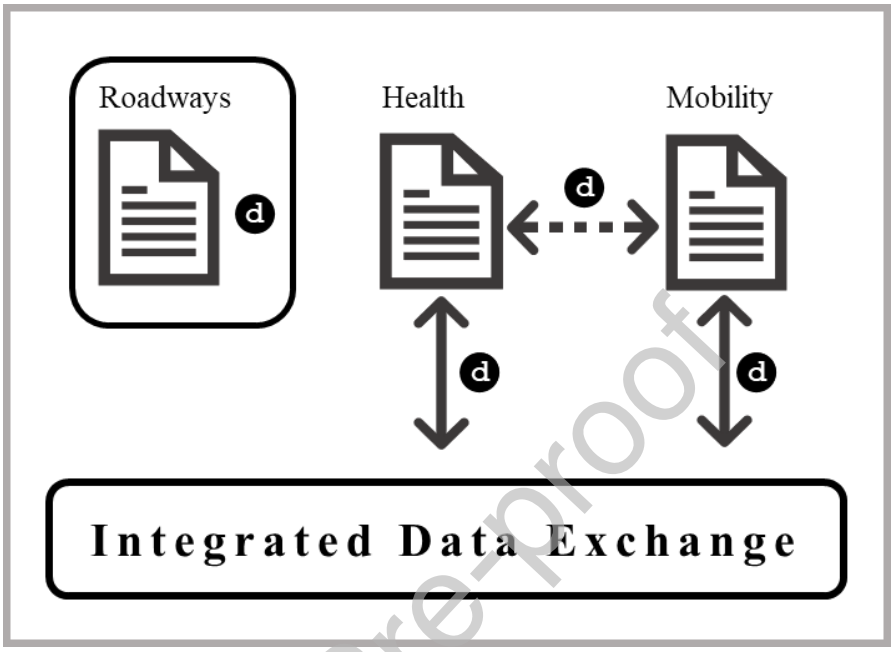

Figure 2: IDE Functions and their relationship to sustainability

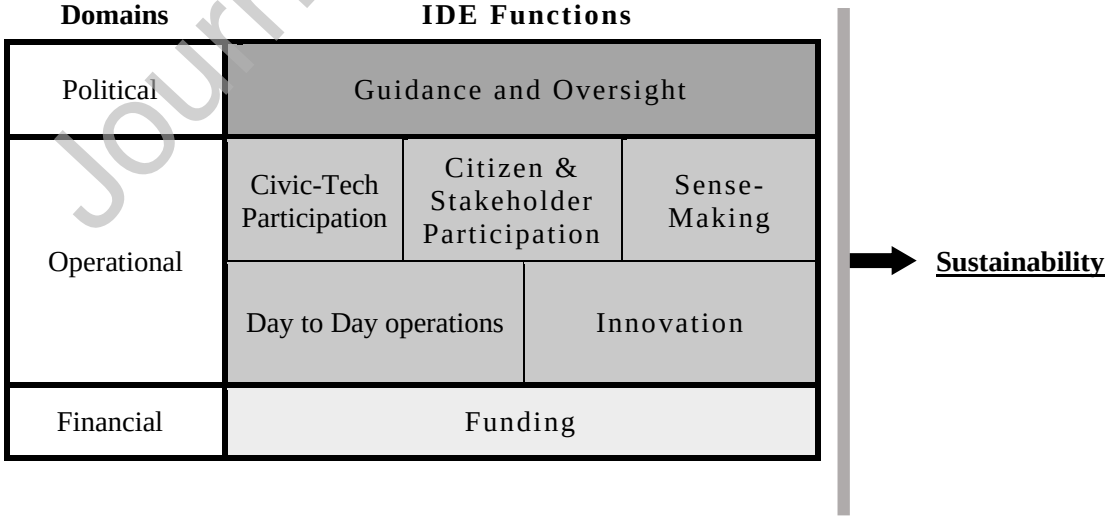

Table 1: Specifying IDE Governance Approaches

Approach	Features	Advantages	Challenges
Public: Municipal	Single jurisdiction Conventional public service model Contracts w/vendors Funding, governance retained by government	Centralized, single governance authority Likely responsive to citizens, public values	Limited financial resources Limited access to talent, skills Heightened political, legal restrictions Constrained utility as data restricted to single jurisdiction
Public: Regional Cooperative	Multi-jurisdiction, may include public universities Conventional public service model Contracts w/vendors Funding, governance retained by government	Potential for economies of scale, shared services Pooled financial resources Greater utility as data is multi-jurisdiction, regional, and shared Likely responsive to citizens, public values, but may be competing for resources across jurisdictions	Limited financial resources Limited access to talent, skills Heightened political, legal restrictions Requires more resources for coordination Higher transaction costs due to coordinating across different systems
Public-Private Partnership	Cross-sector, may include multi-jurisdictions Collaborative public service model Shared funding, governance, risk among parties	Innovation, access to talent, skills Access to capital, flexible resources Greater emphasis on efficiency Pooled financial resources	Disparate, competing goals Potential for differential service quality based on fee-for-service Requires more resources for coordination Less responsive to citizens, public values

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Competing Interests Statement

The authors declare that there are no conflicts of interest. There are not financial or personal relationships with other people or organizations that could inappropriately bias our work.

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