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Understanding Smart Cities: An Integrative Framework

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Abstract

Making a city "smart" is emerging as a strategy to mitigate the problems generated by the urban population growth and rapid urbanization. Yet little academic research has sparingly discussed the phenomenon. To close the gap in the literature about smart cities and in response to the increasing use of the concept, this paper proposes a framework to understand the concept of smart cities. Based on the exploration of a wide and extensive array of literature from various disciplinary areas we identify eight critical factors of smart city initiatives: management and organization, technology, governance, policy context, people and communities, economy, built infrastructure, and natural environment. These factors form the basis of an integrative framework that can be used to examine how local governments are envisioning smart city initiatives. The framework suggests directions and agendas for smart city research and outlines practical implications for government professionals.

1. Introduction

More than half of the World's population now lives in urban areas [18-20]. This shift from a primarily rural to a primarily urban population is projected to continue for the next couple of decades (see http://www.unfpa.org). Such enormous and complex congregations of people inevitably tend to become messy and disordered places [32]. Cities, megacities, generate new kinds of problems. Difficulty in waste management, scarcity of resources, air pollution, human health concerns, traffic congestions, and inadequate, deteriorating and aging infrastructures are among the more basic technical, physical, and material problems [10,40,56,58]. Another set of problems are more social and organizational in nature rather than technical, physical or material. Problems of these types are associated with multiple and diverse stakeholders, high levels of interdependence, competing objectives and values, and social and political complexity. In this sense, city problems become wicked and tangled [16,51,59].

Ensuring livable conditions within the context of such rapid urban population growth worldwide requires a deeper understanding of the smart city concept. The urgency around these challenges is triggering many cities around the world to find smarter ways to manage them. These cities are increasingly described with the label *smart city*. One way to conceptualize a smart city is as an icon of a sustainable and livable city.

Although there is an increase in frequency of use of the phrase "smart city", there is still not a clear and consistent understanding of the concept among practitioners and academia. Only a limited number of studies investigated and began to systematically consider questions related to this new urban phenomenon of smart cities. This paper attempts to start filling this gap by identifying important trends and suggesting research agendas about cities as they invest in new ways to become "smart." By exploring an extensive array of literature from various fields such as e-government, information science, urban studies, and public administration, we identify and discuss challenges, success factors, and impacts of government-driven initiatives to that make a city smart. We identify eight core components of smart city

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initiatives, and propose an integrated conceptual framework to guide future "smart city" studies.

2. Conceptualizing a smart city

As discussed above, the concept of a smart city itself is still emerging, and the work of defining and conceptualizing it is in progress [11,31]. The concept is used all over the world with different nomenclatures, context and meanings. A range of conceptual variants generated by replacing the word smart with adjectives such as digital or *intelligent* are readily used and reused. Some are recognizing the use of *smart city* as an urban labeling phenomenon [31], noting that the label smart city is a concept and is used in ways that are not always consistent. Several working definitions (see Table 1) have been put forward and adopted in both practical and academic use. This cacophony of definitions is resulting in calls for conceptual research in this regard [11].

Table 1. Working Definitions of a Smart City

• A city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens. [24]
• A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens. [28]
• A city "connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city" [29]
• A city striving to make itself "smarter" (more efficient, sustainable, equitable, and livable) [45]
• A city "combining ICT and Web 2.0 technology with other organizational, design and planning efforts to de-materialize and speed up bureaucratic processes and help to identify new, innovative solutions to city management complexity, in order to improve sustainability and livability." [56]
• "The use of Smart Computing technologies to make the critical infrastructure components and services of a city—which include city administration, education, healthcare, public safety, real estate, transportation, and utilities—more intelligent, interconnected, and efficient" [58]

Giffinger *et al*'s [24] definition considers smart as performing in a forward-looking way. The forward-looking development approach to a smart city considers issues, such as, awareness, flexibility, transformability, synergy, individuality, self-decisiveness, and strategic behavior [24]. In Harrison *et al*'s study [29], a smart city denotes an instrumented, interconnected, and intelligent city. Instrumentation enables the capture and integration of live real-world data through the use of sensors, kiosks, meters, personal devices, appliances, cameras, smart phones, implanted medical devices, the web, and other similar data-acquisition systems, including social networks as networks of human sensors. Interconnection means the integration of those data into an enterprise computing platform and the communication of such information among the various city services. Intelligence refers to the inclusion of complex analytics, modeling, optimization, and visualization in the operational business processes to make better operational decisions. In contrast, the Natural Resources Defense Council [45] defines smarter in the urban context as more efficient, sustainable, equitable, and livable. Toppeta [56] emphasizes the improvement in sustainability and livability. Washburn *et al*. [58] view a smart city as a collection of smart computing technologies applied to critical infrastructure components and services. Smart computing refers to a new generation of integrated hardware, software, and network technologies that provide IT systems and real-time awareness of the real World and advanced analytics and actions that optimize business processes [58].

Given the conceptual comprehensiveness of a smart city, it could be thought of as a large organic system connecting many subsystems and components like the ones described above. Dirks and Keeling [19] consider a smart city as the organic integration of systems. The interrelationship between a smart city's core systems is taken into account to make the system of systems smarter. No system operates in isolation. In this sense, Kanter and Litow [34] consider a smarter city as an organic whole—a network and a linked system. While systems in industrial cities were mostly skeleton and skin, postindustrial cities—smart cities—are like organisms that develop an artificial nervous system, which enables them to behave in intelligently coordinated ways [42]. The new intelligence of cities, then, resides in the increasingly effective combination of digital telecommunication networks (the nerves), ubiquitously embedded intelligence (the brains), sensors and tags (the sensory organs), and software (the knowledge and cognitive competence).

3. Success factors of smart city initiatives

Drawing on the rich, but quite different, conceptual definitions of a smart city presented above, this paper proposes a comprehensive set of factors that are essential to understanding smart city initiatives and projects. These factors, brought together into a smart cities framework, can be used to study and determine success factors of smart city initiatives or projects. In addition to sustainability and livability, our framework addresses several internal and external factors that affect design, implementation, and use of smart cities initiatives. Our goal is not to produce a set of components to rank smart cities, but to create a framework that can be used to characterize how to envision a smart city and design initiatives, which advance this vision by implementing shared services, and navigating their emerging challenges. The eight clusters of factors include (1) management and organization, (2) technology, (3) governance, (4) policy, (5) people and communities, (6) the economy, (7) built infrastructure, and (8) the natural environment.

3.1. Management and organization

Only a few studies in the academic literature on smart city initiatives address issues related to managerial and organizational factors. In contrast, a wide array of previous research on IT initiatives and projects has highlighted these issues as important success factors or major challenges [26,53]. Thus managerial and organizational concerns in smart city initiatives need to be discussed in the context of the extensive literature on e-government and IT projects success.

For instance, Gil-Garcia and Pardo [26] suggested a list of success factors and challenges for e-government initiatives (see Table 2). Smart city initiatives might differ from more general e-government initiatives in the context and in some of the characteristics of specific projects, but there is much in common between those two types of initiatives because most smart city initiatives are also driven by governments and leveraged by the intensive use of ICTs to better serve citizens.

Table 2. Managerial and organizational challenges and strategies

Challenges	Strategies
• Project size • Manager's attitudes and Behavior • Users or organizational diversity • Lack of alignment of organizational goals and project • Multiple or conflicting goals • Resistance to change • Turf and conflicts	• Project team skills and expertise • Well-skilled and respected IT leader (technical and social skills) • Clear and realistic goals • Identification of relevant stakeholders • End-user involvement • Planning • Clear milestones and measurable deliverables • Good communication • Previous business process improvement • Adequate training • Adequate and innovative funding • Current or best practices review

Source. Gil-Garcia and Pardo [26]

3.2. Technology

A smart city relies, among others, on a collection of smart computing technologies applied to critical infrastructure components and services. Smart computing refers to a "new generation of integrated hardware, software, and network technologies that provide IT systems with real-time awareness of the real world and advanced analytics to help people make more intelligent decisions about alternatives and actions that will optimize business processes and business balance sheet results" [58].

ICTs are key drivers of smart city initiatives [31]. The integration of ICT with development projects can change the urban landscape of a city [57] and offer a number of potential opportunities [48], they can enhance the management and functioning of a city [48].

Despite proclaimed advantages and benefits of ICTs use in cities, their impact is still unclear [48]. Indeed, they can improve the quality of life for citizens, but they can also increase inequalities and promote a digital divide [48]. Thus, city managers should consider certain factors when implementing ICT with regard to resource availability, capacity, institutional willingness and also with regards to inequality, digital divide and changing culture and habits [48]. Ebrahim and Irani [21] have outlined some of the challenges of using technologies in smart cities (see Table 3).

Table 3. Technological challenges

Dimension	Challenges
IT skills	• IT training programs • Lack employees with integration skills and culture
Organizational	• Lack of cross-sectoral cooperation • Lack of inter-departmental coordination • Unclear vision of IT management • Politics • Culture issues

Source. Ebrahim and Irani [21].

3.3. Governance

Several cities have started transformational projects and initiatives called smart city initiatives to better serve citizens and to improve their quality of life [24,48]. These projects involve multiple stakeholders. Thus, several cities have felt an increased need for better governance to manage these projects and initiatives [27]. In general, (public) governance has been defined "as regimes of laws, administrative rules, judicial rulings, and practices that constrain, prescribe, and enable government activity, where such activity is broadly defined as the production and delivery of publicly supported goods and services." (p. 235) [38]. Governance, hence, involves the implementation of processes with constituents who exchange information according to rules and standards in order to achieve goals and objectives [33]. Scholl *et al*. [53] studied challenges of e-government key projects, and found that stakeholders' relations is one of the critical factors to determine success or failure of such projects. "Stakeholder relations" refers to four main issues: the ability to cooperate among stakeholders, support of leadership, structure of alliances and working under different jurisdictions [53].

Several cities have benefited from the emergence of ICTs that improve their governance. This ICT-based governance is known as smart governance. It widely represents a collection of technologies, people, policies, practices, resources, social norms and information that interact to support city governing activities. According to Forrester, smart governance is the core of smart cities initiatives [8,24]. Thus, it represents an important challenge for smart city initiatives.

Little literature on smart cities addresses issues related to governance. According to Mooij [43], the presence of leadership is important for good governance. In the same way, Lam [35] emphasized on the presence of a "champion" that collaborate with all stakeholders as an essential factor for good governance [35]. Smart governance is described as an important characteristic of a smart city that is based on citizen participation [24] and private/public partnerships [48].

According to Johnston and Hanssen [33], smart governance depends on the implementation of a smart governance infrastructure that should be accountable, responsive and transparent [43]. This infrastructure helps allow collaboration, data exchange, service integration and communication [48]. Table 4 summarizes the relevant governance factors found from the literature.

Table 4. Factors of governance

Factors	Authors
• Collaboration	[35,37,53]
• Leadership and champion	[35,43,53]
• Participation and partnership	[24,48]
• Communication	[48]
• Data-exchange	[37,46]
• Service and application integration	[46,48]
• Accountability	[33,43]
• Transparency	[33,43,46]

3.4. Policy context

Transformation from an ordinary (non-smart) city to a smart city also entails the interaction of technological components with political and institutional components [41]. Political components represent various political elements (city council, city government, and city major) and external pressures such as policy agendas and politics that may affect the outcomes of IT initiatives [9,52]. Institutional readiness such as removing legal and regulatory barriers is important for smooth implementation of smart city initiatives.

The policy context is critical to the understanding of the use of information systems in appropriate ways. Hence, an innovative government stresses the change in policies, because a government cannot innovate without a normative drive addressed in policy [22]. Whereas innovation in technology for a smart city can be relatively easily observed and broadly agreed upon, subsequent changes in the policy context are more ambiguous [30]. The policy context characterizes institutional and non-technical urban issues and creates conditions enabling urban development [60].

Findings in e-government research help inform our paper. Gil-García and Pardo's [26] study on e-government success factors identified legal, regulatory, institutional and environmental challenges of e-government initiatives. Smart city initiatives face similar challenges which influence the policy context. Government organizations are created and operated by virtue of a specific formal rule or group of rules. In making any kind of decision in IT projects, public

managers need to take into account a large number of restrictive laws and regulations [17,39]. Federal systems, as like in the United States, Canada, or Mexico, present additional challenges derived from the particularities of the relationships (intergovernmental relationships) between different levels of governments [9,17,36]. There are also challenges related to a more general institutional framework and the policy environment, in which government organizations operate [13]. In this context, institutions are not only made up of laws and regulations, but also norms, actions, or behaviors that people accept as good or take for granted [54].

3.5. People and communities

Addressing the topic of people and communities as part of smart cities is critical, and traditionally has been neglected on the expense of understanding more technological and policy aspects of smart cities. Projects of smart cities have an impact on the quality of life of citizens and aim to foster more informed, educated, and participatory citizens. Additionally, smart cities initiatives allow members of the city to participate in the governance and management of the city and become active users. If they are key players they may have the opportunity to engage with the initiative to the extent that they can influence the effort to be a success or a failure. Table 5 lists the factors related to smart cities and people and communities as found in the literature.

It is critical also not to refer to members of the city not only as individuals, but also as communities and groups and their respective wants and needs within cities. People and communities is a component that requires smart cities initiatives to be sensitive in balancing the needs of various communities.

Table 5. Factors of people and communities

Factor	Authors
• Digital divide(s)	[6,47,53,55]
• Information and community gatekeepers	[7]
• Participation and partnership	[24,48]
• Communication	[15,48]
• Education	[19,24,58]
• Quality of life	[23,24,50]
• Accessibility	[49]

3.6. Economy

Economy is the major driver of smart city initiatives, and a city with a high degree of economic competitiveness is thought to have one of properties of a smart city. As well, one of the key indicators to measure growing city competition is the capacity of the city as an economic engine [25]. Giffinger *et al*. [24] suggest a smart city framework consisting of six main components (smart economy, smart people, smart governance, smart mobility, smart environment, and smart living). Their operational definition of a smart economy includes factors all around economic competitiveness as innovation, entrepreneurship, trademarks, productivity and flexibility of the labor market as well as the integration in the national and global market.

A series of studies [19,20] released by the IBM Institute for Business Value identify business as one of core systems of smarter cities, which comprise city services system, citizens system, business system, transport system, communication system, water system, and energy system. Capacities for smart business systems include ICT use by firms, new smart business processes, and smart technology sectors. The smart city initiatives are designed to develop information technology capacities and establish an agenda for change by industry actions and business development [14]. Creating an environment for industrial development is pivotal to a smart city [12]. The economic outcomes of the smart city initiatives are business creation, job creation, workforce development, and improvement in the productivity.

3.7. Built infrastructure

The availability and quality of the ICT infrastructure are important for smart cities [24]. Indeed, smart object networks play a crucial role in making smart cities a reality [57]. ICT infrastructure includes wireless infrastructure (fiber optic channels, Wi-Fi networks, wireless hotspots, kiosks) [1-3], service-oriented information systems [4,5].

The implementation of an ICT infrastructure is fundamental to a smart city's development and depends on some factors related to its availability and performance. There is a little literature that focuses on ICT infrastructure barriers of smart cities initiatives. As done in the managerial and organizational section, we will refer to e-government technological barriers since smart cities' initiatives are similar to e-government initiatives in their use of ICT. Ebrahim and Irani [21] presented a set of factors related to the implementation of ICT. Table 6 presents a set of IT challenges grouped in three dimensions; IT infrastructure, security and privacy, and operational cost.

Table 6. Factors of built infrastructure

Dimension	Challenges
IT infrastructure	• Lack of integration across government systems • Existing internal systems have restrictions regarding their integrating capabilities • Lack of knowledge regarding interoperability • Availability and compatibility of software, systems and applications
Security and privacy	• Threats from hackers and intruders • Threats from viruses, worms and Trojans • Privacy of personal data • High cost of security applications and solutions • accessibility
Operational cost	• High cost of IT professionals and consultancies • High cost of IT • Cost of installation, operation and maintenance of information systems • Cost of training

3.8. Natural environment

Smart city initiatives are forward-looking on the environmental front [24]. Core to the concept of a smart city is the use of technology to increase sustainability and to better manage natural resources [45]. Of particular interest is the protection of natural resources and the related infrastructure [28] such as waterways and sewers and green spaces such as parks. Together these factors have an impact on the sustainability and livability of a city, so these should be taken into consideration when examining smart city initiatives.

4. Integrative framework

Drawing on the conceptual literature on smart cities and the factors outlined above, we have developed an integrative framework to explain the relationships and influences between these factors and smart city initiatives. Each of these factors is important to be considered in assessing the extent of smart city and when examining smart city initiatives. The factors provide a basis for comparing how cities are envisioning their smart initiatives, implementing shared services, and the related challenges. This set of factors is also presented as a tool to support understanding of the relative success of different smart city initiatives implemented in different contexts and for different purposes. Similarly, this framework could help to disentangle the actual impact on types of variables (organizational, technical, contextual) on the success of smart city initiatives.

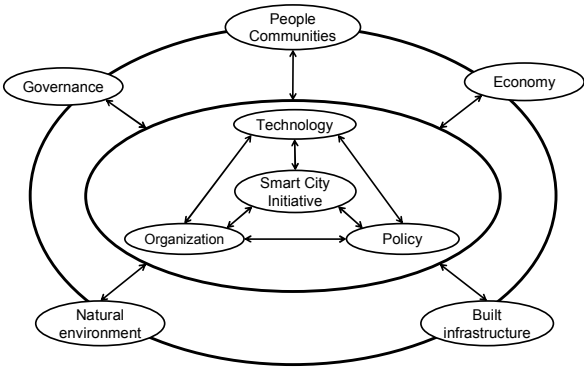

Figure 1. Smart city initiatives framework

It is expected that while all factors have a two-way impact in smart city initiatives (each likely to be influenced by and is influencing other factors), at different times and in different contexts, some are more influential than others. In order to reflect the differentiated levels of impact, the factors in our proposed framework are represented in two different levels of influence. Outer factors (governance, people and communities, natural environment, infrastructure, and economy) are in some way filtered or influenced more than influential inner factors (technology, management, and policy) before affecting the success of smart city initiatives. This counts for both direct and indirect effects of the outer factors. Technology may be considered as a meta-factor in smart city initiatives, since it could heavily influence each of the other seven factors. Due to the fact that many smart city initiatives are intensively using technology, it could be seen as a factor that in some way influences all other success factors in this framework.

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