DESIGNING NEXT GENERATION SMART CITY INITIATIVES - HARNESSING FINDINGS AND LESSONS FROM A STUDY OF TEN SMART CITY PROGRAMS

Complete Research

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Abstract

The proliferation of "Smart Cities" initiatives around the world is part of the strategic response by governments to the challenges and opportunities of increasing urbanization and the rise of cities as the nexus of societal development. As a framework for urban transformation, Smart City initiatives aim to harness Information and Communication Technologies and Knowledge Infrastructures for economic regeneration, social cohesion, better city administration and infrastructure management. However, experiences from earlier Smart City initiatives have revealed several technical, management and governance challenges arising from the inherent nature of a Smart City as a complex "Socio-technical System of Systems". While these early lessons are informing modest objectives for planned Smart Cities programs, no rigorous developed framework based on careful analysis of existing initiatives is available to guide policymakers, practitioners, and other Smart City stakeholders. In response to this need, this paper presents a "Smart City Initiative Design (SCID) Framework" grounded in the findings from the analysis of ten major Smart Cities programs from Netherlands, Sweden, Malta, United Arab Emirates, Portugal, Singapore, Brazil, South Korea, China and Japan. The findings provide a design space for the objectives, implementation options, strategies, and the enabling institutional and governance mechanisms for Smart City initiatives.

Keywords*: Smart Cities, Smart City Design, SCID Framework, Smart Cities Strategies, Design Science Research, Smart Cities Initiatives*

1 Introduction

The unprecedented level of urbanization and consequent growth in size and numbers of cities in different parts of the world present both challenges and opportunities. On the one hand, the phenomenal growth in urban population from 250 million at the beginning of the 20th century, to 2.8 billion at the beginning of the 21st, and to about 9 billion by 2050 (Editors, 2011), challenges traditional approaches to city management and urban lifestyle. Equally interesting is the challenge to leverage opportunities city growth offers arising from the expansion of the much needed intellectual and social capital for socio-economic growth (Ratti & Townsend, 2011) and the relative reduced resource demands for larger cities if optimally managed (Bettencourt, Luis M. A.; West, 2011).

In addressing these challenges, governments at city and other levels are initiating Smart City programs. These initiatives are directed at how the respective cities can transform themselves in different policy areas such as the use of alternative or renewable energy, use and management of natural resources, waste reduction and management, carbon emission, green areas, to desired sustainable socio-economic outcomes.

However, experiences from earlier and on-going Smart City initiatives have revealed several technical, management, and governance challenges arising from the inherent nature of a Smart City as a complex "Socio-technical System of Systems". While these early lessons are informing modest objectives for planned Smart Cities programs, no concrete framework based on careful analysis of existing initiatives is available to guide policy makers and other Smart City stakeholders. Existing frameworks are either conceptual, developed based only on review of Smart Cities literature, for instance (Nam & Pardo, 2011) or they narrowly focus on the technological aspects or architecture of Smart Cities, for instance (Zygiaris, 2012). Rather than providing prescriptive Smart City frameworks or reference models that are detached from the realities of users, we argue that frameworks that offer users a design space consisting of a set of options for different aspects of Smart Cities Initiatives are potentially more effective. Such a framework will allow users to make choices based on the realities of the environment or externalities of the Smart City program under considered.

Motivated by the need to provide Smart City policymakers in a particular City in Asia with a tool to guide their decisions in developing their Smart Cities Program, we present a framework grounded in findings from a detailed study of ten existing and relatively mature Smart City programs including: Smart Amsterdam, Netherlands (Šťáhlavský, 2011); Climate Smart Malmo, Sweden (Malmo City Environment Department, 2009); Smart City Malta, Malta (SmartCity, n.d.); Masdar Smart City, United Arab Emirate (Masdar City, 2011); PlanIT Valley, Portugal (Living PlanIT, 2011); Smart City Singapore, Singapore (Mahizhnan, 1999); Smart Curitiba, Brazil (International Council for Local Environmental Initiatives, 2002); Smart Songdo, South Korea (http://www.songdo.com); Tianjin Eco-City, China (http://www.tianjinecocity.gov.sg/) and Yokohama Smart City, Japan (http://jscp.nepc.or.jp/en/yokohama/). The study is comprehensively documented in a report (Ojo, Dzhusupova, & Janowski, 2012). The framework - "Smart City Initiative Design (SCID) Framework"; is constructed following the Design Science Research Approach; considered appropriate when inventing or building new innovative artifacts for solving problems or achieving improvements of high relevance in an application domain (Iivari & Venable, 2009)(B. A. R. Hevner, March, Park, & Ram, 2004).

The next section presents a conceptualization of the Smart Cities Concept and Smart Cities initiatives. Section 3 describes our Design Science Research (DSR) methodology for developing the SCID Framework and details of the framework are presented in Section 4. Section 5 discusses the issues relating to the use and validation based on the DSR checklist (A. Hevner & Chatterjee, 2010) before presenting the conclusions in Section 6.

2 CONCEPTUALIZING SMART CITIES

The conceptual underpinning for the research was established by performing a mapping exercise on the conceptualizations and definitions of the core concepts of a Smart Cities. The term Smart City (or Smart Cities) has been adopted by different governments, consulting organizations (IBM, 2013) and research groups. Despite the wide use of the term, its meaning remains fuzzy (Caragliu, Bo, & Nijkamp, 2009) (Nam, Taewoo; Pardo, 2011). A Smart City according to (Giffinger et al., 2007) is "A City 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". This definition is based on the traditional regional and neoclassical theories of

urban growth and development. In particular, the axes are based on theories of regional competitiveness, transport and ICT economics, natural resources, human and social capital, quality of life, and participation of societies in cities. Based on Giffinger's definition, (Caragliu et al., 2009) offers a similar definition of the concept as follows – "We believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance".

Smart Cities are expected to dramatically improve their citizens' quality of life, encourage business to invest, and create a sustainable urban environment (Vasseur & Dunkels, 2010). Interestingly, while the term *Smart City* literarily implies an outcome or result, most usage of the term consider it as an 'activator' of change through exploring relevant open innovation processes (Paskaleva, 2011). Other conceptualizations such as (Nam, Taewoo; Pardo, 2011) consider smart city as urban innovation involving technological, organizational, and policy innovation. Finally, a Smart City could be understood as a certain intellectual ability that addresses several innovative socio-technical and socio-economic aspects of growth (Zygiaris, 2012).

Three elements characterizing the Smart City concept identified in (Hollands, 2008) include: 1) utilization of networked infrastructures to improve economic and political efficiency and enable social, cultural, and urban development; infrastructures including ICT; 2) business-led urban development and 3) social and environmental sustainability. Social sustainability implies social cohesion and a sense of belonging, while environmental sustainability refers to the ecological and 'green' implications of urban growth and development. (Komninos, 2011) presents the concept of spatial intelligence of cities as a composite capability enabling communities within the city to harness the intellectual capital, institutions, and material infrastructure in dealing with problems and challenges. Spatial intelligence is composed of three types of intelligence: 1) the inventiveness, creativity, and intellectual capital of the city; 2) the collective intelligence of the city's institutions and social capital; 3) the artificial intelligence of public and city-wide smart infrastructure, virtual environments, and intelligent agents. These three types of intelligence involve all dimensions of the city and map to three types of spaces – physical, institutional, and digital spaces. The "physical space" corresponds to the inventiveness and creativity of the city, the "institutional space" includes the social capital and collective intelligence of a city population, and "digital space" contains the artificial intelligence embedded into the physical environment, including public broadband communication infrastructure and digital technologies.

Focusing on the digital space, (Vasseur & Dunkels, 2010) identified the following infrastructure networks for smart cities. Some of these networks are related to transport, public safety and security, public services, utilities, and social networking. In the physical space, skills and human capital are considered as arguably the most important element. For instance, it is argued that the greatest competitive advantages of cities are qualities that attract the best and brightest from around the world to a city (Bloomberg, 2011). This is supported by the fact that educated cities grow more quickly than less educated ones, since skilled cities are economically more productive and better at adapting to economic shocks (Glaeser & Saiz, 2003).

We summarize the different elements of the definitions of the Smart City concept below in Table 1. Further discussions on the conceptualizations and definitions of the Smart City are provided in (Hollands, 2008), (Caragliu et al., 2009) and (Nam, Taewoo; Pardo, 2011).

No	Description	Reference
Nature	*Is a* (1) forward-looking City in the areas of economy, people, governance, mobility, environment and lifestyle; (2) form of urban innovation; and (3) Intellectual Capital Profile of a City	Giffinger et al. 2007), (Nam, Taewoo; Pardo, 2011), (Zygiaris, 2012)
Essence	*Means to* (1) Information access, bridging digital divide, lifelong learning, social inclusion and economic development; sustainable economic growth and urban	(Hollands, 2008) , (Vasseur & Dunkels,

	development, higher quality of life; and wise management of natural resources; (2) innovative socio-technical and socio-economic growth of a city	2010), (Zygiaris, 2012)
Approach	*Involves* (1) investments in human and social capital; (2) investment in traditional (transport) & modern (ICT) communication infrastructure; (3) promoting participatory governance and engagement of citizens; (4) technological, organizational and policy innovation	(Caragliu et al., 2009), (Nam, Taewoo; Pardo, 2011)

Table 1: Elements of "Smart Cities" Definitions

3 APPROACH

The approach employed in developing the SCID Framework follows the Design Science Research guidelines and process elaborated in (A. Hevner & Chatterjee, 2010), (B. A. R. Hevner et al., 2004) and (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007). Design science in general creates and evaluates artifacts that define ideas, practices, technical capabilities, and products through which the analysis, design, implementation and use of information systems can be effectively accomplished. Our objective was to create an artifact in the form a design tool to assist Smart City policymakers and practitioner in making decisions about different aspects of Smart City initiatives to achieve a set of objectives or desired outcomes. The practical relevance of the tool is related to its goals of supporting the knowledge and decision needs of Smart City policymaker in City Governments responsible for planning Smart City initiatives. We summarize in Table 2 the DSR profile for the SCID Framework design process.

Guideline	**Description**	**SCID Framework Instance**
G1: Design as an Artifact	DSR must produce a viable artifact in the form of a construct, a model, method or an instantiation	We developed a Conceptual Model for Smart Cities Initiatives and a concrete Framework as a design support tool. The framework also serves as a Knowledge Map as it maintains references to origin of design options in the cases.
G2: Problem Relevance	The objective of DSR is to develop technology-based solutions to important and relevant business problems	The SCID framework directly addresses the need of policymakers with the need to know decision options for different aspects of the design of Smart City initiatives
G3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via a well-executed evaluation method	The framework has been reviewed by the targeted users - Smart City policymakers with positive feedbacks on its usefulness. Additional field studies are planned for evaluating the tool with practitioners in different Cities
G4: Research Contributions	Effective DSR must provide clear and verifiable contributions in the areas of design artifact, design foundations and/or design methodologies	The major constructs and relationships in the SCID framework constitute a research contribution in the Smart Cities domain. The SCID Framework contributes to the Smart Cities literature.
G5: Research Rigour	DSR relies upon the application of a rigorous method in both the construction and evaluation of the design artifact.	The SCID framework is grounded in findings from the analysis of ten concrete cases of mature Smart City initiatives. The analysis of the cases is based on the clearly defined conceptual model. Policy domains discovered in smart cities literature are used to map or streamline initiatives identified in the cases.
G6: Design as a research process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.	Each major element of the framework was iteratively developed based on the analysis of each of the ten case studies. Subsequent iterations sought to refine the contents of the framework.
G7: Communication of the research	DSR must be presented effectively both to technology-oriented as well as management-oriented audiences.	The SCID framework has been communicated to the target policymaker users in the form of a toolkit. This paper is one of the attempts to communicate the framework to the technology and research community.

Table w2: Design Science Research Profile for the Study

3.1 Research Framework

The research framework employed is an instantiation of the DSR Framework, comprising three core cycles – relevance, design, and rigor (A. Hevner & Chatterjee, 2010). As shown in Figure 1, the contextual environment for the work is the Smart City Policy environment in Macao SAR, China; as well the knowledge needs of its policymakers charged with the design and implementation of Smart City initiatives. The knowledge base consists of the sources of information on all ten selected Smart City case studies and the literature related to the conceptualization of Smart Cities and Smart City initiatives. The design cycle iteratively builds different elements of the SCID Framework from the analysis of the cases.

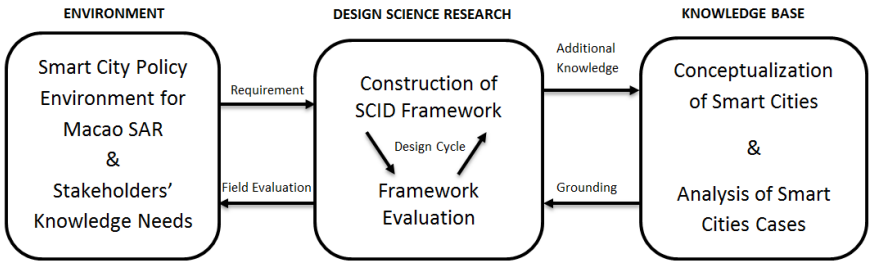

Figure 1: The Research Framework

3.2 Design Process

Guided by the research framework in Figure 1 and elaboration of the DSR methodology process model (Peffers et al., 2007), the design process proceeded in following major steps: 1) Identification and motivation of problem, 2) Definition of objectives for the framework, 3) Design and development of the SCID Framework, 4) Demonstration of use of the Framework, 5) Evaluation of framework and 6) Communication of the framework. As highlighted in Table 2, at least one iteration has been carried out in each step of the process. Further evaluation with larger numbers of users is underway. We have already published the artifact as a toolkit report for policymakers and aim to further disseminate the outcome of the research as scholarly publications.

3.3 Selected Cases - The Ten Smart City Initiatives

Given the centrality of the ten cases underpinning the design of the framework (i.e. Knowledgebase Element of our research framework), we highlight in Table 3 the profiles of the associated cities. The cases were selected based on their maturity, availability of detailed information on the respective initiatives and to some extent the interest of the target users – i.e. policymakers in Macao.

Program Name	City	Population
Smart Amsterdam	Amsterdam, Netherlands	- 783,364 within city, - Urban population of 1,209,419 - Metropolitan population of 2,158,592
Climate-Smart Malmo	Malmo, Öresund region, Sweden	- Third largest city in Sweden with 270,000 inhabitants
SmartCity Malta	Malta, Malta	5,600 knowledge workers (out of 412,000)
Masdar Smart City	Abu-Dhabi, United Arab Emirate	895,000 o in 2009
PlanIT Valley	Paredes, Portugal	
Smart City Singapore	Singapore, Singapore	5 million
Smart Curitiba	Curitiba, Brazil	2.3 million people, 1.6 million of which live in Curitiba. It is expected to reach 3.1 million in 2015

Smart Songdo	Songdo, Incheon, South-Korea	
Tianjin Eco City	Tianjin Binhai New Area, China	300,000
Yokohama Smart City	Yokohama, Japan	3.68 Million

Table 3: Selected of Smart City Programs

4 THE SMART CITY INITIATIVE DESIGN (SCID) FRAMEWORK

The SCID framework is a solution designed to address the lack of a concrete design framework for Smart City Initiatives. It specifies major aspects of Smart City Initiatives and how the initiatives can impact specific policy domains of City Governments. The conceptual model in Figure 2 describes the core aspects of "Smart City Initiatives" that are of interest and how these aspects relate.

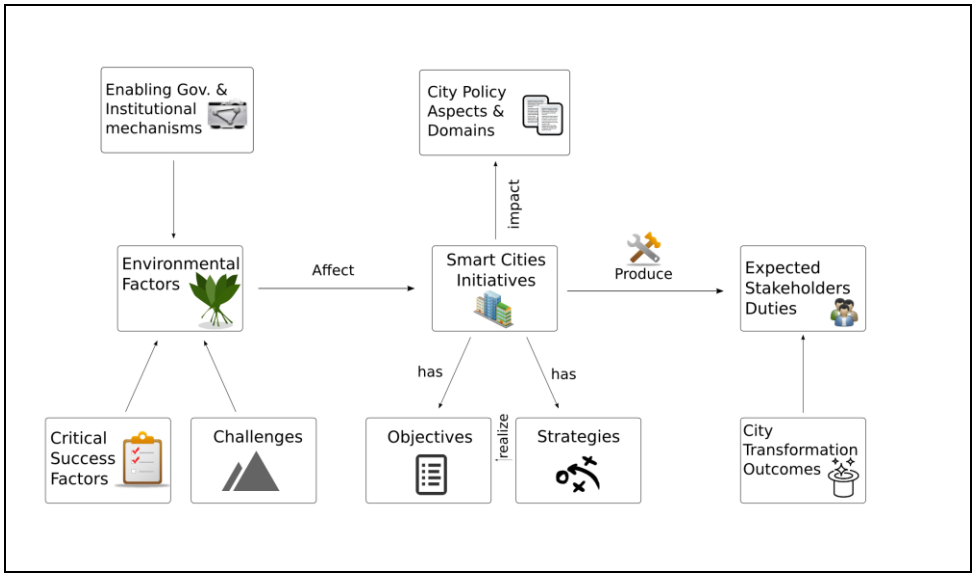

Figure 2: Conceptual Model for Smart City Initiatives

The model was developed based on the analysis of the cases highlighted in Section 3.3. In summary, the Smart City Initiatives have clear objectives that are to be realized through concrete strategies. The initiatives are designed to impact on specify city aspects, or policy domains, and at the same time realize some larger City transformation outcomes desired by the wider stakeholders group. However, initiatives would have to address environmental factors that may pose concrete challenges and at the same time consider lessons from similar initiatives in the form of catalogued success factors. Managers of Smart City Initiatives need to identify specific governance and institutional mechanisms to address the challenges and critical success factors. An important aspect of the model is the explicit link between the initiatives and outcomes. This provides a value-oriented perspective to the solutions associated with the framework. The rest of this section describes elements of the framework and related design choices.

4.1 Overview

In line with the conceptual model in Figure 2, there are six major elements of the SCID Framework – 1) **Smart City Initiatives** – specific smart city related project or program to be implemented, 2) **City Policy Domains** – related set of city aspects to be impacted by the initiatives, 3) **Stakeholders' and City Transformation Outcome** - expected impacts on the city as a whole and desired results by wider Smart City stakeholder groups, 4) **Enablers** – partnerships, institutional and governance mechanisms

required to address critical factors and challenges, 5) **Critical Success Factors** – set of conditions that significantly contribute to the success of Smart City initiatives, 6) **Challenges** – difficulties that policymakers may face in implementing Smart City initiatives. The SCID elements are illustrated in Figure 3.

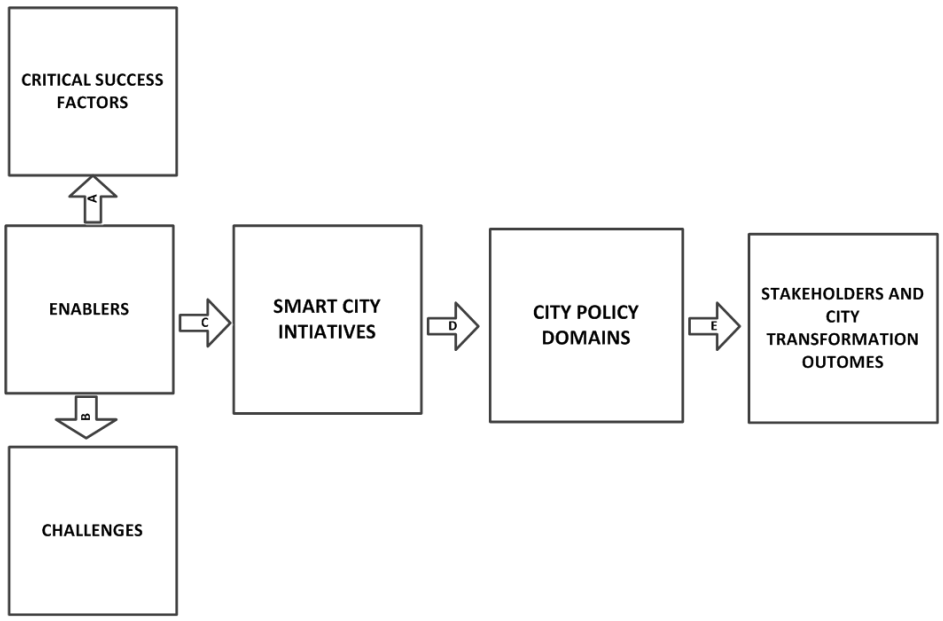

Figure 3: The SCID Framework

At a practical level, each element of the SCID Framework provides multiple choices to the following policymaker's questions about Smart City initiatives:

Q1) What kinds of outcomes could city residents and other stakeholders desire with regards to transformation of the City?
Q2) What aspects of the City life should be transformed to achieve the desired outcomes?
Q3) What types of Initiatives can be pursued towards achieving these outcomes?
Q4) What types of concrete objectives can be set for these initiatives?
Q5) What factors contribute to successful Smart City initiatives
Q6) What are the common difficulties faced by managers of Smart City initiatives?
Q7) What are the typical mechanisms deployed to address success factors and challenges in Smart City initiatives?

4.2 Elements

4.2.1 City Policy Domains

The SCID framework provides answers to the question related to aspects of the city life that should be improved to achieve the desired outcomes (Q2). These city aspects correspond to the major policy areas for city governments that are usually targeted for transformation within the Smart City context. The case study findings revealed the following eight primary domains - Economy, Environment, Energy, People (intellectual endowment and skills), Lifestyle (Building), Mobility (Transportation), Technology and Governance.

Program	Economy	Economy and Environment	Energy	Energy and Environment	Environment	Environment and People	Environment, Energy	Governance	Lifestyle	Lifestyle, Environment	Mobility	Mobility and Environment	Mobility, Governance, Environment	Technology	People
AMSTERDAM			■								■				
MALMO		■	■		■			■	■		■				■
MALTA	■														
MASDA CITY			■		■			■			■				
PLAN IT							■	■			■				
SINGAPORE			■		■			■	■		■				
CURITIBA		■			■	■					■		■		
SONGDO				■	■						■			■	
TIANJIN					■				■	■		■			
YOKOHAMA			■		■										

Table 4: Dimensions Covered in Selected Smart City Programs

While Smart City initiatives may target a single domain, in general initiatives would be expected to target two or more related domains. As shown in Table 4, most of the cases provide examples where two or more policy domains are targeted. The table also shows that Energy, Environment and Mobility are domains most commonly targeted.

4.2.2 Smart City Initiatives

This section provides answer to Q3, what types of Smart City initiatives can be pursued to achieve desired outcomes. The answers are presented in two parts – the objectives of the initiatives and the strategies or mechanisms to realize those objectives.

Objectives of Smart Cities Initiatives

Across all cases, we observe that smart city initiatives in general aim at: (1) Carbon reduction and neutrality; (2) achieving energy efficiency; (3) leveraging ICT to develop niche industries such as those relating to multimedia or knowledge-based industry; (4) attaining the highest quality living environment for residents; (5) developing green areas within the city; (6) developing state-of-the-art information infrastructure accessible to all; (7) achieving economic growth and quality of life simultaneously; (7) developing Sustainable communities; (8) ensuring social harmony among different groups of residents; and (9) evolving city as living laboratory to foster continued improvements. Table 5 details concrete examples of Smart City objectives.

Program	Purpose
Smart Amsterdam	○ Focus on CO_2 reduction, energy efficiency and behavioral change. Become Europe's first "intelligent" city, with an initiative to incorporate a smart grid, smart meters, electric vehicles, and "smart" building design. ○ Reduce energy consumption in commercial properties, public buildings and areas, housing, and transportation. ○ Develop and implement sustainable and cost-effective programs that will help Amsterdam reduce its carbon footprint while exceeding the carbon reduction targets put forward by the European Union's 2020 emissions and energy reduction target.
Climate-Smart Malmo	○ Become a world-leading climate city and Sweden's first climate-neutral city by 2020 with respect to municipal sector activities. ○ Exceed the EU's energy target of reducing CO_2 emissions by 20 % by 2020.
PlanIT Valley	○ Build the world's greenest city from scratch and establish a genuine European alternative to Silicon Valley and a working template for new generation low CO_2 cities. ○ Integrate companies, education, and government into the urban environment, a major difference from the technology parks and Silicon Valley campuses ○ Provide stimulus for the application of advanced technologies in transforming environment and supporting innovation, skills, and education.

	○ Save in both construction and subsequent operation of the city. Target is to save 30-40 per cent on traditional building costs and construct buildings 30-50 per cent faster and to a much higher quality.

Table 5: Summary of Objectives of Smart City Programs

Exemplar Strategies for major dimensions

We provide examples of strategies to realize the objectives presented above. Complete listings of strategies are provided in the practitioner's SCID Framework Toolkit Document. Below we describe the strategies for the most common policy domain, the Environment, and highlight some strategies for both the Energy and Transport domains.

Environment – This dimension is associated with seven categories of strategies including 1) water management, 2) open and green space development, 3) material flow and recycling, 4) sustainable city operations, 5) land use planning, 6) sustainable agriculture and natural resource management and 7) waste management. Table 6 provides strategies for the environment dimension and the information on the sources of the strategy.

Initiative	**Strategies**
Waste Management	○ Waste separation into dry recyclables; wet recyclable, residuals & solid waste. (Masdar) (Curitiba)
	○ Designed to encourage recycling in low-income areas where it was more difficult to reach by the conventional waste management system. (Curitiba)
	○ Involved children in the program by exchanging recyclable garbage for school supplies, chocolates, and food parcel. (Curitiba)
	○ Hired retired and unemployed residents temporarily to clean up specific areas of the city where litter has accumulated. (Masdar)
	○ Minimize the amount of waste, make reuse and recycling possible and enable the use of waste and sewage as an energy source. (Malmo)
	○ Construction of waste separation system in buildings. (Malmo)
	○ Food waste is primarily collected to produce bio-gas for vehicle fuel. (Malmo)
Open and Green Space	○ Build a large 100-acre green space as the city's centerpiece, which was modeled after New York City's Central Park. (Songdo)
	○ Ensure that all blocks to connect pedestrians to open space, walking/biking corridors and public gathering areas. (Songdo)
	○ Design open spaces and public gathering areas to optimize access to sunlight, views, and open sky. (Songdo)
	○ Provide 40% open space to maximize the connection to nature within the city for residents, workers, and visitors. (Songdo)
Material Flow and Recycling	○ 75% of construction waste is targeted to be recycled. (Songdo)
	○ Recycled materials and locally produced/manufactured materials will be utilized to the maximum extent possible. (Songdo)
	○ Portland cement reduction of 20% or more through the utilization of flash-content concrete. (Songdo)
	○ Low-VO (Volatile organic compound) materials incorporated into buildings. (Songdo)
Environmental Sustainability	○ Implement Sustainable Singapore plan. The key targets are: 1) 35% reduction in energy intensity from 2005 levels, 2) raise overall recycling rate to 70%, and 3) introduce 50 ha of skyrise greenery. (Singapore)
Land use Planning	○ Provides a land-use plan that based on transit-oriented development. (Tianjin)
	○ Create centers for each district where local and centralized facilities are provided to serve the needs of residents in each neighborhood. (Tianjin)
	○ More land will be converted to organic agriculture. Crop-free and pesticide-free zones in the agricultural landscape will benefit biological diversity and reduce the spread of nutrients and toxins into watercourse and groundwater (Malmo)
	○ Biological diversity will be preserved and developed hand in hand with nature protection and nature management (Malmo)

Table 6: Strategies for Environment Dimension

Energy – Common strategies for this dimension include: 1) adoption of energy efficient practices particularly in building designs, 2) use of renewable energy such as biogas and wind energy by households, 3) use of smart grid technologies and deployment of energy management system at the community, 4) education of children through projects on how to save energy and 5) promotion of the use of e-vehicles and hybrids.

Transportation – Core strategies in this domain include: 1) focusing on accessibility rather than mobility in transportation planning, 2) provision of networks for non-motorized transportation (bicycles and walking), 3) prioritization parking for fuel-efficient and low emitting vehicles in public places, 4) use of e-vehicles for public transport with charging stations provided across the city, 5) integration of land-use and public fare collection and 6) adoption of transit-oriented development in urban planning.

4.2.3 Stakeholders and City Transformation Outcomes

This section provides answers to Q1 on the type of outcomes desired by stakeholders of Smart City initiatives. Recognition as good practice exemplars featured prominently in the reported outcomes by these programs. The recognitions based on benchmark rankings of smart cities are considered valuable by the different programs. Other outcomes associated with the programs in different areas are presented in Table 7.

Environment	○ Aesthetic value ○ Recycling take-up by residents and businesses ○ Green space per residential unit ○ Recognition - ranking and designation as best practice exemplar ○ Adoption of organic food	**Energy**	○ E-Vehicle adoption ○ Level of biogas production ○ Use of wind energy ○ Energy usage reduction ○ Petrol usage reduction
Transportation	○ Less congestion ○ Less CO_2 emission ○ Self-sustainability ○ Recognition – ranking and designation as best practice exemplar	**Economy**	○ Standard of living ○ GDP contribution ○ Unemployment rate ○ Investment friendly environment ○ Recognition – including competitiveness ○ Employment and job creation ○ Foreign Direct Investment ○ Startups

Table 7: Summary of Desired Outcomes from Smart City Programs

4.2.4 Critical success factors

This section presents the answers to Q5 – the success factors for smart city programs. Analysis of the success factors across cases show that: 1) Political leadership and 2) the adoption of an integrated, holistic, and whole of government approach to smart city development stand out as critical factors. Other identified factors include – 3) creation of dedicated research and think-tank institution to support program, 4) non-compromise on core values, 5) ensuring creativity but affordability of solutions, 6) comprehensive master-planning, 7) regulations and standards for stakeholders, and 8) building stakeholder collaboration and industry partnerships. Examples from cases are provided in Table 8.

Program	Success Factor	Keyword
Curitiba	Leadership and adherence to smart transportation planning has helped Curitiba strive towards becoming a sustainable city while gaining a strong reputation as a great example of successful urban planning.	Leadership and adherence to plan implementation

	IPPUC's creation was an essential to ensure long-term implementation of city plans. IPPUC was effective in ensuring planning continuity and success regardless of political, economic, and social challenges, and made substantial contributions as a laboratory for finding creative, integrated solutions to urban planning problems.	Creation of research and Think-tank Institution
	The combination of core values expressed in the city plan and IPPUC's creation allowed planning for efficiency and sustainability even in difficult circumstances. Commitment to local values such as accessibility, transparency, social justice, poverty reduction, and efficient resource management are what resulted in Curitiba's sustainable development, which is more than simply "environmental."	Non-compromise to Core values
Masdar	Collaborate with a range of partners who share the vision and commitment.	Collaboration
Singapore	Successful water management program would not be possible without institutional reform, such as the adoption of demand management in the new water tariff setting, i.e. removal of subsidy for domestic users.	Institutional reform
	Comprehensive and long-term planning to ensure economic competitive and quality of life at the same time.	Holistic long term planning
	Prudent land use planning enabled Singapore to enjoy strong economic growth, social cohesion, and ensures that sufficient land is safeguarded to support continued economic progress and future development.	Prudent land use

Table 8: Success Factors for Smart City programs

4.2.5 Challenges

This section presents the answers to Q6 on common difficulties faced in Smart City initiatives. A number of challenges were identified across the reviewed programs. These challenges include: 1) obtaining buy-in from stakeholders, particularly the private sector; 2) inclusion of poor areas in the program; 3) sustaining stakeholders' interests and participation; 4) resourcing and funding the program considering high development cost; and 5) obtaining residents participation. Specific examples are presented in Table 9.

Program	**Challenge**	**Keyword**
Curitiba	Since changing circumstances require new approaches, Curitiba's most important future challenge is to continue cooperation among a wide spectrum of people and organizations in order to foster economic prosperity.	Sustained multi-stakeholder cooperation
	Integrating poor areas and shantytowns in city periphery including those not connected to the sewer system.	Coverage of poor areas
Singapore	How to sustain economic growth and ensure high quality of life through better planning.	Balanced growth
PlanIT Valley	PlanIT Valley faced many challenges, not least in terms of convincing others that this vision can become a reality	Buy-in from stakeholders

Table 9: Challenges associated with Smart City Programs

4.2.6 Enablers

This section provides answers to Q7 on mechanisms for addressing the success factors and challenges. Two core mechanisms including partnerships and governance are discussed.

Partnership for smart city programs

Smart City programs are complex and involve a wide range of partners and stakeholders playing different roles. The nature of partners involved in smart city programs include: academia (university and research centers), state-owned enterprises, real-estate firms (e.g. Gale International), architectural practice firms, investment firms (e.g. TECOM investment), engineering construction firms, technology firms (e.g. CISCO, IBM, Microsoft, Hewlett Packard), international consulting firms (Accenture, Mott MacDonald), government departments and agencies, other governments (e.g. Singapore). While some smart city programs are driven by private sector (e.g. Malta and PlanIT

Valley), government entities always play a pivotal role. Table 10 provides examples of the partners for some of the selected programs.

Program	Partner	Partner Type	Partner Role
Curitiba	Curitiba Research and Urban Planning Institute	Academia-Research Institute	Master plan development
	Mayor	Host Government	Coordination
	URBS Urbanizao de Curitiba (URBS)	State-owned Enterprise	Infrastructure maintenance and oversight on bus companies
Songdo	Gale International	Real estate	Main developer
	Korea's POSCO Engineering & Construction company Ltd	Private Sector	Setting up Songdo International City Development (NSIC) as Joint Venture Company in 2002
	Cisco	Private Sector	Create advanced community connected by IT
	Kohn Pedersen Fox Associates	Private Sector	Architectural Design of Sogdo IBD
	Songdo U-Life	Quasi Private Sector	Building of ubiquitous infrastructures & ubiquitous environment for u-services
Masdar	Masdar Venture	Private Sector	Economic diversification via Renewable energy
	Masdar Institute	Academia – Research Institute	Science & engineering of advanced alternative
	Mott Macdonald	Private sector – Engineering firm	Engineering
Singapore	Ministry of National Development	Host Government	Plan, regulate, facilitate & execute development projects
	Urban Redevelopment Authority	Host Government	Promote architecture and urban design excellence.
	Economic Dev. Board	Host Government	Planning and executing strategies to enhance Singapore's position as a global business center
	IBM	Private Sector	Partner on Smarter City Initiative
	Singapore MIT Alliance for Research and Technology	Academia – Research Institute	MIT-supported research in urban mobility system
	Microsoft	Private Sector	Software

Table 10: Examples of Partners for Smart City Programs

Governance

Governance actions constitute the second category of mechanisms. Four types of governance actions have been identified across the studied programs – 1) Coordination and integration; 2) service integration; participation and co-production; and 4) policy and regulations. Coordination and integration actions in smart city programs include identification of an agreed set of projects by stakeholders across sectors, use of administrative and legal instruments for conformance, and integrated planning practices involving multiple sectors. Service approaches integrated utility management with the use of Urban Operating Systems (UOS) for managing urban services. Participation and co-production actions include building multi-stakeholders partnerships with industry, academia, and residents in addition to the participation of internal firms in the development of smart cities. Lastly, policy and regulatory actions include master-planning, institutional development, certification of practices (e.g. buildings), promotional activities (e.g. low carbon growth), and development of framework acts. Specific examples are presented in detail in the toolkit.

5 DISCUSSION

First, we highlight our experience in using the DSR approach in developing the SCID Framework. Our experience shows that the method not only enables a clear rigorous process for building the artifact but also enabled detailed attention to our targeted users' needs. However, while we set out to use our cases only as a Knowledgebase for grounding our artifact, we discovered that the cases were

also a rich source of information on the potential needs of the users, and subsequently provided a detailed requirement specification for a Framework. Second, feedback from users revealed that the options provided by the SCID Framework are useful and the use of the framework is aligned with their IT Management practices in areas such as portfolio management, strategic alignment, and benefits management. Third, as we argued in the Section 1, our objective was not to provide explicitly a prescriptive model, but rather offer possible choices as answers to the questions that Smart City policymakers have on developing initiatives. Although, the users found the options provided useful, rigorous internal evaluation of the tool revealed that there might be the need to better support how specific choices of the options are decided with respect to critical success factors and challenges. Specifically, considering techniques that are used to support decision making in the context of several factors such as the Analytical Hierarchical Process (AHP) (Vaidya & Kumar, 2006) as useful for linking for the environmental factors and strategic choices offered the framework. Fourth, as the SCID framework relies heavily on a knowledgebase of analysis of initiatives, the effectiveness and freshness of the choices offered by the tool will depend on how it is able to capture emerging knowledge from emerging and future Smart City initiatives. Our current plan is to update the framework periodically as triggered by requests from users. However, we consider for the longer-term a more participatory, crowd-sourced and social approach for the dynamic update of the SCID Framework. Finally, we intend to carry out further dissemination and evaluation of the tool with Smart City initiatives managers in the context of an International Collaboration Program involving Smart City practitioners and researchers across North America, South America, Asia, and Europe.

6 CONCLUSIONS

We have shown how the knowledge and experience generated from concrete Smart City initiatives can be harnessed to develop a tool to guide policymaker intending to develop new Smart City initiatives. This work also contributes to the examples of projects where the DSR approach has been used. Obviously, the developed framework in its current form is limited by its existing knowledgebase. Thus, the utility of the tool is partly related to the richness and freshness of its knowledge base. We intend to continue work on dissemination of the tool, monitoring, and evaluation of its use in more diverse environments and its periodic update, while investigating novel social strategies for dynamic updating of the SCID Framework's knowledgebase.

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