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Conference Paper

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22nd Biennial Conference of the International Telecommunications Society (ITS): "Beyond the Boundaries: Challenges for Business, Policy and Society", Seoul, Korea, 24th-27th June, 2018

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Tang, Zhiwei; Jayakar, Krishna; Feng, Xiaodong; Zhang, Huiping; Peng, Xiaoyue (2018) : Conceptualizing implementation frameworks from the bottom up: A content analysis of smart city plans, 22nd Biennial Conference of the International Telecommunications Society (ITS): "Beyond the Boundaries: Challenges for Business, Policy and Society", Seoul, Korea, 24th-27th June, 2018, International Telecommunications Society (ITS), Calgary

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Conceptualizing implementation frameworks from the bottom up: A content analysis of smart city plans

**Presented at the International Telecommunications Society Annual Convention,
Seoul, South Korea, June 2018**

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Abstract

This paper presents a comparative analysis of 52 municipal smart city plans drawn from countries around the world, with the goal of enumerating the specific policies and programs that are included under the general rubric of various “smart city” initiatives. Cluster analysis identified five different models: in addition to an Infrastructure model to which most smart city plans belonged, a Green model, a Utilities model, a Citizen Services model and an E-government model could be identified.

Introduction

After the advent of the “smart city” as a socio-technical innovation made possible by new information and communication technologies (ICTs) and information processing capabilities, many cities around the world had initiated smart initiatives aiming to solve pressing problems in urban planning and governance. Various labeled “smart city,” “smart society,” “intelligent city,” “digital city,” “cyber city” etc., these plans have involved initiatives in a number of areas including housing, transportation management, energy networks, training and education, and e-government. The implementation of smart city programs in these areas has also achieved significant progress.

However, in general terms, the “smart city” remains more of a buzzword, than a clearly articulated, coherent, and integrated program of action. One of the reasons is that there is no clear strategic vision of smart city development. In the literature, there is no widely accepted definition of “smart city” (Albino, Berardi, & Dangelico, 2015; Adapa, 2018). A series of frameworks for the “smart city” have been brought forth (Giffinger, Fertner, Kramar, Kalasek, Pichler-Milanovic, & Meijers, 2007; Nam, & Parelo, 2011; Choubari, Taewoo, Walker, Gil-Garcia, Mellouli, Nahon, Pardo, & Scholl, 2012). Whereas there are significant overlaps in these frameworks, there are also significant conceptual differences with the result that their impact on developing strategic plans remains limited. Cities seeking exemplars for successful smart city development receive limited guidance from mostly theoretical, top-down models of “smart city” development.

Therefore, this paper investigates what smart city planners and managers are actually implementing on the ground to build a conceptual model from the bottom up. In contrast to academic theorists who build theoretical models of smart city development, city planners and managers are motivated by the practical problems confronted by urban areas and their residents. They are also guided by the felt needs of local populations and businesses, the technological affordances of available ICTs and information management systems, and the constraints of budgets and infrastructure investments. A review of actual smart city plans is therefore likely to provide empirical evidence of the emerging contours of smart city models. It is also likely to offer better guidance to city planners as they search for successful exemplars they can emulate in their own smart city plans.

Accordingly, this paper is an exploratory study to investigate how municipal governments have formulated their smart city plans. Though a number of governmental agencies such as national ministries, regulatory bodies, ICT advisory committees and national level urban development authorities have announced smart city plans, we use municipal plans as our unit of analysis since they are the closest to the urban problems that smart city initiatives are expected to solve. Therefore, using municipal smart city plans as the unit of analysis, we ask the following questions: (i) What specific programs and initiatives by issue areas (e.g., transportation, e-government, smart electricity grids) are included in the smart city plans of municipalities? (ii) What are the commonalities and differences between municipal smart city plans? Are there patterns in the distribution of smart initiatives across municipal smart city plans? Based on these patterns, may “archetypes” or “models” be identified into which municipal smart city initiatives may be categorized? (iii) How common are “smart city” models, and what are exemplars for smart city initiatives within each model?

To answer these questions, this paper proceeds as follows. In the next section, currently available definitions of the smart city are presented. It will be shown that while there is considerable overlap between these definitions, there is no consensus. The next section presents the challenges in implementing a vision of the smart city in terms of actual plans, strategies and programs. It focuses on the exemplars, templates and guidelines available to city planners as they seek to implement smart city programs. We seek to demonstrate that these templates are guided by theoretical visions with insufficient attention paid to empirical evidence. In the next section, our methodology and data are introduced: we discuss the process by which a new theorization of the smart city might be enabled through reference to the empirical evidence on smart city implementations around the world. The next section presents the results of our analysis, with a hierarchical cluster analysis to identify the emerging “archetypes” in smart city development. The final section presents the conclusions and directions for further research.

Defining the smart city

The term “smart city” is of relatively recent vintage. It was coined around 2005, to refer to the application of new information and communication technologies (ICTs) and information processing capabilities to the problems of urban design (Picon, 2015). Though predicated on the availability and implementation of ICTs and computing, theorists caution against focusing only on these technological infrastructures. As Picon (2015) points out, smartness or intelligence is the “ability to learn, understand and reason” (p. 28). In that sense, a “smart city” is an entity that has capabilities for perception, reasoning and problem-solving on a separate and higher plane than the individuals and sub-collectivities that constitute it. To quote Picon’s (2015) definition of a smart city:

“As an ideal, it consists of a city whose digital tools allow the optimisation of its functioning and sustainability, as well as of its inhabitants’ quality of life and the types of relationships they can maintain with one another. In so doing, this city demonstrates a form of intelligence with no past equivalent. In the smart city, some mechanisms for learning, understanding and reasoning are internalised; they become intrinsic to the city itself, instead of residing in the minds of the humans who live in it” (p. 29).

The vision Picon lays out in this definition sets a very high bar. It implicates a “smart city” as a self-aware and almost conscious entity with “internalized” mechanisms for learning, understanding and reasoning through the ubiquitous deployment of sensors, monitors and data inputs and the capabilities for the active, real-time and intelligent processing of information to identify solutions. No urban center currently has the capabilities to meet these requirements. It remains at best an aspirational vision.

Other attempts to define “smartness” are no less expansive. Gil-Garcia, Zhang and Puron-Cid (2016) identify eleven characteristics that constitute “smartness” in government: integration, innovation, evidence-based, citizen-centricity, sustainability, creativity, effectiveness, efficiency, equality, entrepreneurialism, citizen engagement, openness, resiliency, and technology savviness.

Nam and Pardo (2011) state that a “smart city integrates technologies, systems, infrastructures, services, and capabilities into an organic network that is sufficiently complex for unexpected emergent properties to develop” (p. 287-288). According to their conceptualization, a “smart city” is constituted of innovation both in technologies as well as organizational processes and policies. They identify three areas within which these innovation come together: technology (physical infrastructure, smart technologies, etc.), institutional factors (governance, policy, regulations etc), and human factors (workforce, social capital etc.).

In view of the definitional ambiguity detailed above, various techniques have been used to evolve a consensus definition from the literature. For example, Chaurabi et al (2012)

conduct an extensive review of the literature and identify eight “critical factors” for smart city plans: management and organization, technology, governance, policy context, people and communities, economy, built infrastructure, and natural environment. Mosannenzadeh and Vettorato (2014) use keyword searches of the “academic, industrial and governmental” to generate a framework for the smart city and each of its sub-systems.

A problem with these theoretical frameworks is that most do not engage sufficiently with developments on the ground, namely the realm of action where smart city plans are actually developed and implemented. It is the contention of this paper that there has to be a two-way traffic of information between the theoretical and the empirical. Accordingly, the next section turns towards an examination of how smart city plans are actually implemented.

Implementing the smart city vision

Though many of the technologies and managerial innovations that undergird the smart city are widely known and available, there is virtually no scholar, consultant or government official arguing that the development of the smart city should be left to natural evolution. Two arguments may be raised in favor of a proactive and interventionist approach. First, the combination of technologies and organizational innovations required to come together for smart city development are too interdependent and synergistic to be implemented piecemeal as a process of natural evolution; instead, they will “invariably require coordinated action by the multiple city stakeholders” (PwC, 2015, p. 12). Second, smart city development is essentially an urban arms race in which cities that do not seize the first mover advantage will concede it to more enterprising competitors (Mulas, Mingos, & Applebaum, 2016; World Bank, 2015). Accordingly, a wealth of literature advocates strategies, plans and programs to actively seek the emergence of the smart city. This responsibility, of strategizing and implementing smart city plans, belongs ultimately with city planners, managers, executives and other decision-makers. Their task is to convert the abstract vision of the smart city advocated by theorists into concrete strategies and plans.

Municipal smart city strategies and plans (see review below) are overwhelmingly conceived of in terms of specific projects or action areas, with performance targets and implementation outcomes. This approach has distinct operational advantages for budget control as well as for post-implementation assessment. In choosing projects to implement, municipal decision-makers confront a set of challenges and incentives, that fall under generally three headings: local and situational conditions; stakeholder advocacy, and governmental guidelines.

Local and situational conditions: Of the eight “critical factors” behind smart city development identified by Chaurabi et al (2012), four may be considered local and situational conditions. These include people and communities, economy, the built

infrastructure, and the natural environment. Municipal administrators are tasked with solving the problems of their people and communities, such as in land use, traffic management, environmental protection, affordable housing and jobs creation. However, they have to accomplish these goals in a manner that is economically and environmentally sustainable: within the constraints of budgets and municipal revenues. The problems experienced by the city and its population create the incentive to implement specific smart city initiatives, while available financial resources constrain the type of projects that may be undertaken. It is therefore unsurprising that the city of San Francisco, confronting problems of traffic congestion in the wider Bay Area, features traffic management prominently in its smart city strategy, or that Dublin, Ireland, with its highly competitive software production sector, includes “innovation solutions” in its smart city strategy, or that the port city of Rotterdam has implemented an Internet of Things (IoT) based system to make its port operations ‘smart.’

Stakeholder advocacy: If local and situational conditions introduce differences between the smart city strategies of various cities, stakeholder advocacy tends to make smart city plans more uniform. External stakeholders may include technology vendors, consultancy firms, regional and international non-governmental organizations and international governmental organizations. According to market intelligence provider Global Industry Analysts (2016), the global market for smart city technologies is expected to reach US\$1.2 trillion by the year 2020. Technology firms such as IBM and Cisco have offered a number of off-the-shelf and customizable systems for smart city implementation for projects including smart parking, traffic monitoring, Wi-Fi networking, open portals, etc. For example, IBM has a program called *Smarter Cities*,¹ while Cisco offers solutions for smart lighting, environmental monitoring, smart parking, safety and security, traffic management and waste management,² and Qualcomm’s smart cities products focus on intelligent networking.³ Consultancy companies such as PwC (2015) and Deloitte (Sen, Eggers, & Kelkar, 2018), and the ICT industry trade body Alliance for Telecommunications Industry Solutions (ATIS, 2017) have also put forward well-articulated ‘road maps,’ ‘free guides’ and ‘migration paths’ for cities to implement smart city strategies. Non-governmental organizations such as the International Council for Research and Innovation in Building and Construction (known as CIB, the acronym of its former French name) (2016) have published their “how to” guides to implement smart city strategies. Finally, international organizations such as the International Organization for Standardization (ISO) have created the Smart City Standards Advisory Group (SAG) for the international harmonization of smart city implementation.

Governmental guidelines: A number of national governments and regional groups such as the European Union have put together guidelines for smart city implementation

¹ https://www.ibm.com/smarterplanet/us/en/smarter_cities/overview/

² <https://www.cisco.com/c/en/us/solutions/industries/smart-connected-communities.html>

³ <https://www.qualcomm.com/solutions/internet-of-things/smart-cities>

within their territories. Unlike various stakeholder inputs described above, these national guidelines often have the authority of legal mandates and/or the ability to offer financial incentives to municipalities in return for compliance with the guidelines. For example, India in 2015 launched a Smart City Mission under the Ministry of Urban Development. The Mission announced a Smart City Guidelines (Smart Cities Mission, 2015) as well as a challenge competition for cities to compete for funding for their smart city projects. The scoring scheme used by the Challenge competition encourages cities to implement programs in the areas identified by the Guidelines, with the result that smart city strategies are harmonized across the country (Adapa, 2018). Similar guidelines, though more flexible, are embodied in the European Union's European Initiative on Smart Cities (European Commission, 2018) and the European Innovation Partnership on Smart Cities and Communities (European Commission, 2015).

To summarize the key takeaways from this section, cities guided by their local and situational conditions are likely to implement a diverse set of smart city project, as they respond to their local conditions. However the marketing of ICT products and services by IT vendors, the advocacy of various roadmaps and migration paths by consultancies and non-governmental organizations, and the implementation of national guidelines by federal governments are likely to exert a powerful harmonizing influence as well. From this review, we frame the following expectations for the exploratory analysis in the next section. First, we expect that, despite the diversity of circumstances and local problems confronting urban areas, smart city strategies will be more alike than different in the set of projects they seek to implement. Second, despite the higher investments required, projects requiring technology solutions (eg. smart parking, mesh networking) will be favored over those requiring organizational innovations or human resource-intensive activity (digital literacy, citizen participation). We test out these expectations in the next section with a coding analysis of municipal smart city strategies followed by hierarchical cluster analysis to identify archetypes of smart city strategies.

Methodology and Data

A convenience sample of municipal smart city initiatives drawn from around the world was located using online search engines. A variety of key words was used: 'strategy,' 'plan,' or 'project' in conjunction with 'smart city,' 'digital city,' 'intelligent city,' 'smart society,' or 'cyber city,' as well as its variants in other languages including 'ciudad inteligente,' and 'cite intelligente.' Only municipal strategy or planning documents were collected: national strategies or the plans of regional coalitions of cities (for e.g. Silicon Valley's Smart Region Initiative) were excluded. As far as possible, official municipal documents were collected: in a few instances, websites or Powerpoint presentations were used, when it was deemed a comprehensive representation of a municipal plan. Based on these criteria, 52 municipal smart city plans were identified for analysis. The names of the cities included in the analysis, and their countries and regions, are reported in Table 1. An effort was made to be geographically inclusive, but the sample does not include example from South America; to be addressed in future versions of this paper.

Table 1: List of Municipal Smart City Plans

City	Country	Region	City	Country	Region
Cape Town	South Africa	Africa	Budapest	Hungary	Europe
Beijing	China	Asia	Dublin	Ireland	Europe
Hong Kong	China	Asia	Turin	Italy	Europe
Shanghai	China	Asia	Amsterdam	Netherlands	Europe
Agartala	India	Asia	Stavanger	Norway	Europe
Chandigarh	India	Asia	St Petersburg	Russia	Europe
Coimbatore	India	Asia	Barcelona	Spain	Europe
Lucknow	India	Asia	Valencia	Spain	Europe
Panaji	India	Asia	Stockholm	Sweden	Europe
Pune	India	Asia	Birmingham	United Kingdom	Europe
Tel Aviv	Israel	Asia	Edinburgh	United Kingdom	Europe
Tokyo	Japan	Asia	Greenwich	United Kingdom	Europe
Lusail	Qatar	Asia	London	United Kingdom	Europe
Singapore	Singapore	Asia	Edmonton	Canada	North America
Seoul	South Korea	Asia	Montreal	Canada	North America
Dubai	UAE	Asia	Ottawa	Canada	North America
Vienna	Austria	Europe	Toronto	Canada	North America
Prague	Czech Republic	Europe	Vancouver	Canada	North America
Aarhus	Denmark	Europe	Bellevue	United States	North America
Copenhagen	Denmark	Europe	Chattanooga	United States	North America
Espoo	Finland	Europe	San Jose	United States	North America
Lyon	France	Europe	Washington DC	United States	North America
Montpellier	France	Europe	San Francisco	United States	North America
Berlin	Germany	Europe	Adelaide	Australia	Oceania
Hamburg	Germany	Europe	Melbourne	Australia	Oceania
Stuttgart	Germany	Europe	Sydney	Australia	Oceania

Once the sample of smart city plans was identified, it was analyzed to identify the specific projects included in each strategy document. Since the documents did not use standardized terminology or follow a similar format, it was necessary to code the documents for this analysis. Two coders were used. Coders were instructed in identifying ‘projects’ based on the following two criteria. First, only ongoing or contemplated projects with a specific objective, implementation location, target demographic etc., were included. Past achievements (“Our city has a high concentration of high tech firms”) or general declaration of intent with no specifics (“We seek to provide high quality of life for all”) were not included. Second, only projects involving ICTs, data analytics, or online communication or other technology application were counted. For example, projects with no identifiable ICT dimension (“We plan to beautify green spaces in the downtown area”) were not included. Subject to these requirements, coders identified projects and assigned them to project categories.

Table 2: Project categories and definitions (alphabetical)

A.	Business ecosystem – electronic approval of new business permits, encouragement to high tech businesses, high-tech innovation zones
B.	Car sharing services – online systems for finding rides, sharing taxis, car-pooling, commuting
C.	Citizen participation – online grievance process, online voting, online comments process on pending legislation; electronic outreach, community partnerships (only electronic)
D.	Clean energy – smart electricity meters, grid management systems, alternative energy sources, consumer information about pollution loads
E.	Crowd management – surveillance, monitoring of public spaces, pedestrian counts, aerial monitoring of events
F.	Digital health care – health care apps, online health information and portals, telehealth programs
G.	Digital skills training – digital literacy programs, ICT workforce training
H.	Digitization of government – digital government, e-government, e-services, online information, implementation of municipal websites/portals, municipal apps, data platforms, data integration, processing, security and privacy of data
I.	Education – use of information technology in formal education
J.	Emergency management – electronic information on floods, earthquake, etc. smartphone based information systems, citizens' reporting emergency information
K.	Environmental protection – monitoring of greenhouse gas emissions, noise pollution; use of apps to communicate information about environment
L.	Fleet vehicle management – not public transportation, but municipal fleet management, first responders, police, fire, medical vehicles
M.	Living standards – electronic monitoring and reporting of quality of life
N.	Mobile networks – mobile network (towers, backhaul) deployment, connection speeds
O.	Public Transportation – online status of public transportation and school buses (arrival and departure time, delays, congestion, electronic ticketing; contactless payments
P.	Self-driving cars – use of autonomous vehicles
Q.	Smart building – electronic monitoring of heating and cooling, building security, CCTV monitoring; private smart homes, home alarms, security
R.	Smart lighting – smart (sensor equipped) street lighting, smart electricity metering
S.	Smart parking – parking apps, smart payment meters, real-time monitoring of parking availability
T.	Smartphone penetration – efforts to encourage smartphone adoption
U.	Traffic management – electronic, real time monitoring of congestion, accident information systems
V.	Urban planning – electronic monitoring of land use, green spaces
W.	Water, sewage and waste management – online scheduling of trash pickup, monitoring of landfills, water use monitoring, sewage monitoring, landfill management
X.	Wi-Fi hotspots – availability of Wi-Fi in public spaces, parks, government buildings
Y.	Wired networks – broadband network deployment, incentives for businesses and households to adopt broadband; critical infrastructure deployment, fiber networks

The categories used by smart parking firm EasyPark (2017) in their 2017 Smart Cities Index Report were used as a starting point to identify project categories, with suitable modifications. To train coders, an initial set of 5 randomly chosen smart city plans was coded by both coders, with a total of 18 project categories ($5 \times 18 = 90$ observations). Inter-coder reliability using percentage agreement was 68.8 percent, which was below acceptable levels. Accordingly, the category definitions were reviewed and clarified, and their wording was revised where necessary. New categories introduced to eliminate potential ambiguities. Eventually, a total of 25 project categories were used in the analysis (See Table 2 for a listing of categories and their definitions). A second round of training conducted with 5 new randomly chosen cases ($5 \times 25 = 125$ observations) yielded a percentage agreement of 86.8 percent, considered satisfactory for coding analysis.

Analysis

Our first research question asked what specific programs and initiatives by issue areas (e.g., transportation, e-government, smart electricity grids) are included in the smart city plans of municipalities? To answer this question, we tabulated the number of occurrences of each project category in our sample of 52 smart city plans. The result is reported in Table 3.

As shown in Table 3, a total of 663 projects were identified in 52 smart city strategy documents. The first column records the number of strategy document that included a project in one of the coding categories. The second column records the percentage of strategy documents that included a project in a coding category, while the last column records the percentage of all projects in each coding category. It can be seen that the most strategy documents (88.7%) included a digital government project, defined as digital government or e-government programs, e-services, online information, municipal websites/portals, municipal apps, data platforms, data integration, processing, security and privacy of data. In contrast, few strategy documents included efforts to increase the coverage of mobile networks, facilitate self-driving cars, or use ICTs to manage municipal fleet vehicles or for crowd management.

Table 3: Frequency of occurrence of project categories (Number of plans = 52)

	number of plans that include category	percent of plans that include category	percent of all projects in category
Digitization of government	47	90.4	7.1
Traffic management	42	80.8	6.3
Business ecosystem	42	80.8	6.3
Clean energy	41	78.8	6.2
Public Transport	40	76.9	6.0
Citizen participation	40	76.9	6.0
Water, sewage and waste mgmt	37	71.2	5.6
Environment protection	37	71.2	5.6
Digital skills training	37	71.2	5.6
Wired networks	31	59.6	4.7
Education	29	55.8	4.4
Wi-fi hotspots	28	53.8	4.2
Smart parking	27	51.9	4.1
Car sharing services	27	51.9	4.1
Smart lights	27	51.9	4.1
Urban planning	26	50.0	3.9
Digital healthcare	26	50.0	3.9
Smart building	16	30.8	2.4
Living standards	16	30.8	2.4
emergency management	15	28.8	2.3
Mobile networks	8	15.4	1.2
Smartphone penetration	7	13.5	1.1
Self-driving cars	6	11.5	0.9
Fleet vehicle management	6	11.5	0.9
Crowd management	5	9.6	0.8
Total projects	663	out of 52	out of 663

We now turn to the second research question, which asked what are the commonalities and differences between municipal smart city plans, and whether there are patterns in the distribution of smart initiatives across municipal smart city plans? We attempted to answer this question in two different ways. First, through calculating co-occurrence probabilities, and second, through hierarchical cluster analysis.

Co-occurrence probabilities

We analyzed which pairs of projects were most frequently found together. This is a pertinent line of investigation since the co-occurrence of two project categories may be indicative of similar outcomes or of technological or operational synergies between them. For example, the same mesh network that enables an area-wide Wi-Fi system to

function may also be used for a CCTV-based crowd monitoring and control system. We therefore calculated the conditional probability of B given A, $P(A|B)$. If a project in category A were included in a municipal plan, what is the probability that a project in category B will also be included in the plan?

The results are reported in Table 4 overleaf. Note that each cell records $P(\text{Column}|\text{Row})$, that is, given that a strategy contains the category in the column, what is the probability that it will include the category in the row? For example reading the cell (I, D), we note that a smart city plan that includes a clean energy project has a 34 percent probability of including a smart building project as well. Of course, $P(A|B) \neq P(B|A)$. Reading from the cell (D, I), there is a 73 percent probability that a plan with a smart building project will also have a clean energy program.

Categories that are particularly likely to co-occur ($p > 0.7$) are shaded. It may be noted that two project categories that are popular have a higher probability of co-occurrence, even if there are no technological or operational synergies between them. On the other hand, high probabilities of co-occurrence between less popular project categories might be indicative of synergies. For example, there is an 81 percent probability that a smart city plan that includes a program on living standards will also include digital healthcare, and a reverse probability of 50 percent that a plan that includes digital healthcare also has a project on living standards. In this case, it might be seen that the high probability of co-occurrence might be attributed to similarity of outcomes, since both living standards and digital healthcare indicate a concern with quality of life.

Table 4: Conditional probability, probability of co-occurrence of pairs of project categories, P (column|row)

		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
Digital government	A	--	0.90	0.88	0.85	0.90	0.90	0.89	0.86	0.89	0.97	0.83	0.93	0.93	0.85	1.00	0.81	0.85	0.88	0.81	0.87	1.00	1.00	0.83	1.00	1.00
Traffic management	B	0.81	--	0.79	0.83	0.90	0.80	0.84	0.84	0.81	0.81	0.72	0.86	0.96	0.85	0.81	0.77	0.77	0.81	0.81	0.87	0.75	0.86	0.50	0.83	0.80
Business ecosystem	C	0.79	0.79	--	0.78	0.75	0.83	0.81	0.81	0.92	0.81	0.86	0.82	0.74	0.70	0.85	0.85	0.81	0.75	0.81	0.80	0.50	0.86	0.67	1.00	0.80
Clean energy	D	0.74	0.81	0.76	--	0.85	0.80	0.84	0.86	0.73	0.81	0.79	0.89	0.81	0.81	0.85	0.92	0.77	0.88	0.69	0.93	0.75	0.71	0.83	0.83	1.00
Public Transport	E	0.77	0.86	0.71	0.83	--	0.83	0.78	0.84	0.73	0.81	0.76	0.82	0.85	0.89	0.85	0.77	0.85	0.81	0.81	0.73	0.88	0.71	0.67	0.83	1.00
Citizen participation	F	0.77	0.76	0.79	0.78	0.83	--	0.81	0.78	0.81	0.81	0.90	0.82	0.78	0.74	0.81	0.73	0.85	0.75	0.88	0.73	0.63	0.71	0.67	0.83	1.00
Water sewage waste	G	0.70	0.74	0.71	0.76	0.73	0.75	--	0.76	0.73	0.68	0.69	0.79	0.70	0.70	0.81	0.85	0.65	0.69	0.56	0.67	0.50	0.43	0.33	0.33	1.00
Environment	H	0.68	0.74	0.71	0.78	0.78	0.73	0.76	--	0.65	0.71	0.69	0.82	0.70	0.78	0.74	0.81	0.73	0.69	0.75	0.87	0.75	0.57	0.67	0.83	1.00
Digital skills training	I	0.70	0.71	0.81	0.66	0.68	0.75	0.73	0.65	--	0.77	0.79	0.79	0.70	0.59	0.74	0.77	0.69	0.63	0.75	0.60	0.75	0.86	0.33	0.83	0.60
Wired networks	J	0.64	0.60	0.60	0.61	0.63	0.63	0.57	0.59	0.65	--	0.59	0.82	0.56	0.56	0.63	0.62	0.65	0.69	0.50	0.60	0.88	0.86	0.50	1.00	0.80
Education	K	0.51	0.50	0.60	0.56	0.55	0.65	0.54	0.54	0.62	0.55	--	0.61	0.56	0.37	0.56	0.54	0.73	0.75	0.69	0.60	0.63	0.43	0.83	0.50	0.80
Wi-fi hotspots	L	0.55	0.57	0.55	0.61	0.58	0.58	0.59	0.62	0.59	0.74	0.59	--	0.56	0.48	0.59	0.58	0.50	0.50	0.50	0.60	0.63	0.57	0.17	0.83	0.80
Smart parking	M	0.53	0.62	0.48	0.54	0.58	0.53	0.51	0.51	0.51	0.48	0.52	0.54	--	0.59	0.44	0.42	0.46	0.63	0.56	0.53	0.75	0.71	0.67	0.33	0.80
Car sharing services	N	0.49	0.55	0.45	0.54	0.60	0.50	0.51	0.57	0.43	0.48	0.34	0.46	0.59	--	0.41	0.54	0.42	0.50	0.50	0.47	0.38	0.43	0.50	0.50	0.60
smart lights	O	0.57	0.52	0.55	0.56	0.58	0.55	0.59	0.54	0.54	0.55	0.52	0.57	0.44	0.41	--	0.54	0.62	0.50	0.50	0.60	0.88	0.57	0.33	0.67	1.00
Urban planning	P	0.45	0.48	0.52	0.59	0.50	0.48	0.59	0.57	0.54	0.52	0.48	0.54	0.41	0.52	0.52	--	0.38	0.31	0.25	0.67	0.50	0.43	0.50	0.50	0.40
digital healthcare	Q	0.47	0.48	0.50	0.49	0.55	0.55	0.46	0.51	0.49	0.55	0.66	0.46	0.44	0.41	0.59	0.38	--	0.81	0.81	0.53	0.63	0.57	0.83	0.67	0.60
Smart building	R	0.30	0.31	0.29	0.34	0.33	0.30	0.30	0.30	0.27	0.35	0.41	0.29	0.37	0.30	0.30	0.19	0.50	--	0.50	0.27	0.38	0.29	0.83	0.17	0.60
Living standards	S	0.28	0.31	0.31	0.27	0.33	0.35	0.24	0.32	0.32	0.26	0.38	0.29	0.33	0.30	0.30	0.15	0.50	0.50	--	0.33	0.38	0.43	0.33	0.50	0.20
emergency mgmt	T	0.28	0.31	0.29	0.34	0.28	0.28	0.27	0.35	0.24	0.29	0.31	0.32	0.30	0.26	0.33	0.38	0.31	0.25	0.31	--	0.25	0.14	0.33	0.33	0.00
Mobile networks	U	0.17	0.14	0.10	0.15	0.18	0.13	0.11	0.16	0.16	0.23	0.17	0.18	0.22	0.11	0.26	0.15	0.19	0.19	0.19	0.13	--	0.43	0.17	0.17	0.40
Smartphones	V	0.15	0.14	0.14	0.12	0.13	0.13	0.08	0.11	0.16	0.19	0.10	0.14	0.19	0.11	0.15	0.12	0.15	0.13	0.19	0.07	0.38	--	0.17	0.50	0.20
self-driving cars	W	0.11	0.07	0.10	0.12	0.10	0.10	0.05	0.11	0.05	0.10	0.17	0.04	0.15	0.11	0.07	0.12	0.19	0.31	0.13	0.13	0.13	0.14	--	0.00	0.20
Fleet vehicle mgmt	X	0.13	0.12	0.14	0.12	0.13	0.13	0.05	0.14	0.14	0.19	0.10	0.18	0.07	0.11	0.15	0.12	0.15	0.06	0.19	0.13	0.13	0.43	0.00	--	0.20
crowd management	Y	0.11	0.10	0.10	0.12	0.13	0.13	0.14	0.14	0.08	0.13	0.14	0.14	0.15	0.11	0.19	0.08	0.12	0.19	0.06	0.00	0.25	0.14	0.17	0.17	--

Hierarchical cluster analysis

Though the calculation of co-occurrence probabilities identifies *pairs* of project categories that are likely to occur together, it does not identify the *groups* of project categories that will occur together. To do so, we performed hierarchical cluster analysis using the process described by Yim and Ramdeen (2015). However, since our data were dichotomous, the standard method in cluster analysis of using Euclidean distance is inappropriate. Following the recommendations of Finch (2005), we chose the ‘binary measure’ option under method in the SPSS hierarchical cluster analysis procedure. Clusters were identified using all three metrics recommended by Finch, Jaccard, Dice and Russel/Rao, but all three provided very similar results. Only the results using Jaccard are reported here in the interest space. The option to identify 2-5 clusters was chosen. The results are presented in Table 4.

Table 4: Cluster analysis

	5 cluster	4 Clusters	3 Clusters	2 Clusters
Cluster 1	43	46	50	51
Cluster 2	1	1	1	1
Cluster 3	4	4	1	
Cluster 4	3	1		
Cluster 5	1			

Note: Cluster 2 – Tokyo; Cluster 3 – Capetown, Edinburgh, Espoo, Stockholm; Cluster 4 – Amsterdam, Lyon, Montpellier; Cluster 5 – Toronto; all other cities were Cluster 1.

It can be seen that the vast majority of smart city plans were placed in the same cluster, indicating that municipalities chose to implement relatively similar plans. To identify the program categories that differentiated the clusters, a one-way ANOVA was performed (the results are not reported here in the interest of space). It revealed that only a few of the content categories were able to differentiate between the clusters: traffic management, public transportation, clean energy, water, sewage and waste management, environmental protection, citizen participation, digital government, education, wi-fi hotspots and self-driving cars. It may be noted that for three of the content categories—digital government, education and self-driving cars—the differences were significant only at the $p < 0.1$ level.

Means for these variables for each cluster are presented in Table 5. It may be noted that two of the clusters (Clusters 1 and 5) had only a single member, the numbers reported for these clusters are obviously not the means but the observations for the single member of these clusters. The F-statistics and the significance values for the means comparisons from the one-way ANOVA are also reported on Table 5, under each project category. The cluster that had the highest mean score under each project category is highlighted.

Table 5: Means for project categories that differed significantly between clusters.

Cluster	# of plans	Traffic mgmt	Public Trans.	Clean energy	Water, sewage & waste	Environment	Citizen participation	Digital government	Education	Wi-fi	self-driving cars
1	43	0.86	0.86	0.89	0.77	0.8	0.82	0.89	0.55	0.64	0.11
2	1	0	0	1	0	1	0	0	1	0	1
3	4	0.25	0.25	0	0.25	0	1	1	1	0	0
4	3	1	0.33	0.33	0.67	0.33	0	1	0	0	0
5	1	0	0	0	0	0	0	1	0	0	0
Total	52	0.79	0.75	0.77	0.7	0.7	0.75	0.89	0.55	0.53	0.11
F-stat sig.		5.63 0.001	5.83 0.001	9.85 0.001	2.66 0.044	5.13 0.002	5.99 0.001	2.41 0.062	2.45 0.059	3.57 0.013	2.41 0.062

We can now turn to the final research question: How common are “smart city” models, and what are exemplars for smart city initiatives within each model? Based on the results in Table 5, we can identify the following smart city implementation models.

Infrastructure model: Cities in this model emphasize infrastructure services such as public transportation, water, sewage and waste management and Internet connectivity, though they also emphasize other aspects such as traffic management and clean energy. This is the model to which most smart city plans belong.

Green model: Cities in this model lay stress on clean energy and environmental protection, though they also perform well under education. However, we caution against over-interpreting this model, since the clustering procedure assigned only one city to this category (Tokyo).

Civic Participation Model: Cities in this model lay stress on securing wide participation of citizens in public affairs. Scandinavian cities are well-represented in this group (Stockholm, Espoo). They performed best under civic participation, digital government and education.

Transportation model: Three European cities were assigned to this model, including two major trading/industrial centers (Amsterdam, Lyon) and a fast-growing French city, Montpellier. Cities in this group emphasized traffic management and digital government, though they also performed close to average on water sewage and waste management.

E-government model: As in the case of the Green model, only one city (Toronto) was assigned to this model. Toronto’s strategic plan appeared to emphasize digital government without a significant presence in any of the other project categories. Here too, we caution against over-interpreting the results based on a single observation.

Conclusions

There is no dearth of conceptualizations of the smart city in the literature. Scholars have employed a number of methodological approaches to explicate the concept of the smart city, but no widely accepted definition has emerged. However, practitioners in the field are not awaiting the emergence of a concrete model before beginning to implement the potentialities of ICTs and computing to solve the pressing needs of urban areas. The objective of this paper was to examine the diverse plans and strategies employed by city managers to implement the smart city in their communities. We argue that such an effort is a necessary complement to theory-building since emerging theoretical structures and empirical data illuminate each other.

Accordingly, we compiled a convenience sample of municipal smart city plans and inventoried the specific projects that were included in the smart city strategies. IN choosing these projects, we expected that cities would be guided by their local and situational conditions; as a result diverse models of the smart city would emerge since the conditions and challenges that urban areas confront are varied and different. However, our cluster analysis revealed substantial similarity in the combinations of projects that cities chose to implement. We attribute this to the harmonizing effect of the marketing of ICT products and services by IT vendors, the advocacy of various roadmaps and migration paths by consultancies and non-governmental organizations, and the implementation of national guidelines by federal governments.

The outcome of this research will be of interest to theoreticians of smart cities as an alternative to the prevailing “top-down” conceptualizations of smart city development. By consulting the actual plans and programs that are implemented by city governments, this “bottom up” approach will be more solidly grounded in empirical fact and observation. Our identification of “smart city models” is also likely of interest to urban planners and smart city developers seeking to learn from the experiences of other jurisdictions.

This paper suffers from several limitations that may be addressed by future research. First, the paper is based on a convenience sample. Future research may seek to compile a more comprehensive database of smart city implementations, and choose randomly from it. Second, though we aimed for geographical representativeness, our sample omits the continent of South American entirely, and has only one representative from Africa (Capetown). Future research may seek to restore this imbalance. Third, our sample, due to our own linguistic limitations is heavily skewed towards documents in the English language. Our search procedures attempted to compensate for this by using search phrases in non-English languages, but with only limited success.

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