A Comparative Analysis of Seven Smart City Development Projects: Institutional, Economic, Technical, and Policy Perspectives

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Abstract

This paper argues for the use of a multifaceted, and contextualized approach to smart city development by unpacking how individual smart city initiatives have planned and implemented diverse projects based on their distinct environments, stakeholders, and goals. We evaluated and compared the institutional, economic, technical and policy characteristics of seven smart city initiatives (Montgomery, San Diego, New York City, Calgary, London, Vienna, Singapore). Our findings demonstrate three principal implications in smart city development. First, the surveyed smart cities established concrete cases for the use of different project development models in terms of leadership and governance styles, adoption of smart city applications, and planning and management strategies. Second, such differences stemmed from the multifaceted interactions that link environment, stakeholders, and goals. Finally, knowledge management (KM) played a crucial role in ensuring the accumulation and transferability of organizational and policymaking infrastructure within and between smart city initiatives.

Keywords: Smart city, comparative analysis, Internet of Things, knowledge management

1. Introduction

In recent years, smart city projects have attracted attention from both local governments and researchers, constituting an innovative breakthrough in the advancement of solutions that address diverse problems within each city mainly through the development and organization of technology-based solutions.

The ongoing COVID-19 pandemic, which began in early 2020, has forced most local governments to reduce nearly all financial expenses except for those related to public health and slow down the development of smart city projects. Such challenges have highlighted the fact that the development or evolution of smart cities results from the interactions among various elements and participants, in addition to technological factors. In this regard, an interdisciplinary and comparative approach to smart cities is required in order to obtain an apt understanding of how smart city projects can be more successful (Komninos & Mora, 2018).

This paper aims to investigate different contexts, elements, and stakeholders involved in smart city projects. It first develops an analytical framework based on a literature review (Section 2) followed by a detailed survey of key factors in smart city development, such as a) leadership and governance (Section 3), b) smart applications (Section 4), and c) planning and feedback (Section 5). Based on our analysis, the paper compares and synthesizes different smart city project initiatives (Section 6). The paper concludes with lessons learned and ideas for future research (Section 7).

2. Analytical framework

This section presents our framework for the analysis of smart city development projects. We first explain our distinctive approach and then describe our categorization of key facets of smart cities. Finally, we describe the seven smart city projects we selected for our research.

2.1. Overall approach

The complex characteristics of smart city projects in terms of goals, participants/stakeholders and technology, and the organization of these elements pose considerable difficulties for researchers in establishing an appropriate framework for analysis of the factors that lead to their success or failure. From a review of 51 smart city governance papers, Meijer & Bolívar (2016) conclude that existing literature shows conflicting views on the technical and social nature of smart cities, the need for transformation of local government, and the emphasis on outcomes and processes.

In this regard, existing literature leans toward multi-faceted frameworks which integrate various elements. For instance, Chourabi et al. (2012) present a multi-dimensional framework encompassing eight success factors for smart city initiatives. Similarly, Barkis et al. (2019) have created an architectural conceptual

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framework combining ‘upper horizontal’ bands (overarching elements), ‘vertical’ domains (common domains where applications are deployed), ‘lower horizontal’ bands (underpinning infrastructures), and vision, execution, knowledge, and insight. Serrao et al. (2022) recently suggested the Holistic KPI (H-KPI) Framework, which aims to measure three interacting levels of analysis in the context of smart cities, i.e., technologies, infrastructure services, and community benefits. A multi-faceted approach has the advantage of providing a broader perspective of smart city projects.

However, such frameworks tend to adopt an idealized approach instead of analyzing the nuanced contexts and conditions of different cities. For example, some cities, given their circumstances and goals, may only adopt a couple of ‘smart solutions’ to solve or at least to begin to address their most crucial issues. More to the point, multi-faceted frameworks are essentially static and thus render it difficult to grasp the overall evolution of a smart city.

In this regard, recent accounts of smart cities have shifted their focus to temporal and/or process based approaches which consist of planning, implementation, and outcomes. For example, Kubina et al. (2021) argue that smart cities have different elements for their implementation models such as vision statements, problem sets, processes, and sustainability models, to mention a few. Similarly, Noori et al. (2021) attempt to develop an Input-Throughput-Output (IO) model of smart cities through the application of systems theory to analyze the processes comprising a smart city project. However, the specific models which both groups of researchers suggest lack a time dimension and therefore do not consider the actual interventions or adjustments to the project over time.

In contrast, this paper adopts a four-stage development model for smart city projects with a systematic approach. Figure 1 presents the evolution of a smart city project through ongoing IO processes over time. In its initial stage, a project requires both the input of financial and human ‘resources’. Such an effort occurs within a given ‘environment’ or conditions. Once the project is on board, internal activities (‘process’) and external cooperative interactions (‘governance’) play a leading role in developing the project. Outputs can be ‘adoptions’ of products and services that have direct efficacies, or more indirect and long-term ‘effects’. The outputs return to inputs of the next term through feedback processes, i.e., ‘evaluation’ and ‘improvement’.

Table 1 shows the principal practices of each development stage for smart city projects. The ‘deliberation’ stage primarily consists of the conceptualization of the overall goals and plans of a project. The project leaders aim to build a foundation for the project by establishing organization(s), pooling resources, and coordinating stakeholders. Initial implementation of (pilot) projects with small-scale collaboration occurs in the ‘introduction’ stage. In the ‘growth’ stage, a smart city project attempts to expand its scale in both applications, collaboration, and resources. If a smart city project achieves its principal goals with solid foundations and ongoing optimization, we can consider that the project attained its ‘maturity’.

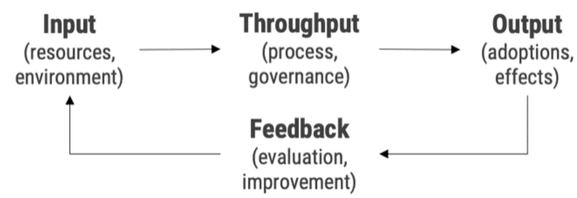

Figure 1. Ongoing input-output process

Table 1. Development stages for smart city project

Stage	Practice
Deliberation	Conceptualization Establishing organizations Coordination among stakeholders Pooling resources
Introduction	Initial implementation Pilot projects Small-scale collaboration
Growth	Expanded projects Larger-scale collaboration Additional/Expanded resources
Maturity	Optimization, Sustained projects New innovative initiatives Solid cooperation

However, we apply the model not to entire projects but to each constituent aspect of individual smart city projects in order to render possible the comparison of different development levels/situations ‘within’ a smart city project as well as ‘between’ diverse projects. In this regard, the developmental levels of smart city projects have been determined to depend on the circumstances of each city, not on absolute amounts (e.g., money, infrastructure) or scales (e.g., income). Therefore, one should not interpret the suggested model as a ‘linear’ approach which can be used to determine the ‘rankings’ of smart cities based on standardized criteria, given the many limitations of smart city rankings such as disregarding complex interrelations, causalities, and conditions; selective sampling; and methodological naivety (Giffinger & Gudrun, 2010, pp. 12-13).

2.2. Key facets of smart cities

The concept and domains of smart cities have become increasingly ambiguous due to their exponential growth in popularity throughout both research and practice (Komninos & Mora, 2018). Furthermore, recent initiatives of urban development over the past few decades have produced overlapping but non-identical 'city' categories such as sustainable cities, green cities, digital cities, information cities, resilient cities, and ubiquitous eco-cities, in addition to smart cities (de Jong et al., 2015). The definition and purview of a smart city varies depending on the researchers and practitioners in question, though they are not without certain commonalities (see Table 2).

Against such a backdrop, this paper essentially applies identifications suggested by existing literature and reorganizes them into three high-level categories which utilize Noori et al.'s (2021) IO model: (1) leadership and governance; (2) smart applications; and (3) planning, management, and feedback (see Table 3). However, we still consider the core of smart city projects to be the development of 'smart solutions' based on technology (i.e., IoT) or their integration into existing projects. On the other hand, this paper distinguishes public safety and security from privacy and risk management in its categorization, considering the significance of privacy issues in smart city projects.

Table 2. Different identifications of smart cities

Authors	Identification
Giffinger & Gudrun (2010)	Smart economy, Smart people, Smart governance, Smart mobility, Smart environment, Smart living
Chourabi et al. (2012)	Management and organization, Technology, Governance, Policy context, Natural environment People and communities, Built infrastructure, Economy
Noori et al. (2021)	Modern ICT infrastructure and data, Financial resources, Governance Human infrastructure and entrepreneurial capital, Smart citizens and applications, Sustainability and high quality of life

Table 3. Categorization of smart city projects

Category	Sub-category
Leadership and governance	Form of leadership and governance, Pooling resources, Community engagement
Smart applications	IoT infrastructure, Mobility, Public safety, Environment, Economy, Urban living, Social inclusion, Smart government
Planning, management, and feedback	Vision and planning, Privacy and risk management, Documentation and feedback

Note. Adapted from Noori et al. (2021, p. 77).

It is worth noting that smart city projects mostly span various domains at the same time. For example, smart streetlights are related to various areas ranging from mobility (traffic measurement) to public safety (crime prevention), environmental issues (energy saving), and others. We focused on the categorization or emphasis given by each government in charge of the smart city initiative that we surveyed.

2.3. Selected cases

One of the primary goals of this paper is to compare the similarities and differences between smart city projects and use this analysis to develop a functionally dynamic and interdisciplinary model to explain how different processes and interactions among stakeholders—along with different technical, economic, and governance conditions—can shape the outcomes and development of smart city projects. In this regard, we decided to conduct a qualitative evidence synthesis review (Pare et al., 2015, p. 189), which aims to make sense of heterogeneous evidence/documentation produced in complex interventions and diverse contexts by each project so as to inform policy and decision-making.

To this end, we selected seven smart city initiatives in different regions whose smart city projects have distinct circumstances and features. Four of these cities are located in North America, two in Europe, and one in Asia (see Tables 4 and 5). Thus, our approach avoided a simple categorization of smart city development projects that uses limited groupings/categories (e.g., American vs. European vs. Asian models) and the elaboration of an all-encompassing ranking.

Table 4. Selected cases

State	City	Features
USA	Montgomery	Downtown revitalization, active NPOs
	New York City	Megacity, finance hub, education, tourism
	San Diego	Environment, tourism, R&D (ICT and biotechnology)
Canada	Calgary	Industry and finance hubs, energy, transportation
UK	London	Megacity, finance hub, education, tourism
Austria	Vienna	International organizations, culture hub, tourism
Singapore	Singapore	City-state, finance hub, human resources and education

Several sources were used to select our smart city case projects. The Municipal Internet of Things Blueprint (Barkis et al., 2019) and Smart 50 Awards were used to survey the smart city efforts of local governments in North America. Comparative research on European smart cities (e.g., Gil et al., 2020; Kubina et al., 2021) and the IDC Smart City Asia Pacific Awards were used to survey the smart cities in Europe and Asia. To focus on influential smart city cases, we chose cities that had consistent project development and/or had won awards more than once.

Table 5. Principal statistics of selected cases

City	Core land area[a] (sq. km)	Population[b] (Number)	GDP[c] (Million USD)
Montgomery	2,078	447,101	19,975
New York (Greater)	12,496	19,785,371	1,727,927
San Diego	11,059	3,332,427	220,619
Calgary	848	1,678,718	97,214
London	2,943	12,451,423	818,922
Vienna	413	3,004,660	163,520
Singapore	733	5,685,807	475,772

Note. Adapted from OECD.Stat (https://stats.oecd.org/) and the Department of Statistics Singapore
[a] As of 2021 [b] As of 2020 [c] As of 2018 (base year 2015)

To achieve inter-rater consistency and reliability, we independently gathered data for each city through websites and official documents of government offices and partner organizations as of December 2021. When necessary, press releases in news media outlets were occasionally used to complement the survey as well.

3. Leadership and governance

The successful adoption and implementation of a smart city project fundamentally depends on effective leadership and governance. This section analyzes forms of leadership and governance, methods through which to pool resources, and forms of community engagement for smart city projects.

3.1. Form of leadership and governance

The complexity of smart city projects requires stable collaborations among participants/stakeholders. From our analysis of smart city projects, most have leading figures and/or departments in local government taking active steps toward envisioning smart city projects which encourage affiliated departments to adopt and apply technology and data-driven methods to their existing operations.

However, styles of leadership and governance can vary depending on the circumstances and conditions of each city. For instance, San Diego's smart city program is based on a participatory approach achieved through an industry-driven regional collaborative initiative (Smart Cities San Diego) led by a nonprofit organization (Cleantech San Diego), whereas Singapore, as a city-state, established a nationwide government organization (Smart Nation and Digital Government Office) and a Government Technology Agency (GovTech) under the Prime Minister's Office from the earliest stages of their project. Calgary locates itself in the middle ground by encouraging civic engagement in its projects. On the other hand, Vienna represents an exceptional form of leadership in that a think-tank owned by the city government (Urban Innovation Vienna) coordinates all planning and implementation of smart city projects. It follows an expert + technical-oriented city planning approach rather than an administrative or industry-driven approach.

Such different forms of leadership also tend to be reflected in the proportions of participants from government, industry, academia, and civic communities in smart city-related organizations. Overall, San Diego, London, and Singapore include more participants from industry than other cities. However, the characteristics of industry participants are found to differ from city to city. While several financial and banking institutions were included in Singapore, San Diego has more real estate and land developers. Montgomery shows a high ratio of participation from academia, civic communities, and NPOs. Montgomery is also distinct from other cities in that the U.S. Air Force is included in its leading organizations.

3.2. Pooling of resources

It is worth noting that one of the significant functions of governance is pooling resources for smart city projects. Most cities pool their required funds from public sources such as their city budget or federal/central government programs. However, depending only on their own budget may not be a reliable method for sustaining smart city projects. For example, Calgary, which applied for the 'Smart Cities Challenge' launched by the Canadian federal government in 2017 but was not selected as a finalist, seems to have slowed down in its smart city development due to a lack of funding despite its initial commitment to smart city projects (see Section 4). Furthermore, Calgary's official smart city website has not undergone any substantial update since 2019. Unlike other cities mentioned, London is more active in engaging private funding for smart city projects through measures such as the London Economic Action Partnership.

3.3. Community engagement

Some of the surveyed cities provide different degrees of opportunities for active community engagement in their smart city projects. However, most cities tend to organize temporary platforms or campaigns limited to a specific project rather than offer more sustained forms of participation.

Vienna and New York City (NYC) have organized long-term programs in which various stakeholders participate. For example, Vienna's Deep Demonstration aims to engage participants in deliberating on how to tackle climate change. Although the program itself does not integrate smart technology, Vienna includes this effort under its 'Smart City Wien Framework Strategy'. Similarly, NYC pursues community-driven innovation through 'Co-Labs,' in which community and agency partners (local NPOs, academic institutions) co-create smart solutions that meet the residents' own needs.

Such practices show that smart city projects should be understood from the perspective of knowledge management (KM) as well as from that of technological innovation. Researchers in KM have long considered practical issues related to the management of knowledge enablers and flows/processes using information technology in organizational settings based on Polanyi's (1962) distinction between explicit knowledge and tacit knowledge ('know-how') (see Alavi & Leidner, 2001; Bolisani & Handzic, 2015). Therefore, KM plays a vital role in smart city projects which require connecting stakeholders, managing various information infrastructures, and processing/managing big data.

4. Smart Applications

This section presents a concrete analysis of the smart applications/solutions adopted in the surveyed smart city development projects following the categorization provided in Section 2 (see Table 3). Only the most relevant application domains and examples were included on account of space limitations.

4.1. IoT infrastructure

Most cities emphasize their IoT infrastructure as a key item of their smart city initiatives. There exist certain differentiations among the surveyed cities with regard to their considerations of what exactly 'IoT infrastructure' is. While San Diego lists smart streetlights with sensors as an example of IoT infrastructure, the city categorizes them as part of its energy- and cost-saving effort under the label of 'Energy and Water Efficiency'. Singapore, on the other hand, considers smart lamp posts as a platform for effective urban safety planning (e.g., safer trails and roads) (see Section 4.3).

On the other hand, NYC, London, and Singapore have developed standards and guidelines for a long-term vision pertaining to smart infrastructure and government services. Both the UK and Singapore endeavor to measure their efforts via how well they have embraced different aspects of digital transformation. NYC has proven to be the most active in establishing global partnerships with other smart city initiatives. It has also developed several standards and guidelines in order to help other governments and partners deploy and harness IoT technologies in a coordinated and consistent manner. These frameworks—such as Open Data Policy and Technical Standards and Guidelines for the Internet of Things—address best practices, resources, and frameworks which embrace privacy, security, data management, infra-structure, and sustainable operations.

4.2. Mobility

Most of the surveyed cities, except for Vienna, envision or employ smart mobility applications. However, given the necessity of further technological improvement, high costs, and legal and ethical issues involving smart mobility equipment such as autonomous vehicles (Dileep, 2020; Van Brummelen et al., 2018), most applications are still in the deliberation or pilot stages. Instead, smart parking services (Montgomery, Calgary) and automated traffic data (Montgomery, NYC, Calgary, Singapore) have been deployed in several cities.

Vienna promotes eco-friendly transportation such as parcel delivery using cargo bikes (RemiHub) and electric and hydrogen-fueled buses (Eco-buses for Wiener Linien), but these applications are not directly connected to smart IoT technology.

4.3. Public Safety

Improved public safety to address emergencies and crime is one of the expected benefits of smart cities, typically based on the deployment of various kinds of sensors. Some cities deploy smart applications for public safety such as crime prevention (Montgomery), emergency reporting (Calgary, London), and road safety (Singapore). In particular, London and Singapore have actively established cyber security policies and institutions to protect privacy in related public safety solutions. However, other cities still remain at an introductory level in this area and demonstrate limited applications of related technologies. This may be due to privacy issues related to the use of certain technologies.

4.4. Environment

Many smart technologies have the potential to contribute to improving the environment because they can reduce energy consumption through networked operations and data analytics. In particular, smart streetlights and metering systems are promising initiatives toward enhancing energy efficiency. Reflecting such expectations, several of the surveyed cities have adopted said applications (Montgomery, NYC, San Diego, Calgary, Singapore).

NYC, San Diego, Vienna, and Calgary implement several projects for environmental sustainability (e.g., solar power generation to charge electric vehicles). However, London does not focus much of its smart city projects on environmental issues except for some data gathering pertaining to energy consumption and waste.

4.5. Economy

Most of the surveyed cities regard smart city projects as a strong vehicle for sustainable economic growth in their plans. In particular, Singapore announced the Digital Economy Framework for Action in 2018, which included three strategic priorities—'accelerate' (digitalizing industries), 'compete' (integrating ecosystems), and 'transform' (industrializing the digital)—and four enablers—'manpower development,' 'research and innovation,' 'physical and digital infrastructure,' and 'governance, policies, and standards'. Vienna included smart solutions as one of its key agenda items in the 'Vienna Visitor Economy Strategy 2025' (2021) as well. Calgary is implementing a four-year digital transformation program (2021-2024) worth 20 billion dollars, although it has done so without labeling it as a smart city project.

On the other hand, most cities support startups and small and medium-sized enterprises (SMEs) through 'living labs' (Montgomery, Calgary) and 'grants' (NYC, London, Singapore, and Vienna). It is also worth noting that London, Singapore, and Vienna focus on the cultivation of human resources through education and training as well as the recruitment of data scientists, software developers, engineers, and designers. This implies that cities can employ different strategies for pooling expertise (from inside and/or outside government) based on their unique situations.

San Diego identifies its endeavor to promote economic growth through smart technology deployment using the term 'green businesses' (e.g., San Diego Green Business Network), not 'smart businesses.' Nevertheless, San Diego includes a high ratio of industry actors in the leadership of its smart city projects. Again, this implies the existence of different approaches to economic development strategies.

4.6. Urban living

Urban living includes projects for smart building, land use, local communities, and public spaces, all of which are closely related to residents' everyday lives. For example, Vienna has created a 3D model of the city using 30 million images of Vienna's streets, which can serve as a resource for developing public spaces. However, out of the cities we analyzed, only three had projects in this field (NYC, Vienna, Singapore) either in the deliberation or introduction stages.

4.7. Social inclusion

Social inclusion generally refers to improving equity in the opportunities accessible to disadvantaged groups and minorities. In this regard, smart city projects can play a positive role in enhancing social inclusion through smart and digital technologies such as free Wi-Fi (NYC, Montgomery, Calgary, London). In particular, NYC has focused on enhancing connectivity for marginalized groups such as older adults and low-income tenants. It also created the Cities Coalition for Digital Rights Initiative as an institution for advancing residents' and visitors' digital rights.

London, Vienna, and Singapore have opted to concentrate on digital education and training for their citizens. In particular, London ('Digital Talent Program' and 'Digital Leadership Program') and Singapore ('Digital Readiness') have more systematic plans for education initiatives in place.

4.8. Smart government

Smart government was found to be the most common domain for smart city projects. Almost all cities have established open data portals as a primary platform for smart government, but San Diego and London do not promote open data portals as part of their smart city projects, which may be due to having started their open data portals initiatives well before the initiation of their smart city projects.

We also discovered numerous mobile apps for government services. For example, Vienna developed the 'Sag's Wien App' as a platform through which citizens can provide feedback to government agencies or town councils. In particular, Singapore provides various types of open data resources for both citizens and businesses. These range from a one-stop open data portal (Data.gov.sg and SingStat) to transport and geospatial datasets/APIs (e.g., Land Transport DataMall, OneMap) to an online authentication and identity verification app/API (Singpass) to better support businesses and developers. Singapore has also consistently pursued 'digital government' from as early as the year 2000 and considers digital government as one of the integral parts of its smart nation project together with 'digital society' and 'digital economy'.

On the other hand, NYC has developed multi-language translation services for access to government services. These applications reflect the importance of the city's large-scale global and multi-racial communities.

5. Planning, management, and feedback

This section focuses on how smart city development projects lay out their visions and plans, manage privacy and risk issues, and establish the documentation and feedback processes for ongoing innovation.

5.1. Vision and planning

Each city that we analyzed adopts a different approach for planning its smart city projects (see Table 6). Montgomery, Calgary, and London produced one or two principal plans for their smart city projects, whereas NYC, San Diego, Vienna, and Singapore produced more than three plans. In particular, NYC and Singapore developed various types of documents (vision, blueprint, framework, planning, and strategy) embracing several smart city domains which fall under the purview of smart cities. Such structured plan-making appears to be reflective of leadership characteristics which have a more cohesive (NYC) and hierarchical (Singapore) structure than typical municipal governments.

Table 6. Principal plans for smart city projects

City	Plan (Year)
Montgomery	Connecting MGM with E-TRANSIT (2016)
NYC	Building a Smart + Equitable City (2015) The NYC IoT Strategy (2021) The NYC AI strategy & AI Primer (2021)
San Diego	Climate Resilient SD Plan (2015[2021]) 2030 District (2017)
Calgary	Smart Cities Challenge Submission (2017)
London	Smart London Together (2013[2018]) Connected London Program (2017[2019])
Vienna	Smart City Wien Framework Strategy (2014[2019]) Visitor Economy Strategy 2025 (2021)
Singapore	Three Pillars of a Smart Nation (2014) Smart Nation: The Way Forward (2018) Digital Government Blueprint (2018[2020])

5.2. Privacy and risk management

This paper distinguishes between public safety and security and privacy. Safety has to do with the prevention of physical damage to persons and devices. Security, on the other hand, means protecting a system against attack or crime (Atlam & Wills, 2020). Finally, privacy, despite some differences of opinion among researchers, generally describes how individuals and groups control or regulate access to information about themselves (Margulis, 2011).

Privacy threats can be understood as the result of a failure of safety and/or security. Issues with privacy which can occur with the use of IoT technologies are one of the most salient risks for smart city projects. For example, San Diego used collected data from smart streetlights to prevent crime, which resulted in the deactivation of sensors on all smart streetlights in the face of issues surrounding surveillance and the privacy concerns of the residents (Wray, 2020). Although the San Diego City Council approved ordinances to regulate surveillance technology, privacy issues still seem latent in the city. In Calgary, the security vulnerabilities of non-encrypted parking data came with privacy issues such as the exposure of drivers' personal information (Whittaker, 2021). These security flaws were directly connected to threats to resident privacy.

Given such extensive privacy threats due to IoT, smart cities have increasingly begun to establish policies, regulations, and institutions dedicated to privacy and data ethics. NYC, London, and Singapore have particularly well-developed guidelines and policies. Nevertheless, most efforts are only a few years in the making and still require constant review and improvement reflecting rapid changes in technology and social circumstances.

5.3. Documentation and feedback

The documentation and feedback processes have prominent roles in the execution of a smart city project (Noori et al., 2021). Most of the surveyed cities, if not all, provide various forms of documentation and feedback (i.e., reports and outcomes) which trace and demonstrate smart city improvement.

However, some cities (Montgomery, Vienna, Calgary) do not provide enough materials which could keep their citizens and participants informed of ongoing or previous smart city projects. Furthermore, most cities tend to focus on qualitative achievements (e.g., satisfaction, security, and accessibility), the deployment of infrastructure (e.g., the number of smart streetlights), and the amount of collected data rather than actual quantitative outcomes (e.g., energy efficiency and job growth) gained through such deployment. These discrepancies may imply that most smart city projects within the surveyed cities have not attained the expected level of maturity projected in their initial visions.

6. Comparison and synthesis

Based on the analysis from Sections 3, 4, and 5, this section conducts a comparison and synthesis employing radar (or 'spider') charts to grasp the similarities and differences in the characteristics of smart city projects and to avoid an idealized and linear approach to the general analysis of smart cities. The different characteristics (i.e., shapes) of the radar charts demonstrate how each surveyed city focuses on and develops specific aspects of its smart city projects. Nevertheless, these charts could help identify the strengths and weaknesses of different approaches and strategies 'under the present circumstances'. In other words, different conditions and interactions between elements (i.e., input and throughput) have a marked potential to change the future directions (i.e., output) of the surveyed cities.

6.1. Leadership and governance

Leadership styles and leadership participants for smart city projects vary within each city we analyzed (see Section 3). NYC, Vienna, Singapore demonstrate a 'visionary' style of leadership, in which government organizations/agencies lead and coordinate smart city projects. San Diego can be labeled as having a 'participatory' style in that NPOs and industry lead their projects. Montgomery, Calgary, and London were located in the middle ground, involving diverse participants from academia and industry in their leadership and/or decision-making processes. However, most cities, except for Montgomery and San Diego, do not engage civic participants as much as they do incorporate industry or academia participants (Table 7).

Table 7. Leadership style

City	Leading organization	Leadership style
Montgomery	TechMGM	Mixed
NYC	Mayor's Office of the Chief Technology Officer	Visionary
San Diego	Cleantech San Diego, San Diego 2030 District	Participatory
Calgary	City Council	Mixed
London	Smart London Board	Mixed
Vienna	Urban Innovation Vienna	Visionary
Singapore	SNDGO, GovTech	Visionary

6.2. Smart applications

To integrate the maturity level analysis of the smart city applications for each city into radar charts, we assigned values according to the following criteria: (a) assign levels '1, 2, 3, and 4' according to the average development level of each domain (deliberation, introduction, growth, and maturity); (b) assign a level '0' when any sort of application for the domain is not available. In the following sub-sections we summarize some of the significant findings identified from comparisons among the surveyed cities.

6.2.1. Balanced vs. focused development. Each of the smart cities analyzed adopts fairly different developmental strategies (see Figure 2). While Montgomery has steadily expanded smart city applications in a balanced manner through partnerships and collaborations with industry, academia, and even the Air Force, San Diego has focused on two domains (smart government and environment) despite a long history of work in various smart city projects.

On the other hand, Vienna was found to address only about half of the smart city application domains, all of which seem to reflect Vienna's strategic economic interests. Vienna, following its 'Visitor Economy Strategy 2025,' has made an effort to foster high quality urban living, which helps to attract foreign tourists. Additionally, its plans for environmental sustainability tend to be separated from smart city initiatives except for one project in 'Smart Inspection' which employs drones to maintain technical infrastructure such as wind farms and industrial chimneys.

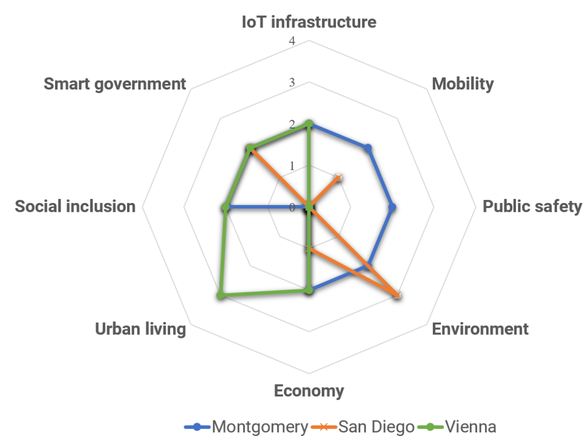

Figure 2. Applications (Montgomery, San Diego, Vienna)

6.2.2. Two megacities. NYC and London, the two megacities included in our survey, have some common economic and social characteristics, which in part explain the similarities in their overall smart city development stages (see Figure 3). It is worth mentioning that they share common interests in organizational and policymaking infrastructure as well.

However, these two megacities diverge in their smart city development strategies. London concentrates on technology-driven (IoT infrastructure, economy, and public safety) and human-driven (smart government and social inclusion) approaches. In particular, London places emphasis on fostering high-quality human resources through various training and education programs. NYC, however, pursues a more balanced development approach which includes mobility and urban living. In terms of social inclusion, NYC, unlike London, tends to encourage more participatory local projects.

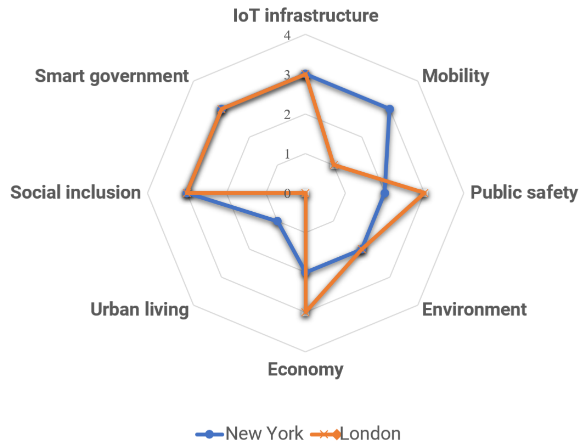

Figure 3. Applications (NYC, London)

6.2.3. Smart government, safety, and economic growth. Both Calgary and Singapore can be grouped as smart cities which focus on smart government, public safety, and economic growth (see Figure 4). However, their leadership styles differ. In particular, Singapore has a cohesive and hierarchical government organization on the basis of a city-state, which helps it place its smart government initiative at the highest levels of power out of all the cities surveyed. As with London, Singapore focuses on the cultivation of human resources to promote its economic growth.

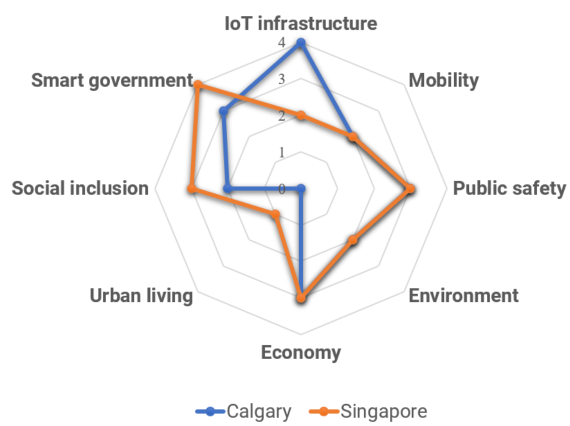

Figure 4. Applications (Calgary, Singapore)

On the other hand, Calgary began providing IoT infrastructure early on in the city's smart city project development. It now owns a municipal fiber and a LoRaWAN network for the deployment of and experimentation with smart city applications and uses these and other resources to promote startups and SMEs. However, Singapore focuses on the cultivation of human resources to promote its economic growth.

6.3. Planning, management, and feedback

We assigned values for the planning, management, and feedback domains employing the same criteria used for the Applications domain (see Section 6.2). The results are presented in Table 8. Singapore shows the most organized and comprehensive approach to the planning, management, and feedback domains. London and San Diego have also established various mechanisms to address each domain. However, Montgomery, Calgary, and Vienna lack measures for privacy and risk management. In particular, Vienna does not include specific plans for ensuring public safety in its documentation (see Section 4.3). Considering the ongoing expansion of smart city applications in the future, fundamental rules and policies should be established to prevent avoidable privacy threats.

Table 8. Planning, management, and feedback

City	Vision /plan	Privacy /risk	Document /feedback
Montgomery	2	0	2
NYC	4	3	4
San Diego	3	2	4
Calgary	2	1	3
London	3	3	4
Vienna	3	2	2
Singapore	3	3	4

Note. 0 = No application, 1 = Deliberation, 2 = Introduction, 3 = Growth, and 4 = Maturity

7. Lessons learned

We suggest an original analytical framework combining developmental (Deliberation-Introduction-Growth-Maturity) and processual (Input-Throughput-Output) perspectives but also employ a comparative approach to analyze and evaluate smart city initiatives in terms of a) leadership and governance, b) smart applications, and c) planning and feedback.

We found that forms of leadership and governance differ in smart city initiatives. Government and industry were the most prevalent participants, but academia and technical experts play a significant role in some initiatives (Montgomery, Vienna). The surveyed smart cities also established concrete cases for different directions in the adoption of smart city applications. Such differences stemmed from the multifaceted interactions that link environments, stakeholders, and goals of each initiative. For example, Vienna's smart application domains are considered to reflect the city's characteristic of visitor economy. Our analysis supports the argument that basic smart city rankings and reports are insufficient to describe the diverse characteristics of smart city development projects, including their inception, management, and evolution.

Moreover, we highlight the importance of knowledge management (KM) in ensuring the accumulation and transferability of organizational and policymaking infrastructure within and between smart city initiatives. Several cities (NYC, San Diego, London, Singapore) demonstrate the significant role of documentation and constructive feedback for the effective development of smart city initiatives. In particular, the two megacities of NYC and London were found to focus on establishing not only physical IoT infrastructure but also organizational and policymaking infrastructure (e.g., guidelines, standards, frameworks). Furthermore, some cases of privacy threats which were identified in our research illustrate the need to establish policies for managing collected data from IoT deployments. These findings and implications can be used to structure smart city frameworks with KM perspectives, an endeavor most often still in its beginning stages of consideration in the development of smart city initiatives (see Israilidis et al., 2021; Laurini, 2021; Roblek & Meško, 2020).

The lessons that we learned from the research raise two interesting questions for future studies. First, the 'continuity' of smart city development projects against changes in leadership, resources, and IoT should be further refined. Second, empirical investigations (e.g., participant observation and interviews) should be conducted to understand the practical interactions between actors and institutions of smart city projects.

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