Journal of Urban Management 12 (2023) 33–43

HOSTED BY

ELSEVIER

Contents lists available at ScienceDirect

Journal of Urban Management

journal homepage: www.elsevier.com/locate/jum

Research Article

The contextualization of smart city technologies: An international comparison

Huaxiong Jiang [a,*], Stan Geertman [b], Patrick Witte [b]

[a] Department of Geographical Science, Beijing Normal University, 100875 Beijing, No.19, Xinjiekouwai Street, Haidian District, Beijing, 100875, PR China
[b] Faculty of Geosciences, Department of Human Geography and Spatial Planning, Utrecht University, Utrecht, 3584CS, the Netherlands

ARTICLE INFO

Keywords:
Smart governance
Technocracy
Platformization
ICT
Context

ABSTRACT

In smart city practice, urban policymakers show to focus foremost on the technologies sec. This often leads to quite uniform, technocratic and corporate-led ways of handling urban issues. In contrast, more attention should be paid to the question of appropriateness of smart city technologies. This entails that quite uniform urban issues in different contexts ask for distinctive approaches and as a consequence, for specific smart city technologies. In other words, the context plays a decisive role in the choice for the urban issues themselves and in the ways to 'solve' or govern these, and in the choice for specific smart city technologies. This study examines the role of context in the handling of urban issues with the help of smart city technologies in three smart city projects: Hangzhou City Brain (China), Singapore Smart Nation, and Amsterdam Smart City (the Netherlands). The results reveal that the specific contextual factors influence urban city developments and the application therein of smart city technologies. This includes: a technology-driven management approach to fixing Hangzhou's traffic congestion; a mixed technocratic and platform-oriented approach to effecting transformation in Singapore's government services, businesses and urban living; and a platform-oriented, open-minded mechanism to improve Amsterdam's livability and economic prosperity. This paper concludes that rather than treating the technology itself as smart, the real smartness in smart cities is to develop and implement appropriate technologies according to its local context to solve targeted urban issues.

1. Introduction

Scholars have highlighted the promise of smart city technologies (e.g., sensors, artificial intelligence (AI), networking, Internet of Things (IoTs), cloud computing, urban analytics, etc.) in responding to the COVID-19 pandemic (Pan, Geertman, et al., 2022; Hassankhani et al., 2021; Inn & Tan, 2020). In that they show there is an eagerness among policymakers, technologists, and urbanists alike to seize this moment to "build back better" and re-imagine the city of the future with the help of smart city technologies. As a set of technical tools, instruments and capabilities, smart city technologies are used to improve the operation and efficiency of cities (Capra, 2016). A range of studies on smart city technologies has offered insights into their application, implementation and usefulness. Some studies focused on the role of smart city technologies in gathering and analyzing data for better government decision-making (Barns, 2018; Hu & Zheng, 2021; Sarker et al., 2018). In this process, city sensors and Internet of things (IoT) networks have become keys to the city, enabling government and citizens to receive instant information about hospitals, libraries, traffic, crime, and other community

* Corresponding author.
E-mail addresses: huaxiong.jiang@bnu.edu.cn (H. Jiang), S.C.M.Geertman@uu.nl (S. Geertman), P.A.Witte@uu.nl (P. Witte).

https://doi.org/10.1016/j.jum.2022.09.001
Received 20 May 2022; Received in revised form 15 August 2022; Accepted 7 September 2022
Available online 15 September 2022

services (Rathore et al., 2018). During COVID-19, for instance, governments used instant data and information collected through mobile applications, social media channels, and Artificial Intelligence (AI) based real-time surveillance footages to track and monitor positive cases and coordinate activities of various government departments for the intervention purpose (Inn & Tan, 2020). Other studies center on employing smart city technologies to encourage citizen participation and enable them to create solutions and services in a collective way (Repette et al., 2021). This, as Jiang et al. (2020a) highlight, helps citizens to have an active and participatory role in influencing public service provision and guarantee that services are offered in their needs. Typical smart city technologies include smart urban labs, open government portals, citizens' dashboard, and social media, digital twins, etc.

In practice, however, a technology-driven, corporate-led approach is prevailing in the development and implementation of smart city technologies. Hollands (2015) argues that many smart city projects worldwide adopted a globalized business model, focusing on developing robust urban infrastructures and deploying business investments for so-called digital economies. However, a business-oriented model of promoting smart city projects foremost accords corporate interest, meanwhile ignoring the non-technology centered model of city development (e.g., the community-based, small-scale model). Verrest and Pfeffer (2019) criticize that many smart city projects foremost revolve around developing and implementing smart technologies (IoT, connected devises, city sensors, cloud platform) instead of on satisfying the more actual needs of ordinary people and handling preexisting urban problems. The urban issue is deemed as a technological issue. As Jiang et al. (2020b) point out, the appropriate usage of smart city technologies is more subtle, more changeable, and shaped by a range of situations and contexts. Instead of relying on the instrumental characteristics, potentials of smart city technologies are highly affected by the environment in which it is embedded. However, there is still an incomplete understanding of the meaning of context and how it is able to shape the roles of smart city technologies.

From this, the aim of this study is to investigate the influence of context on the application and usefulness of smart city technologies in practice. We use three smart city projects—Hangzhou City Brain (China), Singapore Smart Nation, and Amsterdam Smart City (the Netherlands)—to examine the role of context in the handling of urban issues with the help of smart city technologies. This comparable case study is an attempt at understanding the role of context in influencing the appropriateness of smart city technologies.

2. Literature review

2.1. A conceptual framework

When smart city technologies are applied in practice, they face implicit situational information (Verrest & Pfeffer, 2019). In a traditional technology-driven approach, technology users are devoid of ways to connect technological innovations with contextual information (Krivý, 2018). Thereby, potentials of technologies are hardly acquired fully. Jiang, Geertman, and Witte (2019) argued that what could be gained from smart technologies is largely affected by contextual factors like political institution, policy process, characteristics of urban issues and user preference and skills. This paper integrates the earlier works by Geertman (2006) and Jiang et al. (2020a) and builds towards a conceptual framework to indicate context, capabilities of smart city technologies and the relevant smart approaches towards urban problem-solving (Fig. 1). It illustrates that contextual factors influence the development and application of technological capabilities, which together contributes to the production of smart approaches to solving urban problems.

In the framework, contextual factors include "political context," "characteristics of the urban issue," "planning style," "user characteristics," and "the technology itself" (Geertman, 2006). Here, the term "capability" refers to the ability of a supportive instrument to achieve a goal. Jiang, Geertman, and Witte (2021) categorize technological capabilities into three groups: "informing," "Communicative," and "analyzing & designing". The interaction between context and technological capabilities produces two smart approaches towards urban problem-solving: a technocratic, management approach and a platform-enabled, collaborative approach. Below, we will detail the components of the framework.

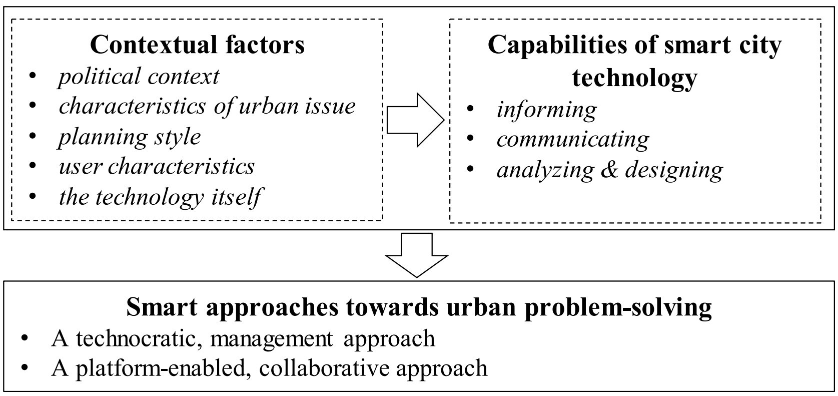

Fig. 1. Conceptual framework for the influence of context on the capabilities of smart city technology.

2.2. Contextual factors

Context in smart cities is the application environment of smart city technologies. Geertman (2006) argued a variety of contextual factors that influence the supportive role of technology in planning practice. His study encouraged many studies focusing on interrelationships between context and diffusion of technology, usefulness of technology, and technological barriers (in particular: Tomor & Geertman, 2020; Vonk, Geertman, and Schot 2007a). To clarify the content of the notion of contextual factors, we will now define and illustrate the most important ones.

2.2.1. Political context

Political context means the political systems and institutions that influence the policy making process in which technologies are implemented (Geertman, 2006). It influences the types of technological functions selected and the way they are implemented in practice. For instance, Tomor and Geertman (2020) identified that small-scale technological capabilities were developed to facilitate citizen engagement for coproducing solutions in democracies like the Netherlands, whereas in top-down institutions like Saudi Arabia (Aina et al., 2019), technologies engaged in big data analysis, processing and simulations were applied to facilitate public decision making and urban management in a technocratic way.

2.2.2. Characteristics of the urban issue

Characteristics of the urban issue are the attributes of policy issues shaping the organization of technological functions. In planning practice, the requirement of technological functions for solving an urban transportation issue differs from that of handling a waste-disposal problem. Then, strategic urban issues often need technologies that can process long-term, abnormal, ill-defined data (Rittel & Webber, 1984); in contrast, short-term urban issues encourage technologies to collect and analyze well-structured data. In consequence, there is a need to discern attributes of urban issues and find out how introducing technological solutions fit the targeted issue.

2.2.3. Characteristics of the technology itself

According to Geertman (2006), characteristics of the technology itself significantly influence the appropriateness of smart technologies, since they can be contextual and problematic in planning practice. They are contextual because functionality and usability of an instrument would influence the actual performance of that tool. For instance, technology with low usability would lead to low effectiveness and efficiency, thus reducing its acceptance and adoption in practice. They are problematic because the accessibility of data affects in what sense technologies can provide support to the handling of the issue at hand. In this paper, the technology itself as a contextual factor is embodied in its availability. Normally, a high level of technology obtainability makes it possible for city governments to reshuffle the policy making process and solve unexpected or targeted issues in a responsive way (Geertman, 2006).

2.2.4. The dominant policy style

A policy style means the prevailing form of decision-making process in a certain background. It offers a set of time-bound regulations and rules that policy makers should follow. Policy style changes in different countries. For instance, in a democratic society, engaging citizens and building forms of collaborative mechanisms is the common choice for coproducing policies or solutions (G. Vonk, Geertman, and Schot 2007b); thereby, technology that can promotes two-way communication and inspires debates between actors is preferred. In contrast, the policy making process with top-down approaches is foremost a closed system that governments determine what policy and procedures should users abide by. Influenced by this, technology is chiefly developed to help the policy maker to collect data and information, analyze them, and draw insightful and actionable conclusions (Geertman & Stillwell, 2004).

2.2.5. User characteristics

Characteristics of technology users influence the acceptance and usage of technologies as knowledge and skills of users concerning technology differs considerably between individuals (Chesbrough et al., 2006). According to Jiang (2021), the adoption rate of open platforms and networks is higher when the level of digital literacy of local residents is high. In the same vein, user preference towards technologies could affect how technology is implemented to handle tasks as required (Jiang, Geertman, & Witte, 2021). According to Vonk and Geertman (2008a), a positive and open-minded technology user would tend to be early adopters and be more sensitive to novel technical products. From this view, it would be beneficial to engage users in technological innovations for addressing wider urban issues.

2.3. Capabilities of smart city technologies

In this paragraph we will elaborate on a few identified capabilities of smart city technologies, summarized under the headings of "informing," "Communicative," and "analyzing and designing" (Jiang et al., 2020c).

2.3.1. Informing

The first capability of *informing* allows user to access and interpret knowledge and information from a sender. It involves transferring information from a send to a receiver in a single direction. In practice, top-down political institutions prefer to make use of informing capability to publish policy making policies and offer services to the public (Jiang et al., 2020c). The commonly used informing capabilities include but are not limited to geo-data gathering, geo-data storage, and visualization tools.

2.3.2. Communicative

In contrast to the capability of informing, communication supports the flow of information in a bidirectional way (Vonk & Arend Ligtenberg, 2010). In planning practice, *Communicative* capability is used to facilitate discussions and dialogues between those involved in planning (e.g., Touch Table) (Jiang et al., 2020b). It is often applied to involve stakeholders and promote the levels of participation ranging from tokenism to partnership to delegated power (Arnstein, 1969; Vonk & Geertman, 2008b). For instance, social media networks are widely used to enlarge the networks of stakeholders and build various large-scale online networks for collective actions (Lin, 2022; Lin & Kant, 2021). Typical Communicative ICT often includes interactive government websites, platforms, smart online living labs and other networks and apps.

2.3.3. Analyzing and designing

The third capability of *analyzing and designing* is about processing data to identify urban patterns and the underlying processes, and creating and presenting design ideas (Geertman 2014). According to Jiang et al. (2020c), analyzing capability investigate the component and structure of information, particularly for purposes of explanation and understanding. For instance, urban data analytics analyzes big data (e.g., mobile-phone data and transit smart-card data) to capture spatial–temporal movement of people in a city for smart mobility planning (Rathore et al., 2018). Another typical designing capability is geo-design. It offers a design framework and functions for designers to leverage geoinformation to design proposals that help policy makers initiate better-informed decisions (Vonk & Guido, 2006).

2.4. Smart approaches towards urban problem-solving

Besides elaborating on contextual factors and the identified capabilities of smart technologies it is needed to identify different ways of implementing and operating smart technologies. Based on the literature we distinguish two distinct, ideal-typical approaches—a technocratic management approach and a platform-enabled collaborative approach.

2.4.1. A technocratic, management approach

A technocratic management approach is a typical data- and technology driven approach in which it is believed that effective and smart decision-making should be based primarily on data, information, and knowledge (Jiang et al., 2020b). In this process, governmental officials are required to own enormous knowledge in technical skills and expertise. This is because rather than relying on merely subjective ideas and suggestions, the decisions made by governments should base more on objective methodology and scientific data and information. Unlike an elected politician, an official deemed as a technocrat might not have the institutional and political intelligence. In reality, the technocrats tend to be more practical, functional, pragmatic in the policy arena.

As for smart technologies, they are often equipped with informing capabilities that are developed to facilitate governmental policy-making (Kitchin et al., 2017; Shelton & Clark, 2016). Through gathering, analyzing and transforming data about issues concerned into visualized forms like table and diagram, policy makers think that the produced scientific knowledge helps them better explain the essence of urban issues, thus making smarter decisions (Verrest & Pfeffer, 2019). In addition, governments often adopt a technocratic approach to provide services to the public via websites in which residents are able to download documents, services information and other data for self-use (Jiang, Witte, & Geertman, 2021).

2.4.2. A platform-enabled, collaborative approach

In his study on Helsinki Smart City, Anttiroiko (2016) summarized the development model of Helsinki Smart City as a “City-as-a-Platform” approach. This approach relies on many participatory platforms and collaborative networks that engage citizens and establish innovation ecosystems for dealing with disputes, controversies and wicked urban problems. Differing from the technocratic approach, a platform-enabled, collaborative method centers on citizens and their interaction with government and other stakeholders to co-produce solutions towards public issues and events (Webster & Charles, 2018). In such a policy setting, the creation of public services is not relied on traditional bureaucratic government systems and the inherent centralized, “top-down” decision making. Instead, the active involvement and collaboration of service users and citizens are encouraged by the decentralized, communicative government in the co-production process.

Communicative channels, platforms, and social networks are the commonly used smart technologies in this process (Webster & Charles, 2018). As for citizens, novel innovative participation mechanisms are facilitated and established by these new communicative ICTs. They are introduced as a means of altering the distribution of power during the policy-making process and promote collective actions (Repette et al., 2021). Consequently, the critical characteristics of this platform-enabled, collaborative approach is the development and application of information flows in a variety of “smart” way (Webster & Charles, 2018). For instance, this approach is able to gather new sources of data, not only from service and administrative portals, but also from social media, citizen platforms, and new sensory devices, for decision making purposes.

3. Methodology

Relying on an intensive review of academic literature, policy documents, index systems, research reports and other websites, we selected three smart city projects in three different countries to explore the influence of context on the appropriateness of smart city technologies. These three cases are 1) Hangzhou City Brain Project, China; 2) Smart Nation Singapore; and 3) Amsterdam Smart City, the Netherlands. The reason for selecting these cases is that their embedded urban contexts differ substantially in characteristics of urban issues, levels of technological development, political institution, user characteristics, etc. For instance, the city of Hangzhou is in a period of accelerated urbanization and explosive industrialization, which causes a series of problems, such as traffic congestion, housing shortages, education resources storage, etc. (Lin et al., 2018). In Singapore, although it has a high ranking of the UN Human Development Index and a high GDP per capita (PPP), the city-state faces a shortage of natural and human resource (Jiang, 2021). For Amsterdam, due to its large number of knowledge workers (with 44 per cent of the population receiving higher education), social tolerance and high level of digital penetration, there is a need to integrate those human and social capital for urban innovations and sustainable development (Capra, 2016). As we have already mentioned above, “one size fits all” technology-driven solutions are preferred by entrepreneurial interest among local governments and private sectors. However, these solutions and responses might not meet the true demand of local citizens like participation pursuits and solve the real urban issues at handle. The three cases embedded in distinctive urban settings enable us to examine the contextualization of smart city technologies to local use cases.

We used the Google Scholar search engine and the Baidu search engine (a Chinese search engine) to collect the data for the three cases. Between January and March 2022, multiple sources of data have been retrieved in multiple digital databases. A total of 161 data sources were identified, including policies and reports produced by governments and other institutions that substantively delineate the debates and discussions on these three cases. Detailed data sources include project policy reports, brochures, website pages, academic articles, press releases, and digital newspaper archives.

A coding analysis was further conducted to process the multiple data collected from the various sources. This stage of analysis accorded to the procedure proposed by Corbin and Strauss (1990). Through the coding process, raw data were reorganized as units to characterize the design and development of the smart city technologies. Thereafter, we conducted a close discursive analysis of the coded units, which allows us to capture reflections and contemplations by governments, researchers, specialists, and journalists.

4. Results

4.1. City Brain project in Hangzhou

4.1.1. Contextual information

With rapid socioeconomic development and speedy urbanization, the number of motor vehicles in Hangzhou has increased from 196,700 in 2001 to 2,82 million in 2020 (Hangzhou Municipal Bureau of Statistics, 2021). Consequently, severe urban traffic problems cause the city to become one of China's most congested cities. Given the background, the Hangzhou government launched the “City Brain” project, specializing in gathering and analyzing traffic big data and helping make better decisions for traffic management (Caprotti and Dong, 2020a).

A management- and problem-oriented government characterized with a monopolistic decision-making power contributed to the initiation and establishment of this project. This is because large scale urban problems need an integrated and holistic view of the situation and a deterministic government to explore and decide on the best solution. Then, vigorous technological innovation capabilities of the city also played a role. As the headquarter of Alibaba (an international company major in internet and artificial intelligence (AI)), Hangzhou leads hi-tech innovation in China. This establish a sound basis for technological innovation in Hangzhou.

4.1.2. Smart city technologies

A “Smart Government” approach was adopted by the Hangzhou government to implement the City Brain system. Here, so-called smart government means that governments make full use of smart technologies like AI, big data, cloud computing technologies to augment city operation components and digitalize public decision making process, aiming to deliver public services and intelligently response to urban events and issues (Jiang, 2021).

In this process, Alibaba was appointed as a strategic partner centering on developing hardware and software and implement ICT plans (Zhang et al., 2019; Caprotti and Dong, 2020a). The overall goal of City Brain is to collect and utilize the traffic data in real time to reduce traffic congestion. In detail, the City Brain systems leverages a range of deep learning algorithms, computer graphics and video image analysis to develop city-scale AI models (Wang et al., 2022). The city-scale AI models are capable of processing a large amount of real-time vehicles, pedestrians and incidents data at high speed. For instance, as one part of the system, the Visual Search Engine visualize real-time data to enhance search and recognition accuracies (Hua, 2018; Zhang et al., 2019). Based on insights received from heterogeneously visualized events and situations, transportation practitioners or policy makers are able to locate the traffic-relevant events and make an intervention in that situation. Furthermore, the City Brain also has functional support like digital signages and AR-based messaging systems that can be applied to check road conditions and prompt alerts, reminders and informatics interventions for maintaining or preserving works.

After several years of testing and working, the system showed to have shortened commutes and help the city to reduce the congestion rate largely. According to Hangzhou Municipal Bureau of Statistics (2021), the City Brain system has largely helped increase Hangzhou's transportation speed by 15% and optimize pathway for emergency and specialty vehicles (e.g., policing, fire trucks and ambulances) by 50%. Spurred by the success of the City Brain project, the Hangzhou government currently plans to enlarge the application of the system in wider aspects such as emergency preparedness, environment protection, housing construction, law enforcement, etc. However, the extent to which the benefits of the systems are made available to wider stakeholders, especially citizens, will depend on governmental organization transformation, effective citizenship and digital responsibilities. Thus, the system developers and the city managers intend to integrate the citizen into the system via using technological products such smartphone, wearable apps and health technologies and establish a coproduction mechanism for improving the system (Caprotti and Dong, 2020b).

4.1.3. Smart approaches towards urban problem-solving

What we find in Hangzhou is that a technology-driven, technocratic approach was applied to manage its traffic problems. In this process, the deterministic factors for designing and implementing the City Brain systems mainly include the presence of severe congestion, centralize decision-making, as well as strong technological basis for innovation. The large-scale nature of the traffic issue requires an integral ICT-augmented approach to handle its complexity. Then, the strong technological basis enabled the city to initiate an ICT-based strategy of developing capabilities and functions to collect, analyze and visualize traffic data for smart decisions. The top-down, problem-oriented government facilitates the policy implementation of this project. By further making use of the real-time data, the Hangzhou government manages traffic, both by improving transportation logistics and reducing congestion and fatalities.

4.2. Smart nation Singapore

4.2.1. Contextual information

In the past 50 years, Singapore has become one of the significant international economic transportation and financial centers (Hoe, 2016). However, because of its limited land area, the city-state faces a lack of natural resources. More recently, an increase in aging population has caused shrinking human resources, which further poses challenges to its economic competitiveness and sustainable development (Dresel et al., 2020). Thus, the Smart Nation Singapore project was proposed to attract more talented people, provoke innovation and entrepreneurship activities and increase residents' quality of lives. Note that Singapore has a long tradition to make use of technologies to improve productivity and service quality (Teddy-Ang & Toh, 2020). As a pioneer of technology application in urban planning and development, the city-state carries on applying smart technologies to create sustainable development, preventing itself from falling behind other competitors.

The Smart Nation Singapore initiative adopted a collaborative mechanism to develop people-centric solutions towards its urban issues. Interactions between government, industry and citizens intends to harness ICT to facilitate transformation in businesses, government services, transportation, urban management and environment protection. The program and works were led and coordinated by a cabinet minister. According to Ho (2017), data, transportation and elderly were the three policy priority areas. As a city-state, more sustainable urban mobility solutions are needed to handle the traffic congestion. New facilities are required to satisfy the needs of the elderly due to its growing population. Then, informed government administration requires improving data accessibility.

4.2.2. Smart city technologies

As a smart nation, Singapore was first in implementing smart technologies and data to handle the concerned issues. For instance, an integral, digital government administration system—the Core Operations, Development Environment, and eXchange—was built by using the "informing" ICT. This system was intended to enhance government capabilities of offering public services and reducing service segmentation (Choudhury, 2019, p. 2019). To enable private companies, research institutions and individuals to perform civic innovation and creative campaigns, the Singapore open government data portal (https://data.gov.sg/) was built to make government data understandable and accessible to the public. The government's one-stop portal consists of datasets from 70 public agencies, including finance, infrastructure, society, environment, etc. (Chan, 2013).

With the proliferation of big data, many "analyzing and designing" tools were created to collect, process and analyze data that provoke consequential examination and application. For instance, the Grab-NUS AI Lab was established by a partnership between the National University of Singapore and Grab to analyze mobility data for cutting-edge smart mobility solutions. Products include the creation of richer maps for delivering accurate localization and transportation services) (Intelligent Transport, 2018). Another example is the effort by the Urban Redevelopment Authority's (URA) Digital Planning Lab to develop the Spatial Data Analytics to support planning analyses on a range of issues. Those issues could include but are not limited to employment accessibility, mobility patterns, amenities availability, school distribution, and demographic changes (Huang, 2018). More recently, visualization and geo-spatial analysis tools were even leveraged to evaluate COVID-19's impact on Singapore and support a post-COVID recovery. For instance, "vaccine passport and related applications" and "smart watches" were initiated to support mobile healthcare under COVID-19 (Yu, 2020).

Communicative ICTs like open platforms, social media groups, and networking apps were initiated by public-private partnerships and other forms of collaborations to build a system of mechanisms for open innovation. Typical illustrations are embodied in the development of various open platforms to encourage experimentation and risk-taking investment in services and products innovation. For instance, AI Singapore—an online open innovation platform——was developed to engage all Singapore-based ecosystems of AI companies, researchers, colleges, AI startups, and AI companies for startup innovation (Teddy-Ang & Toh, 2020). A government wide partnership including Integrated Health Information Systems, National Research Foundation, and SNDGG played a vital role in initiating and executing this platform. Other Communicative ICTs consist of hackathons, open innovation laboratories, living labs and crowd-sourcing that were built to attract AI talents, grow start-ups with advisory services and create ICT-based solutions. Besides, various social networks were used to help seniors to stay in touch with their family and communicate with loved ones.

4.2.3. Smart approaches towards urban problem-solving

In Singapore, the city has adopted a mixed approach (technocratic and platform-oriented) towards handling its urban issues (Ho, 2017). The city-state with limited resources, sustainability problems, path dependence on technology, along with collaborative mechanism between different stakeholders are contextual factors that largely determine this mixed approach. For instance, the development of various informing ICTs and capabilities to improve aspects of government operations, public service and scientific decision results from the urgency of sustainability problems (Kong & Woods, 2018). Then, the establishment of various communicative

ICTs and platforms to engage multiple actors for collective solutions is due to the status of Singapore as a city-state with limited resources. The increase of start-ups could be treated as an indication of the platform-enabled, collaborative approach. Taken together, we see the rise of a combination of a smart technocratic approach and a more platform-enabled, collaborative approach in facilitating a problem-solving mindset.

4.3. Amsterdam Smart City

4.3.1. Contextual information

The smart city strategy in Amsterdam is called "Amsterdam Smart City Programme". It was in 2007 that a partnership between the Amsterdam municipal administration, Liander (an energy-network operator) and the Amsterdam Innovation Motor proposed and started this concept (Mora & Bolici, 2015). The determination of Amsterdam Smart City is clear: maximizing the usefulness of modern ICTs to support city organizations and individuals to handle its socioeconomic and environmental issues and build a durable, non-expendable society. In this process, Amsterdam's democratic culture and active civil society, as well as its bottom up policy-making process, have facilitated the establishment of this collaborative mechanism in tackling its sustainability challenges. For instance, multiple roles have been played by the Amsterdam government including not only initiator or leader of innovation activities, but also as a facilitator for citizen participation and multi-actor collaboration. As for non-state actors such as universities, research institutions, societal organization, citizens, and high-tech companies, they are vital in offering resources, information and knowledge, expertise, time, material assets, and finance to facilitate the coproduction and co-implementation of smart initiatives. Technology was recognized as key enabler and facilitator in this process (Putra, Dinar, & GM van der Knaap, 2018).

4.3.2. Smart city technologies

A smart living lab methodology was selected to promise high citizen involvements in the process of developing the projects (Mora & Bolici, 2015). As the facilitator of collective actions, the Amsterdam Smart City platform (https://amsterdamsmartcity.com/) was developed to engage multiple actors, especially citizens, for co-producing services and solutions that could meet their real demands (van Winden et al., 2016). With between 1500 and 2000 startups initiated in Amsterdam at the same time, the platform acted as a digital marketer for any posted smart city project, thereby greatly accelerating the open innovation process (Macpherson, 2017). For instance, the platform facilitated the development of StartupAmsterdam, a project established via a collaboration between the city government and 250 stakeholders in the tech sector. This project intends to integrate the startup systems in Amsterdam and build a holistic innovation eco-system for entrepreneurship on a grand scale (Noori, Hoppe, and de Jong 2020). Besides, the Amsterdam Smart City platform contributed to the establishment of The Green Urban Living Lab to tap into the tech culture and create a learning and co-creating environment (Mancebo, 2020). Different stakeholders could jointly test and create green smart solutions for environmentally friendly cities.

Except for the open platform, website technology was used to build the initiative of open government data in Amsterdam (Bicknese & van der Oord, 2015). Citizens, businesses and research institutions can find multiple new datasets available on several data portals, including geography, environment, economic development, social affairs, transportation, and tourism, etc.

We also identified schemes like Repair Cafes or Tool Lending Libraries that firstly were initiated in Amsterdam and are operated completely by the public, for the public. Also, the app Verbeterdebuurt, literally translated as 'Improve The Neighborhood', offered

Table 1
Comparison of the three smart city cases.

Items	Hangzhou City Brain	Smart Nation Singapore	Amsterdam Smart City
Context	• Large-scale nature of the traffic congestion • Strong technological basis • The top-down, problem-oriented government	• Limited natural and social resources • Technological tradition and basis in city development • Top-down institution and collaborative society Sustainable development challenges	• Democratic culture • Active civil society • Collaborative government • Sustainable urban issues Strong technological basis
Capabilities of smart city technologies	• An integrated traffic systems • City-scale AI models • Urban data analytics • Visualization function	• Digital government administration system • Open government data portal • Open living labs • Networking apps	• Open and collaborative platforms • Open data portals • Living labs • Real-time urban big data analytics
Smart approaches	• A technocratic, management approach	A mixed approach (technocratic and platform-oriented)	• A platform-enabled, collaborative approach
Outcomes	• Improved traffic management efficiency • Reduced congestion rate	• Improved government administration • Improved innovation capabilities in business and startups • Improved lives and livelihoods	• Improved ecosystems for innovation • Improvement to city and public services • Improved life satisfaction of locals

Amsterdammers with an appropriate channel to identify problems and propose suggestions for changes (Schrammeijer et al., 2021). Furthermore, another web-based platform called Social Glass applied real-time urban big data analytics and forecasting to produce a "reflection of the human landscape" (Macpherson, 2017). Via gathering individual emotions, facts, situation of information in real-time and from a diversity of people and analyzing word meanings with advanced lexical semantics, policy makers are able to recognize the situation, sentiment, needs of local residents and develop better intervention proposals.

4.3.3. *Smart approach towards urban problem solving*

Amsterdam's bottom up policy making process, active citizens and democratic arrangements contributed to the establishment of a platform-enabled, collaborative approach towards reducing environmental issues and boosting technological innovation in the metropolitan area of Amsterdam. Traditionally, the policy makers use a top-down and vision-led method to chiefly collaborate with private companies for handling urban issues (Verrest & Pfeffer, 2019). However, issues in cities pretend to be more multi-dimensional in nature that no single stakeholder can handle in isolation. Gradually, there is the recognition of the value of a bottom-up approach highlighting the role of multiple non-state actors (e.g., small and medium-sized companies, start-ups, not-for-profit organizations, and citizens) to co-produce the innovative solutions (Hollands, 2015). In Amsterdam, taking advantage of the potentials and capabilities offered by ICTs, open apps and collaborative platforms were created to allow ordinary people to partner with the government. This cooperative mechanism goes beyond the public sector and promotes co-creation of services and products and breakthrough results. According to Capra (2019), the platform-enabled, citizen-centric city governance approach in Amsterdam gave back the economic and social value from the private sector to the citizens, which is crucial for the smart city transformation.

5. Reflections

Table 1 compares the contextualization process of smart city technologies in the three smart city cases. Based on the table, we further reflect on the findings.

5.1. *Roles of context*

The analysis indicates that the specific context indeed influences the design and development of relevant smart city technologies in responding to the concerned urban issues. In Hangzhou, severe traffic congestion, along with its strong technological basis and top-down, problem-oriented government simulate the initiation of a top-down, comprehensive management platform for governing traffic congestion and other mobility issues. Via processing various historical and real-time traffic data, traffic managers are better informed; consequently, proposing better interventions for traffic management. In Singapore, the rise of mixed smart approaches is largely subjected to contexts like entrepreneurial government and Singapore's position as a city-state with limited resources. In this process, a smart technocratic approach centers on developing informing and analyzing tools to improve digital connectivity and make better informed government for producing high quality services. By using communicative ICTs, networking apps and platforms, a platform-enabled, collaborative approach engages all relevant stakeholders in technological innovations, startups, and city entrepreneurship. Overall, the technocratic approach along with the increased platform-enabled collaborations between multiple stakeholders restructured Singapore's government, policy making process and the living settings of the Singaporeans.

In Amsterdam, influenced by the bottom-up systems, strong capability of technological innovation, and participation culture, triple helix cooperation and comprehensive innovation platforms were developed to handle Amsterdam's sustainability issues. The platform-enabled approach extends the role of different stakeholders, especially citizens, in innovation activities. Different stakeholders are able to join the cocreation and coproduction activities via informing and exchanging information, knowledge, and projects in a fair way. According to Capra (2016), Amsterdam Smart City put residents and users of the city at the center of interests. It is a platform for doers (governments, researchers, planners, designers, technology developers, active residents) coming together to collaborate for Amsterdam's future. Accordingly, these cases indicate that more sensitivity toward contextual factors is valuable and even deterministic in the design, development and implementation of smart city technologies.

5.2. *Usefulness of smart city technologies*

Usefulness and added value of technological capabilities and functions are well illustrated in these cases. Many authors argue that technological innovations are the key factor to make efficient utilization of natural and human resources in the digital era (Kitchin et al., 2017; Rathore et al., 2018). The importance is becoming increasingly obvious when there is urgent need to improve the people's quality of life socio-economically. In Hangzhou, a comprehensive traffic management platform was developed to build on-demand smart analysis capabilities for the traffic command center to put forward quicker and more efficient interventions. In Singapore, the Smart Nation project was initiated to utilize the potentials of big data, web technologies, AI, networks and other platforms to reorganize public administration and re-orient state-citizen interactions. Smart technologies contributed to more essential shifts in Singapore's governing milieu and create technology-enabled solutions to its sustainable issues. The usefulness of smart city technologies is also illustrated in the case of Amsterdam. The Amsterdam Smart City platform provides an open web-based channel for all relevant stakeholders to take and give information and knowledge through it, anytime, anywhere and for free (Mancebo, 2020; Noori, Hoppe, and de Jong 2020; van Winden et al., 2016). Enabled by this platform, innovations and solutions can be tested in actual environments through engagement from multiple agencies and stakeholders, especially local residents who know their surroundings well. According to Capra (2016), the Amsterdam Smart City platform and many other platform technologies contributes to the rise of the Public-Private-People Partnership in every project. This not only maximizes social and human capital but also improves the living environment and the level of wellbeing of its inhabitants.

Nevertheless, there are still doubts that whether ordinary people are capable of influencing the decision-making process with the help of so-called smart technologies (Kummitha, Reddy, & Crutzen, 2017; Ho, 2017). For instance, many present ways engaging policy interventions are initiated and implemented by local communities instead of by technology; thus, the scope and the extent to citizens are able to engage in policy-making is questioned (Kummitha et al., 2017). Besides, in bourgeois neighborhood, citizens are often more active and exert greater influence in the policy making process, whereas the levels of citizen engagement are much weaker in less affluent communities (Kummitha et al., 2017). From this perspective, usefulness of smart city technologies should pay more attention to local and informal knowledge that could influence technology operating models.

5.3. The two smart approaches

The technocratic, management approach and the platform-enabled, collaborative approach are never mutually exclusive but supplement each other. In this paper we argue that a typical smart approach is appropriate and adequate when it fully considers its embedded context. In other words, the approach itself is not being good or wrong, and the important thing is whether it is suitable for the problems that need to be solved in that situation (Pan, Kwak, & Deal, 2022).

As our analyses show, although two distinctive approaches were developed in Hangzhou and Amsterdam, these two approaches both achieve their goals. The reason for this is that both cities have fully considered their context-relevant strengths and restraints that shape their development pathways. Then, the mixing of the two approaches in Singapore also indicates their complementary relationship, that is, each approach is in charge of a different aspect of their city and shares responsibility in Singapore's urban problem-solving. This greatly makes up for the deficiency of resources for urban innovation and sustainable development in this city. In this sense, there is a need to break away from the “silo mentality” and avoid the simple binary opposition of smart approaches in city development. Instead, being more context-sensitive is necessary for different cities across the world to transfer the knowledge and innovative practices based on each other's experiences and lessons.

Still, there are concerns about the real capability of these two approaches towards urban problems solving. For instance, the technocratic, management approach was often criticized for its negligence of the real needs and demands of the ordinary people since the governmental technocrats often have specialized knowledge and skills that the general public lacks (Kummitha et al., 2017; Komninos et al., 2019). Besides, governmental technocrats may not be accountable to the traditionally broad public-interest formulations; consequently, policy goals may not be well achieved in the approach. As for the platform-enabled, collaborative approach, limitations such as the digital divide among regions and demographics also prevent its wider applications (Jiang, 2021). For instance, even in Amsterdam, a city where people have a generally high level of digital literacy, the gap between women with different socio-economic position in access to smart city technologies is still large (Goedhart et al., 2019). Furthermore, the incentives to facilitate participation may not be insufficient to catch and retain Internet users if no forms of “reward” can be given to the participants. From these views, more awareness should be raised to the hidden restraints and/or negative impacts of these two approaches.

6. Conclusion

In the literature, it is argued that smart city technologies, as digital methods, techniques and approaches, can be used to enhance the operation and management of a city in an innovative way. In practice, however, urban policymakers show to focus foremost on the technologies sec. This often leads to quite uniform, often technocratic and corporate-led, ways of handling urban issues. Many authors argue that one should start from the urgent urban issues themselves in their specific context (e.g., economic, political, technological) for which smart city technologies are intended. In this paper, we explore the influence of context on the appropriateness of smart city technologies, based on three smart city projects.

The results reveal that the specific contextual factors influence urban city developments and the application therein of smart city technologies. More specifically, in Hangzhou, the existence of a government with strong political power along with high levels of technological capabilities result into a technology-driven management approach. Therein, the focus is foremost centered on large-scale technological solutions for widespread city problems, for instance fixing traffic congestion. In Singapore, characterized by close public-private partnerships and just restricted innovation resources (available, accessible, financial support and innovation actors) lead to a mixed approach (technocratic and platform-oriented) to effecting transformation in government services, businesses, health, transport, and urban living. In Amsterdam, the nature of small-scale urban problems and its high sociotechnical interaction in urban planning processes produces a platform-oriented, open-minded mechanism for shaping social innovation, aiming at improving Amsterdam's livability and economic prosperity.

This paper concludes that the real smartness of smart city technologies is the appropriateness of developing and implementing technologies according to its local context to solve real targeted urban issues. The comparative study on these three smart city cases merely offers a meaningful reference. It tells us that cities in different socio-spatial contexts are confronted with differed development levels, thus we need to develop appropriate smart city technologies that suit their local contexts. Consequently, another boarder contribution of the paper is to propose a more generalized framework of evaluating contextualization of smart city technology in practice. From this, we further suggest that the appropriateness of smart city technology should focus more on the influence of context and on the contextual impact towards derived smart approaches that involves new insights around urban problem-solving.

Funding

This study is supported by The National Natural Science Foundation of China (42201207) and The Fundamental Research Funds for the Central Universities (2021NTST37).

Declaration of competing interest

The authors declare that there is no conflict of interest.

References

Aina, Y. A., Alex, W., Fethi, A., & Alshuwaikhat, H. M. (2019). Top-down sustainable urban development? Urban governance transformation in Saudi Arabia. *Cities, 90*, 272–281.
Anttiroiko, A.-V. (2016). City-as-a-Platform: The rise of participatory innovation platforms in Finnish cities. *Sustainability, 8*(9), 922.
Arnstein, S. R. (1969). A ladder of citizen participation. *Journal of the American Institute of Planners, 35*(4), 216–224.
Barns, S. (2018). Smart cities and urban data platforms: Designing interfaces for smart governance. *City, Culture Soc., 12*, 5–12. https://doi.org/10.1016/j.ccs.2017.09.006
Bicknese, L., & van der Oord, M. (2015). Open city Statistics: The first results with open data in Amsterdam. *Statistical Journal of the IAOS, 31*(1), 111–115.
Capra, C. F. (2016). The smart city and its citizens: Governance and citizen participation in Amsterdam smart city. *International Journal of E-Planning Research, 5*(1), 20–38.
Capra, C. F. (2019). The smart city and its citizens: Governance and citizen participation in Amsterdam smart city. In *Smart cities and smart spaces: Concepts, methodologies, tools, and applications, 1407–27*. IGI Global.
Caprotti, F., & Dong, L. (2020a). Platform urbanism and the Chinese smart city: The Co-production and territorialisation of Hangzhou city Brain. *Geojournal, 1–15*.
Caprotti, F., & Dong, L. (2020b). Platform urbanism and the Chinese smart city: The Co-production and territorialisation of Hangzhou city Brain. *Geojournal, 1–15*.
Chan, C. M. L. (2013). From open data to open innovation strategies: Creating e-services using open government data. In *2013 46th Hawaii international Conference on system sciences, 1890–99*. IEEE.
Chesbrough, H., Vanhaverbeke, W., & West, J. (2006). *Open innovation: Researching a new paradigm*. Oxford: Oxford University Press on Demand.
Choudhury, A. (2019). "*What is CODEX? The tech behind Singapore's smart nation." GovInsider, april 24*. https://govinsider.asia/connected-gov/what-is-codex-the-tech-behind-singapores-smart-nation/.
Corbin, J. M., & Strauss, A. (1990). Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology, 13*(1), 3–21.
Dresel, R., Henkel, M., Scheibe, K., Zimmer, F., Wolfgang, G., & Stock. (2020). A nationwide library system and its place in knowledge society and smart nation: The case of Singapore. *Libri - International Journal of Libraries and Information Services, 70*(1), 81–94.
Geertman, S. (2006). Potentials for planning support: A planning-conceptual approach. *Environment and Planning B: Planning and Design, 33*(6), 863–880.
Geertman, S., & Stillwell, J. (2004). Planning support systems: An inventory of current practice. *Computers, Environment and Urban Systems, 28*(4), 291–310.
Goedhart, N. S., Broerse, J. E. W., Kattouw, R., & Dedding, C. (2019). 'Just having a computer doesn't make sense': The digital divide from the perspective of mothers with a low socio-economic position. *New Media & Society, 21*(11–12), 2347–2365.
Hassankhani, M., Alidadi, M., Sharifi, A., & Azhdari, A. (2021). Smart city and crisis management: Lessons for the COVID-19 pandemic. *International Journal of Environmental Research and Public Health, 18*(15), 7736.
Ho, E. (2017). Smart subjects for a smart nation? Governing (smart) mentalities in Singapore. *Urban Studies, 54*(13), 3101–3118.
Hoe, S. L. (2016). Defining a smart nation: The case of Singapore. *Journal of Information, Communication and Ethics in Society, 14*(4), 323–333.
Hollands, R. G. (2015). Critical interventions into the corporate smart city. *Cambridge Journal of Regions, Economy and Society, 8*(1), 61–77.
Hua, X.-S. (2018). The city Brain: Towards real-time search for the real-world. In *The 41st international ACM SIGIR conference on research & development in information retrieval* (pp. 1343–1344).
Huang, Z. (2018). *Data analytics in urban planning: New tools for old problems* (Vol. 4, p. 2018). Marsh McLennan Offical Website, September. https://www.brinknews.com/data-analytics-in-urban-planning-new-tools-for-old-problems/.
Hu, Q., & Zheng, Y. (2021). Smart city initiatives: A comparative study of American and Chinese cities. *Journal of Urban Affairs, 43*(4), 504–525.
Inn, & Tan, L. (2020). *Smart city technologies take on COVID-19* (p. 841). World Health.
Jiang, H. (2021). *Smart urban governance: Governing cities in the 'smart' era*. PhD Thesis. Utrecht University.
Jiang, H., Geertman, S., & Witte, P. (2019). Smart urban governance: An urgent symbiosis? *Information Polity, 24*(3), 245–269. https://doi.org/10.3233/IP-190130
Jiang, H., Geertman, S., & Witte, P. (2020a). A sociotechnical framework for smart urban governance: Urban technological innovation and urban governance in the realm of smart cities. *International Journal of E-Planning Research, 9*(1), 1–19. https://doi.org/10.4018/IJEPR.2020010101
Jiang, H., Geertman, S., & Witte, P. (2020b). Ignorance is bliss? An empirical analysis of the determinants of PSS usefulness in practice. *Computers, Environment and Urban Systems, 83*, Article 101505.
Jiang, H., Geertman, S., & Witte, P. (2020c). Smart urban governance: An alternative to technocratic 'smartness. *Geojournal, 1–17*.
Jiang, H., Geertman, S., & Witte, P. (2021). The effects of contextual factors on PSS usefulness: An international questionnaire survey. *Applied Spatial Analysis and Policy, 14*(2), 221–245.
Jiang, H., Witte, P., & Geertman, S. (2021). Smart governance and COVID-19 control in Wuhan, China. In S. Geertman, C. Pettit, R. Goodspeed, et al. (Eds.), *Urban informatics and future cities* (Vols. 17–32). Springer.
Kitchin, R., Coletta, C., Evans, L., Heaphy, L., & Mac Donncha, D. (2017). Smart cities, urban technocrats, epistemic communities and advocacy coalitions. In *The programmable city working paper 26*. The Programmable City Working Paper https://osf.io/preprints/socarxiv/rxk4r.
Komninos, N., Kakderi, C., Panori, A., & Tsarchopoulos, P. (2019). Smart city planning from an evolutionary perspective. *Journal of Urban Technology, 26*(2), 3–20.
Kong, L., & Woods, O. (2018). The ideological alignment of smart urbanism in Singapore: Critical reflections on a political paradox. *Urban Studies, 55*(4), 679–701.
Krivý, M. (2018). Towards a critique of cybernetic urbanism: The smart city and the society of control. *Planning Theory, 17*(1), 8–30.
Kummitha, R. K., Reddy, & Crutzen, N. (2017). How do we understand smart cities? An evolutionary perspective. *Cities, 67*, 43–52.
Lin, Y. (2022). Social media for collaborative planning: A typology of support functions and challenges. *Cities, 125*, Article 103641.
Lin, Y., Chi, Y. J., Deng, J., & Wang, Z. (2018). Urbanization effect on spatiotemporal thermal patterns and changes in Hangzhou (China). *Building and Environment, 145*, 166–176.
Lin, Y., & Kant, S. (2021). Using social media for citizen participation: Contexts, empowerment, and inclusion. *Sustainability, 13*(12), 6635.
Macpherson, L. (2017). 8 Years on, Amsterdam is still leading the way as a smart city. *TDS, 8*, 2017. https://towardsdatascience.com/8-years-on-amsterdam-is-still-leading-the-way-as-a-smart-city-79bd91c7ac13.
Mancebo, F. (2020). Smart city strategies: Time to involve people. Comparing Amsterdam, Barcelona and paris. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 13*(2), 133–152.
Mora, L., & Bolici, R. (2015). How to become a smart city: Learning from Amsterdam. In *International conference on smart and sustainable planning for cities and regions* (Vols. 251–66)Springer.
Municipal Bureau of Statistics, H. (2021). *Statistical yearbook of Hangzhou city (2021)*. Beijing: China Statistical Press.

Noori, N., Hoppe, T., & Martin de Jong. (2020). Classifying pathways for smart city development: Comparing design, governance and implementation in Amsterdam, Barcelona, Dubai, and Abu Dhabi. *Sustainability, 12*(10), 4030.

Pan, H., Geertman, S., Deal, B., Jiao, J., & Wang, B. (2022). Planning support for smart cities in the post-COVID era. *Journal of Urban Technology, 29*(2), 1–5. https://doi.org/10.1080/10630732.2022.2069938

Pan, H., Kwak, Y., & Deal, B. (2022). Participatory development of planning support systems to improve empowerment and localization. *Journal of Urban Technology*, 1–22.

Putra, Z., Dinar, W., & Gm van der Knaap, W. (2018). Urban innovation system and the role of an open web-based platform: The case of Amsterdam smart city. *Journal of Regional and City Planning, 29*(3), 234–249.

Rathore, M., Mazhar, Paul, A., Hong, W.-H., Seo, H. C., Awan, I., & Saeed, S. (2018). Exploiting IoT and big data analytics: Defining smart digital city using real-time urban data. *Sustainable Cities and Society, 40*, 600–610.

Repette, P., Sabatini-Marques, J., Tan, Y., Sell, D., & Costa, E. (2021). The evolution of city-as-a-platform: Smart urban development governance with collective knowledge-based platform urbanism. *Land, 10*(1), 33.

Rittel, H. W. J., & Webber, M. M. (1984). In N. Cross (Ed.), *Developments in design methodologyPlanning problems are wicked problems* (pp. 135–144). New York: John Wiley & Sons.

Sarker, M. N. I., Wu, M., & Hossin, M. A. (2018). Smart governance through bigdata: Digital transformation of public agencies. In *2018 international Conference on artificial Intelligence and big data (ICAIBD)* (Vols. 62–70)IEEE.

Schrammeijer, E. A., van Zanten, B. T., & Verburg, P. H. (2021). Whose park? Crowdsourcing citizen's urban green space preferences to inform needs-based management decisions. *Sustainable Cities and Society, 74*, Article 103249.

Shelton, T., & Clark, J. (2016). *Technocratic values and uneven development in the 'smart city*. '" Obtenido de sitio Web De Metropolitics.

Teddy-Ang, S., & Toh, A. (2020). AI Singapore: Empowering a smart nation. *Communications of the ACM, 63*(4), 60–63.

Tomor, Z., & Geertman, S. (2020). The influence of political context on smart governance initiatives in Glasgow, Utrecht and curitiba. In S. Geertman, & J. Stillwell (Eds.), *Handbook of planning support science. Edward elgar publishing* (pp. 238–256). Cheltenham: Edward Elgar.

Transport, I. (2018). NEWS artificial intelligence laboratory launched to improve transport in southeast Asia. *Intelligent Transport, 2018*. July 24 https://www.intelligenttransport.com/transport-news/70021/ai-laboratory-southeast-asia/.

Verrest, H., & Pfeffer, K. (2019). Elaborating the urbanism in smart urbanism: Distilling relevant dimensions for a comprehensive analysis of smart city approaches. *Information, Communication & Society, 22*(9), 1328–1342.

Vonk, G., & Arend Ligtenberg. (2010). Socio-technical PSS development to improve functionality and usability—sketch planning using a maptable. *Landscape and Urban Planning, 94*(3–4), 166–174.

Vonk, G., & Geertman, S. (2008a). Improving the adoption and use of planning support systems in practice. *Applied Spatial Analysis and Policy, 1*(3), 153–173.

Vonk, G., & Geertman, S. (2008b). Improving the adoption and use of planning support systems in practice. *Applied Spatial Analysis and Policy, 1*(3), 153–173.

Vonk, G., Geertman, S., & Paul, S. (2007a). A SWOT analysis of planning support systems. *Environment and Planning A, 39*(7), 1699–1714.

Vonk, G., Geertman, S., & Paul, S. (2007b). A SWOT analysis of planning support systems. *Environment and Planning A, 39*(7), 1699–1714.

Vonk, & Guido, A. (2006). *Improving planning support: The use of planning support systems for spatial planning*. Utrecht: KNAG/Netherlands Geographical Studies.

Wang, L., Chen, X., Xia, Y., Jiang, L., Ye, J., Hou, T., Wang, L., Zhang, Y., Li, M., & Li, Z. (2022). Operational data-driven intelligent modelling and visualization system for real-world, on-road vehicle emissions—a case study in Hangzhou city, China. *Sustainability, 14*(9), 5434.

Webster, C. W. R., & Charles, L. (2018). Smart governance: Opportunities for technologically-mediated citizen Co-production. *Information Polity, 23*(1), 95–110.

Winden, W.van, Oskam, I., Daniel van den Buuse, Schrama, W., & Egbert-Jan van Dijck. (2016). *Organising smart city projects: Lessons from Amsterdam*. Amsterdam: Hogeschool van Amsterdam.

Yu, E. (2020). *Singapore retains smart city lead with tech use in COVID-19 pandemic. 17* p. 2020). September https://www.zdnet.com/article/singapore-retains-smart-city-lead-with-tech-use-in-covid-19/.

Zhang, J., Hua, X.-S., Huang, J., Shen, X., Chen, J., Zhou, Q., Fu, Z., & Zhao, Y. (2019). City Brain: Practice of large-scale Artificial intelligence in the real world. *IET Smart Cities, 1*(1), 28–37.