Cite as: Dan Zhang, L.G. Pee, Shan L. Pan, Lili Cui (accepted in Sep 2021) Big data analytics, resource orchestration, and digital sustainability: A case study of smart city development, forthcoming in *Government Information Quarterly*.

Big Data Analytics, Resource Orchestration, and Digital Sustainability: A Case Study of Smart City Development

Abstract

Smart cities are expected to improve the efficiency and effectiveness of urban management, including public services, public security, and environmental protection, and to ultimately achieve Sustainable Development Goal (SDG) 11 for making cities inclusive, safe, resilient, and sustainable. Big data have been identified as a key enabler in the development of smart cities. However, our understanding of how different data sources should be managed and integrated remains limited. By analyzing data applications in the development of a sustainable smart city, this case study identified three phases of development, each requiring a different approach to orchestrating diverse data sources. A framework identifying the phases, data-related issues, data orchestration and its interaction with other resources, focal capabilities, and development approaches is developed. This study benefits both researchers and practitioners by making theoretical contributions and by offering practical insights in the fields of smart cities and big data.

Keywords: smart city, big data, digital sustainability, resource orchestration, socio-technical issues

1. Introduction

As the urban population surges, cities worldwide are increasingly challenged to improve their efficiency and effectiveness in managing urban issues such as public services, public security, transportation, natural resource utilization, environmental protection for sustainable development, and disaster management (Albino, Berardi, & Dangelico, 2015; Kuk & Janssen, 2011; Wang, Medaglia, & Zheng, 2018). These issues call for transformation in the existing pattern of city management (Liu & Zheng, 2018). The concept of "smart cities" responds to this need by focusing on innovative solutions for urban issues through the adoption of information and communication technologies (ICTs) (Chong, Habib, Evangelopoulos, & Park, 2018; Gil-Garcia, Pardo, & Nam, 2016).

Building on the capabilities of ICTs, smart cities not only aim to satisfy citizens' needs and demands at the local level but also to advance city development by facilitating service integration and citizen interactivity (Belanche-Gracia, Casaló-Ariño, & Pérez-Rueda, 2015; Nograšek & Vintar, 2014). Many cities and metropolises worldwide have embarked on smart city development, including Amsterdam (Capra, 2016; Zygiaris, 2013), Barcelona (Bakici, Almirall, & Wareham, 2013; Gascó-Hernandez, 2018), Milan (Gascó, Trivellato, & Cavenago, 2016), and Seoul (Lee, Hancock, & Hu, 2014). These smart cities harness ICTs for urban transformation, such as smartcards for public transportation and recreation (Belanche-Gracia et al., 2015) smart grids for energy management and sustainability (Albino et al., 2015; Giest, 2020), and artificial intelligence applications for public healthcare (Pee, Pan, & Cui, 2019). In the United States, California has undergone an ICT-driven transformation to improve traffic flow and upgrade aging water, sewer and electric infrastructure. The city also launched the "Smart Capital" project to enhance business, local government, and community through the use of Internet resources to reduce digital divide (Nam & Pardo, 2011; Pee, Kankanhalli, & On Show, 2010). Although the specified objective of different smart city initiatives varies (Kar, Ilavarasan, Gupta, Janssen, & Kothari, 2019), they share a common core of improving the living environment and the quality of life for citizens (Axelsson & Granath, 2018).

Big data have been identified as a key in the development of sustainable smart cities (Matheus, Janssen, & Maheshwari, 2020) by offering "the potential for cities to obtain valuable insights from a large amount of data through various sources" (Hashem, Chang, Anuar et al., 2016, p. 748). Effective utilization of data is expected to enhance public services (Al Nuaimi, Al Neyadi, Mohamed, & Al-Jaroodi, 2015), reduce costs of management, and optimize resource consumption (Batty, 2013). Nevertheless, our understanding of how different data sources should be managed and integrated to support the development of smart cities remains limited, as Hashem et al. (2016, p. 756) stated: "the vision of the smart city is to integrate such a large amount of data from multiple sources; data integration within the smart city is one of the important challenges to be addressed.” Managing data from different sources is more than a technical challenge of ensuring data quality – it also demands attention to socio-technical issues such as political power and privacy. For example, the privilege of access to data by different individuals or political groups in different powers or positions must be taken into consideration and addressed carefully (Al Nuaimi et al., 2015). Accordingly, the research question addressed in this study is: ***How can different data sources be orchestrated to facilitate the development of a smart city?***

To address this question, this case study analyzed data management in Wuhu, a prefecture-level city in China, with the resource orchestration perspective as the initial theoretical lens. Wuhu is one of the earliest smart cities in China and has since developed various data applications for e-government services, urban management, community development, and tourism. The variety of data utilized to make the city smarter makes it an exemplary case for understanding the management of different data sources. The theoretical lens of resource orchestration provides a useful conceptual basis for peering into the black box of various data applications to examine the different types of data involved as well as how they can be organized to create value (Cui, Pan, Newell, & Cui, 2017; Sirmon, Hitt, Ireland, & Gilbert, 2011).

The paper is structured as follows: The next section provides an overview of the conceptual background. This is followed by an explanation of the research design, including case selection, data collection, and data analysis approach (Section 3). Section 4 details the case in terms of the three phases of development, while Section 5 identifies the data orchestration processes. Section 6 discusses the contributions for research and practice, and Section 7 concludes the study.

2. Conceptual Background

Given the research question, we focus on reviewing the conceptual foundation of smart cities, research on big data for smart city development, and the theoretical perspective of resource orchestration.

2.1. Smart cities

Researchers have defined smart cities differently, and they offer insight into the key components and functions of smart cities. Caragliu, Del Bo, and Nijkamp (2011) argue that a city is smart “when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of nature resources through participatory governance”

(p. 70). Gascó-Hernandez (2018) consider smart cities an umbrella term for how ICT can help improve the efficiency of a city's operations and its citizens' quality of life while also promoting the local economy. Wu and Chen (2021) contend that a smart city not only includes the application of ICT to its infrastructure but also has the capacity to integrate people, information, and technology in building an efficient, sustainable, and resilient infrastructure that provides high-quality services and promotes the quality of life of its citizens. Johnson, Robinson, and Philpot (2020) summarize that the smart city is "a contested term with dozens of definitions and visions of city as a technology-driven optimized system, sustainable organism, site of equitable citizen engagement, platform for corporate control, and even a possible future of democracy" (p. 1). Thus, the concept of smart cities has been applied to describe a variety of cities, as Gil-Garcia, Zhang, and Puron-Cid (2016) argued that "every city could attain a different level of smartness within a range, rather than falling in black and white categories of smart or not" (p. 524).

Conceptual frameworks have also been developed to characterize smart cities. For instance, Meijer and Bolívar (2016) identified the following three major focuses of smart cities based on a literature review: (1) smart cities with a technological focus (referring to cities that adopt smart technologies); (2) smart cities with a human resource focus (referring to cities with smart people); and (3) smart cities with a governance focus (referring to cities that emphasize smart collaboration). Giffinger, Fertner, Kramar, and Meijers (2007) considered the smart city to be a city that performs well in a forward-looking way in some possible dimensions, such as the economy, people, governance, mobility, the environment, and living. Chourabi, Nam, Walker et al. (2012) proposed an integrative framework to conceptualize smart cities that contains the eight dimensions of management and organization, technology, governance, the policy context, people communities, the economy, built infrastructure, and the natural environment.

One major value of smart cities is in tackling the constantly emerging urban problems that normal cities cannot handle (Albino et al., 2015). Researchers have argued that smart cities can initiate, foster, and enable innovation, which provides solutions to city issues and satisfies citizens' growing needs (Bakici et al., 2013). A city that undergoes smart city development can be regarded as a laboratory that enacts innovative approaches to improve city management (Sanchez, Muñoz, Galache et al., 2014; Zygiaris, 2013). As a result, a smart city can enable effective monitoring, understanding, analyzing, and planning to improve the efficiency, equity, and quality of life of its citizens (Batty, Axhausen, Giannotti et al., 2012).

Despite the widely acknowledged importance and potential value of smart cities (Albino et al., 2015; Neirotti, De Marco, Cagliano, Mangano, & Scorrano, 2014), only a limited number of cities have achieved their goal of successful development (Bakici et al., 2013; Paroutis, Bennett, & Heracleous, 2014). Unlike a business, a city is characterized by a huge population of citizens, complex systems, and sophisticated management processes, which make development difficult and risky (Bach & Loibl, 2016; Desouza & Flanery, 2013). Furthermore, city development involves numerous concerns, such as the selection and utilization of resources, multi-stakeholder cooperation, and the creation of urban innovation (Dameri & Rosenthal, 2014; Medaglia & Zheng, 2017; Schaffers, Komninos, Pallot et al., 2011). Thus, it is important to carefully decide the proper development approaches in an effective and secure way.

2.2. Big data for sustainable smart city development

An essential component of smart cities is ICT. Smart cities rely on a combination of ICTs that provide real-time awareness of the practical world and advanced analytics to inform decisions about alternatives and actions that will optimize processes and maximize performance dynamically (Chourabi et al., 2012). The development and management of smart cities involve instrumentation, interconnectedness, and intelligence (Harrison, Eckman, Hamilton et al., 2010). Instrumentation enables the capture and integration of real-time, real-world data through the use of sensors, meters, personal devices, cameras, the Internet, and other similar data-acquisition mechanisms. The data should be interconnected to generate information that can support intelligent decision making.

Much of the smart city data can be characterized as big data, which refers to enormous datasets that require more powerful tools and approaches for acquisition, storage, management and analysis (Wixom, Ariyachandra, Douglas et al., 2014). The main characteristics of big data involve five “Vs” (Al Nuaimi et al., 2015): volume (referring to the size of data), velocity (referring to the speed at which data are generated), variety (referring to the different types of data), variability (referring to how the structure and meaning of data constantly changes), and value (referring to the possible advantage that big data can offer).

Key applications of big data in smart cities include improving public services (Allen, Tamindael, Bickerton, & Cho, 2020; Desouza & Jacob, 2017), observing weather (Kitchin, 2014), optimizing transportation (Matheus et al., 2020), informing pollution management (Zhang, Pan, Yu, & Liu, 2019), and promoting public safety (Díaz-Díaz, Muñoz, & Pérez-González, 2017). Real-time big data support timely and accurate assessments of urban situations (Kitchin, 2014). Furthermore, big data enable a city to gain innovative and valuable insights from a considerable amount of data acquired from diverse sources, which assist decision processes, promote sustainable development, and provide novel services to improve citizens’ quality of life (Hashem et al., 2016).

Despite the promises, the success of big data applications in smart cities is critically affected by socio-technical issues, especially political power and privacy concerns. As part of policy implementation, a smart city is not neutral but needs to be understood as an effort that could influence perceptions, build alliances, and exert power, thereby intervening in political dynamics (Meijer, 2018). Other than realizing policy objectives, smart cities have the capacity to change the game. In the public domain, data can be ambiguous, interpretive, incomplete and strategically manipulated (Stone, 2012). From this political perspective, data are not a neutral resource, as data engineers see it, but a political resource. Accessing and controlling over data may determine who is able to influence decisions and the agenda. At the same time, open data can enable disadvantaged groups and strengthen their political position. The management challenge is to guarantee checks and balances in access to data to ensure a balance of power between the various groups (Meijer, 2018).

It is also necessary to acknowledge people's concerns about their privacy in the development of smart cities (Van Zoonen, 2016). Left unaddressed, people are unlikely to support and participate in smart city initiatives continuously. For example, the Toronto smart city project in Canada was abruptly abandoned in May 2020. The project, described as “the world’s first neighborhood built from the Internet up”, raised many privacy concerns among the community with regard to the mass collection of data and management of the city by a private company. The working proposals and subsequent roundtables failed to adequately address privacy concerns (Mulholland, 2019). Despite initial support from the community and high-profile backing from public officials and prominent figures, the project was eventually dogged by fears of data harvesting, privacy risks, and an overall lack of transparency.

As a critical resource in the development of smart cities, big data – data from diverse sources in different formats – is challenging to acquire, integrate, and manage (Anthopoulos, Janssen, & Weerakkody, 2016; Hashem et al., 2016; Meijer & Thaens, 2018). The interactions between data and various other elements need to be understood to promote the success and sustainability of smart cities (Foster, Mcleod, Nolin, & Greifeneder, 2018). Nevertheless, there is still a limited understanding of how to effectively and efficiently use big data from different sources for smart city development (Al Nuaimi et al., 2015; Lim, Kim, & Maglio, 2018). This study seeks to address this gap by examining the orchestration of big data in Wuhu.

2.3. Resource orchestration perspective

The resource orchestration perspective adopted in this study is based on the premise that organizations are formed with a collection of resources that determines their performance (Sirmon et al., 2011). The resource orchestration perspective seeks to improve the traditional view of resources, which tends to be static and overlooks the influence of the environment

(Cui & Pan, 2015). Resource orchestration recognizes the ability of an organization to achieve good performance by continuously reconfiguring diverse resources according to environmental changes. Furthermore, as some studies have argued, the actions taken to use the resources rather than the resources themselves influence performance (Chan, Hackney, Pan, & Chou, 2011; Ndofor, Sirmon, & He, 2011). The resource orchestration perspective advanced this by supplementing the traditional view of resources with resource management actions (Sirmon et al., 2011).

Responding to the general call by Sirmon et al. (2011) to conduct more empirical research on orchestrating resources, studies have focused on investigating resource orchestration to affect organizational performance or to gain competitive advantages in different contexts (Baert, Meuleman, Debruyne, & Wright, 2016; Carnes, Chirico, Hitt, Huh, & Pisano, 2017; Pan, Cui, & Qian, 2020). For instance, Cui and Pan (2015) generated a process model to explicate how resources are orchestrated in successful adoptions of e-commerce by manufacturers. Symeonidou and Nicolaou (2018) examined the effects of resource orchestration in start-ups by investigating its key contingencies. Cui et al. (2017) conducted a study on e-commerce development in rural China and found that both individual and community capabilities for e-commerce development were created through the orchestration of the resources of product knowledge and technology platforms.

This study focuses on the process of using big data for smart city development. The resource orchestration perspective is appropriate and valuable for the study because the key to making better decisions and implementing smart city initiatives lies in understanding how data can be effectively utilized in this context (Al Nuaimi et al., 2015; Hashem et al., 2016). In previous literature, there is relatively limited knowledge on the development approach in relation to using big data to achieve smart city initiatives (Kar et al., 2019). Moreover, although big data have been acknowledged as one of the core resources in smart cities, it has been argued that this kind of resource alone is unlikely to influence performance (Ross, Beath, & Quaadgras, 2013). To achieve specific objectives, an organization needs to orchestrate big data to build corresponding capabilities, thereby realizing desired outcomes. This is also in line with the framework of the resource orchestration process proposed by Sirmon et al. (2011).

Guided by the research objective of understanding how different data sources can be managed to facilitate the development of a smart city, this study applies the resource orchestration perspective as the initial theoretical lens to analyze the case of Wuhu. Specifically, according to the resource orchestration perspective, we identified the data resources and other related resources. We also examined how they were interrelated to generate capabilities and value in the development of the smart city. Furthermore, we build on the resource orchestration perspective and the case findings to develop a conceptual framework of big data orchestration in the development of smart cities (see Section 5).

3. Research Design

To address the research question, we conducted a case study of Wuhu, a smart city in China. The case study method is particularly suitable for this study for several reasons. First, we attempt to answer a "how" question, and the case study method is appropriate for addressing such questions (Pan & Tan, 2011). Second, this study focuses on the process of sustainable smart city development, and the case study method is especially useful for tracing how a situation and events evolve and develop (Gummesson, 2000). Third, the case study method allows us to identify novel insights in context (Walsham, 2006), which is expected to enrich knowledge and deepen the current understanding of smart cities. The case selection, data collection, and data analysis are detailed in the following sections.

3.1. Case selection

In case study research, a case is selected either because it is critical, unique, revelatory, or exemplary in offering an appropriate context for addressing the research questions (Yin, 2003). We selected Wuhu in this study for two reasons. First, Wuhu began its transformation in 2011 and is one of the first smart cities in China as well as the world. The rich history of Wuhu's development provides a wealth of experience for other governments seeking to build sustainable smart cities and allows us to understand how earlier decisions affected key outcomes later (Zhu, Li, & Feng, 2019). Second, Wuhu has developed a wide variety of big data applications, including e-government services, urban management, environmental conservation, healthcare, transport and logistics, public safety, community development, and tourism. The variety of data utilized to make the city smarter and more sustainable makes it an exemplary case for understanding the management of different data sources as well as related socio-technical issues such as political power and privacy concerns.

3.2. Data collection

The data for this study were collected in two steps from both primary and secondary sources (Silverman, 2011). In the first step, we obtained research access in September 2017. To prepare for the collection of interviews, secondary sources, including newspapers, magazines, television, and the Internet, were searched. We retrieved news reports and articles related to smart cities, Wuhu City and its government, and the technology provider iFlyTek Company, Limited (iFlyTek). These materials provided background information in the case of Wuhu, such as information on existing issues, big data applications, data management, the technologies adopted, the achievements made, and the timing of the development process. Additionally, we collected information on both Wuhu City and iFlyTek from their official websites, such as information regarding the city's development goals and planning, functional departments of the city's government, and announcements on the collaboration between the city and iFlyTek.

In the second step, we collected data on site in Wuhu. We interviewed 32 informants from different sectors and organizations, including government departments, local communities (Xingchen), citizens, and the technology provider (iFlyTek). The list of interviewees and their roles in the smart city are shown in Table 1. Interviews were semi-structured, aiming to explore the detailed process of smart city development based on big data from different stakeholders' perspectives. The set of preliminary questions used in the interviews is shown in Table 2. Follow-up questions were asked based on responses provided to gather details as necessary. Each interview lasted 60 to 90 minutes, and they were voice recorded and transcribed. We also took field notes in the form of written text, photographs, and short videos, as government representatives demonstrated key data applications in the development. The transcripts, field notes, photographs, short videos, and secondary sources allowed for the triangulation of data for analysis and substantiated our findings (Klein & Myers, 1999).

Table 1. List of interviewees

Organization	Organization Introduction	Role	Number
Wuhu's government	*Wuhu's government* played the most significant role in Wuhu's smart city development by initiating, executing, and optimizing the development process. The heads of staff and staff members in five departments related to this study were interviewed. *The Governmental Administration Office* is mainly responsible for city planning, policy making, and leading and coordinating other departments. *The Informatization Department* focuses on the tasks/projects required to implement information technologies in the activity of various levels of authorities. *The Big Data Center* is a separate governmental department specifically in charge of collecting, storing, processing, and using data for the city's operation and development. *The City Management Department* is responsible for the daily operation and safety of the city. *The Public Service Center* is a department open to the public that provides public services to the citizens and residents of Wuhu City.	Head of the Governmental Administration Office	1
		Staff member of the Governmental Administration Office	2
		Chief engineer of the Informatization Department	1
		Staff member of the Informatization Department	2
		Head of the Big Data Center (BDC)	1
		Staff member of the BDC	2
		Staff member of the City Management Department	2
		Head of the Public Service Center	1
		Staff member of the Public Service Center	3
Xingchen community in Wuhu	The Xingchen community in Wuhu is a recognized smart community that is famous for providing convenient and safe living for residents.	Head of the neighborhood committee	1
		Staff member of the neighborhood committee	2
		Residents in the community	3
Not applicable (Wuhu's citizens)	Wuhu's citizens are the participants and the beneficiaries of smart city development; they also use some of the products and services generated during the development process.	Wuhu citizens	5
iFlyTek (technology provider)	iFlyTek is the technology provider for Wuhu's smart city development. Two related departments of the company were involved in the interviews of this study. *iFlyTek's government collaboration department* is responsible for the process of big data and the design and implementation of systems based on big data. Engineers from *the R&D department* focus on designing and developing related products, such as government robots and citizen-oriented apps.	Head of iFlyTek's government collaboration department	1
		Staff member of iFlyTek's government collaboration department	3
		Engineer of iFlyTek's R&D department	2
Total			32

Table 2. Sample interview guide

Organization	Role	General questions
Wuhu's government	Head of the Governmental Administration Office Staff member of the Governmental Administration Office	- Why did Wuhu begin its smart city development? - What projects/actions have been undertaken to promote the development? - What resources, especially big data resources, have been involved in each action/project? - How does the government manage the use of big data resources and other resources for the development? - Have the actions/projects changed the city's ways of operating and its government's function? If so, how? - What has the smart city development in Wuhu achieved? - How does the government manage the cooperation between internal governmental departments and external organizations regarding the development? - What difficulties/challenges were encountered during the development and what has been done to address them? …
	Chief engineer of the Informatization Department Staff member of the Informatization Department Head of the Big Data Center (BDC) Staff member of the BDC	- What are the department's/center's role and responsibilities in smart city development? - What data have been adopted in the development? - How does the department/center manage the use of these data for the development? Have any other resources been involved in this process? If so, how? - What data-related services/products were launched for the development? How were they developed? Have they changed any aspects of the city for the development? If so, how? - How does the department/center cooperate with other internal departments and external organizations, such as IT companies? - Has the department/center attempted to address any difficulties or challenges in the development process? If so, how? …
	Staff member of the City Management Department Head of the Public Service Center Staff member of the Public Service Center	- What new data-based systems/applications have been adopted in city management/public-service delivery for the smart city development? - How do you work with these new systems/applications? - Have these systems/applications changed the way you work? Have the systems/applications changed any aspect of the city? If so, how? - Do you find these systems/applications useful? Why/why not? - What are your suggestions for the improvement of the current data-based systems/applications? Why? - Have any other resources been involved in the development process? If so, how? - How does the department manage and coordinate data resources and other resources needed for the promotion of the smart city?

Organization	Role	General questions
		- What difficulties/challenges were encountered by the department during the development and what has been done to address them? …
Xingchen community in Wuhu	Head of the neighborhood committee Staff member of the neighborhood committee Residents in the community	- What data-based applications related to smart city development have been used in the community? - How do you work with/use these applications? - Have the applications changed the way in which you work/live in the community? - Do you find the applications useful? Why/why not? - What difficulties/challenges were encountered when you used the applications and what has been done to address them? …
Not applicable (Wuhu's citizens)	Wuhu's citizens	- Have you ever used any data-based services/systems/apps related to smart city development? - What did you use the services/systems/apps for? Did you find them useful? Why/why not? - Have you ever participated in any action related to the development? If so, how? - Can you describe some differences between living in Wuhu before and after the smart city development? …
iFlyTek (technology provider)	Head of iFlyTek's government collaboration department Staff member of iFlyTek's government collaboration department Engineer of iFlyTek's R&D department	- What data-based technologies/systems/apps were involved in Wuhu's smart city development? How did they support the development? - How have those technologies/systems/apps changed the city and citizens' lives? - How does iFlyTek cooperate with Wuhu's government? - What big data and other resources are needed for the cooperation between iFlyTek and Wuhu's government? - What innovative data-based products/services have been generated based on this cooperation and what has been done to generate them? - What difficulties/challenges were encountered during the cooperation regarding the development and what has been done to address them? …

3.3. Data analysis

Data analysis was conducted concurrently with data collection to constantly improve the fit between data, existing theories and literature (e.g., resource orchestration), and the proposed framework addressing our research question (Eisenhardt & Graebner, 2007). To understand the development of the smart city, we first organized the data temporally to identify key phases. The data were then analyzed from the resource orchestration perspective (Sirmon et al., 2011) using an abductive approach (Timmermans & Tavory, 2012) to identify relevant data-related resources and capabilities. Specifically, we performed data analysis in three stages. In the first stage, we coded both the interview transcripts and the secondary sources to generate first-order concepts related to data management and applications. In the second stage, we clustered the first-order concepts into second-order themes based on their conceptual similarity. For example, first-order concepts related to data-focused actions were condensed into three second-order themes of "data sourcing", "data processing", and "data utilizing" (see Appendix A). In the third stage, the second-order themes were aggregated further into conceptual dimensions. These dimensions serve as the building blocks of the process model addressing the research question.

An iterative approach was used in the analysis. The first author identified the initial set of conceptual dimensions through categorization. The others played the role of devil's advocates by questioning the analyses and purposively looking for counterevidence (e.g., the themes identified were not as comprehensive as inferred). This prompted discussions that led to refinements and better agreement among data, analyses, and results. This constant comparative method helped to ensure that the themes were not based on instances related by a nonrepresentative informant or nonrepresentative events described by a representative informant. Interactions continued until theoretical saturation was reached (Pan & Tan, 2011).

4. Case Analysis – Phases of Development

The idea of sustainable smart city development in Wuhu was initially conceived by the local government in 2011. A citizen-centric objective was identified, as the head of the Governmental Administration Office stated:

> *"We aimed to make the city smarter to provide a more convenient, sustainable, safer, and happier life for citizens. We wanted to increase their sense of happiness, sense of security and sense of commitment in the city."*

The local government identified two major obstacles to achieving this objective. One was the low efficiency of public-service delivery; the other obstacle was the generally slow response to crimes and emergencies. These were approached in three phases, as discussed next.

4.1. Phase One: Developing a unified public-service system for citizen convenience and sustainability (2011-2014)

Before smart city development began in Wuhu, the existing public services were uncoordinated and complicated, resulting in low citizen satisfaction in government efficiency. A Wuhu citizen described an example of the issue:

> *"At that time, when I applied for a settling-in allowance as an overseas returnee, I went to several governmental departments at different sites for different certificates required for the application. For instance, the application materials include a certificate of resident status from the Police Department, a certificate of employment status from the Department of Human Resources and Social Security, a certificate of overseas academic qualification from the Education Department, and a certificate of personal property information from the Department of House Property. To obtain each certificate, I had to prepare different certification materials, go to the designated place, and fill out some forms. The whole tedious process made me feel frustrated then and took almost two months for the final approval."*

To tackle these efficiency issues and make the city smarter, the Wuhu government realized the need to simplify public services and make them more accessible for the convenience of citizens. Through a deep analysis of the situation, the government found that the redundancy and complexity of public-service delivery was caused by data silos, which resided in isolated information systems operated by different governmental departments. Thus, to simplify and unify the application and approval process, it was urgent and vital to break down data silos by connecting departmental data and accordingly establishing a unified system based on the integrated data to collectively provide public services. The head of the Governmental Administration Office recalled the process of completing this task:

> *"It was harder than expected to break down data silos. As each department had huge volumes of data in diverse forms from various sources, it was impossible to simply put all the departmental data together and use them as the input of the unified (information) system. The actual process was complex and progressive, like wading across a stream by feeling the way."*

To proceed with the task, cataloging the existing public-service processes was the first step taken to identify the data involved. As a result, 398 types of services were identified, covering 54 departments made up of 218 governmental entities, including the police, civil administration, industrial and commercial departments, health departments, etc. The big data identified in this phase consist of a variety of structured administrative data as well as real-time (velocity) and real-world data (variability) collected at regular intervals (thus voluminous) by sensors located throughout the city (veracity), such as energy meters and air quality monitors. Big data were used to manage environmental pollution and conserve natural resources as part of the city's digital sustainability efforts. To facilitate the data collection and data process, a new department—the Big Data Center (BDC)—was established by the Wuhu government. However, the BDC encountered problems, as the departments were reluctant to share data given the uncertainty in how it would affect their power. The head of the BDC described the difficulties:

> *"The task was stuck at the very beginning, as no department handed in its data to us. Through further communication with department heads, some expressed their concerns on the security of data sharing and the possible changes in their operation processes."*

To address the problem, the city governors held several internal meetings with the department heads to emphasize the significance and necessity of gathering departmental data. The chief engineer of the Informatization Department stated that

> *"In the meetings, we were told that if the department heads would not hand in the data to the BDC, they may need to hand in their resignations to the government instead."*

At the same time, the staff members of the BDC went to other departments several times for further communication. They used their information technology (IT) knowledge to explain to department heads the expected benefits of linking data on the operation and management of their departments. As a result, under pressure from the city governors and attracted by the proposed outcomes, departments gradually started to provide their data to the BDC.

As the data were collected from a variety of sources in different forms, the next step was cleaning, filtering and consequently standardizing the data. To achieve this goal, iFlyTek, a leading IT company that provides professional solutions for city governments in China, was selected to offer technical support to process the data. Afterwards, all the collected data were aggregated into 1,011 major categories and stored and updated in an integrated database; these categories could be further divided into 17 subject sub-databases, such as demographic, corporation, and housing sub-databases.

Supported by the integrated database, a unified information system that comprised all public services was developed in 2013 based on the cooperation between the BDC and iFlyTek. The system was piloted in the Jinghu District of Wuhu. In the testing process, some run-time errors and problems were detected, and the integrated data were further adapted to ensure the smooth operation of the system. After the test and adaptation, the unified system was formally launched in Wuhu. With the help of a system based on integrated data, all the relevant governmental departments, although located at different physical sites, can work collectively to deliver public services. As a result, the previously tedious service procedures were maximally simplified into "one-stop" services that citizens can apply for with personal ID cards at a citizen service center. Furthermore, some derivative citizen-oriented applications were also developed. As one Wuhu citizen stated,

> *"An official (citizen-oriented) service website, Yihu, and a smartphone application, City Link, were launched for us. I can use them to view and modify my personal information, apply for some public services, and track corresponding processes online. For me, it's very hard to imagine such a convenient life before."*

In addition to mastering the personal application for public services online, Wuhu citizens can use the app of City Link to pay for electricity, water, and gas, as their energy consumption data are sent to the unified system in real time. They can also receive the daily air quality index of the city and obtain early warnings of air pollution. Moreover, based on the integrated data and unified system, City Link covers many additional functions, including real-time inquiry on public transportation, online registration for hospital appointment and primary education, personalized recommendation for leisure activities and charity activities in their communities.

4.2. Phase Two: Embedding a new approach to citizen safety and participation (2014-2016)

In the first phase, the integrated data were manually and periodically updated through the data access interface by the governmental departments (e.g., the police, civil administration), while sensor data (e.g., the data from smart meters and air quality monitors) were automatically and dynamically updated. However, to improve responses to crimes and emergencies, real-time, situational data about public spaces are necessary. Therefore, the Wuhu government installed video cameras in public places and implemented a local administration system with local people as sensors.

Video cameras were installed in public spaces, such as the main streets, parks, and local attractions. The cameras capture visual images that are analyzed with artificial intelligence (AI) in real time to identify potential public security threats and manage the crowd. A staff member of the BDC provided some examples:

"The camera images allow us to manage the visitor crowd in public parks and local attractions in real time. Especially during public holidays and festivals, it helps to provide early warning on crowding and facilitate prompt response to overcrowding.

…the (camera) images on main streets are used to manage the traffic through a self-adaptive traffic signal control system. This has significantly improved traffic management efficiency. The system also improved road and pedestrian safety by identifying dangerous driving.

… we also installed cameras in industry parks to detect illegal emissions of air pollutants."

The head of BDC highlighted privacy protection as the most significant concern in the design of the camera system:

"The local government developed a set of guidelines and regulations around planning, development, maintenance, application, and legal responsibility (of the camera system)… For example, it requires that cameras are only installed at designated public places with specific angles to collect images of public spaces."

A local administration system involving citizen participation was also developed. The city was organized into geographical grids, and each had a local administrator. Responsible for gathering data from local residents about demographic changes, financial needs, social concerns, community development, and various problems encountered in daily living, local administrators update data frequently and regularly. The data were used to identify emerging local needs and demands.

To process the data from diverse sources, Wuhu's government collaborated with iFlyTek to develop efficient algorithms. For example, an algorithm was developed to automatically identify discrepancies related to data divergence, data exceptions, or unusual changes in sensor data. The algorithm played a critical role in ensuring data quality and early detection of criminal behavior, as a staff member from the City Management Department illustrated:

"When a sudden rise in the water and electricity usage in one apartment was automatically detected from the real-time energy consumption data measured by smart meters, a task was then created and sent to the local administrator. He visited the apartment and observed that many people were gathered there working on illegal pyramid sales. He reported the situation to the police, and the criminals were all arrested in a timely manner."

The local administration approach to gathering data also improved emergency responses and decision making. A staff member of the Governmental Administration Office stated such an example:

> *"During a fire rescue process, the city's Emergency Management Office immediately retrieved the data on all residents from the database and verified them with the administrative data to confirm the number of residents in the burning building. Accurate information with other important data, such as on buildings, firefighting facilities, the surrounding environment, and transportation, provided a scientific basis for on-site rescue and post-disaster assistance…It helped the government make quick decisions and responses. Finally, there was no casualty in the fire…Moreover, it ensured that sufficient relief goods were immediately distributed to the victims to stabilize their emotions. The day after the disaster, based on the data, victims were able to obtain temporary identity cards through the green channel opened by the government."*

Some citizens were concerned about the security and privacy risks of the local administration system. To address these concerns, the city government took steps to ensure data security. As the chief engineer of the Informatization Department explained:

> *"We regard data security as the key to the success or failure of the entire system. For this reason, the system adheres to the principle of 'conducting hierarchical management to ensure security', with data hierarchy, management hierarchy and access authority control in the city, its counties, towns, streets, communities, and grids, respectively."*

To ensure data privacy, the city government has established measures at the network, system and data levels and protected personal privacy through strict technical design. For instance, all local administrators must adopt role-based CA (Certification Authority) authentication when updating the database. This ensures that local administrators, community workers, county administrators and other users can only access the data within their own local area. Furthermore, the government has developed security and confidentiality rules and regulations that all users must adhere to. Users are also required to undergo regular security and privacy training. Citizens are informed of the data collection and protection policy as well as the relevant concrete measures via the website of the government information openness and the offline campaigns enabling direct communication between the citizens and the governmental staff.

Other than local administrators, citizens also act as "sensors", providing data about issues of personal interests. For example, since 2015, citizens have been invited to report issues related to public facilities or public cleanliness using the city's app, City Link. They can also follow up on their reports by checking the progress of resolution. The head of a neighborhood committee used an example to explain this process:

> *"When reports of clogged drains were received from citizens through the City Link App, the system notified the local administrator in charge… The local administrator confirmed that some drainage pipes needed replacement and communicated with the residents, the residential property office, the City Construction Department, the Environmental Protection Department, and the Traffic Management Department to schedule the repair work and plan the rerouting of traffic…Eventually, when the repair was completed, an app notification was automatically sent to citizens who submitted the reports. They were invited to rate and comment on the efficiency and effectiveness of the government response."*

4.3. Phase Three: Introducing advanced applications for city innovation (2016 to the present)

With citizens' support and trust, the Wuhu government built on the experiences of implementing data applications in phase two to identify other innovation opportunities for making the city smarter. First, it was noted that the delay between a fault report involving street lighting or fire hydrants and on-site repair should be minimized. Leveraging the Internet of Things technology, the Wuhu government fitted them with smart components that would report errors and alert the relevant maintenance unit automatically. This enabled the timely dispatch of repair personnel and faster location of the faulty unit.

Second, to understand citizen needs, the government set up official social media accounts to provide a more convenient and direct communication channel for citizens to voice their concerns. The text data are analyzed to inform policy decisions. A staff member from Wuhu's Governmental Administration Office explained:

> *"We opened official accounts under the Wuhu government on social network sites, such as Weibo and WeChat…We are now able to communicate with our citizens directly and understand their concerns and what they actually need from the city government."*

Third, to offer more convenient yet secured payment options, the Wuhu government also experimented with blockchain technology. By combining blockchain technology with financial big data, a cross-border financial service platform that supports a privacy-preserving trade financing process was developed and launched in late 2019.

In addition, to enhance computing power for the growing big data, a cloud computing center was launched by the government in late 2016. The head of the BDC described the impacts of establishing this center:

> *"It provides more independent, secure, controllable, and efficient data storage and data processing for the operation of the relevant systems and platforms."*

At the same time, a Big Data Research Center (BDRC) was launched that collaborated with the leading IT technology companies and high-level universities in China. The BDRC aimed to assist the government in further developing a smart, cooperative, and innovative "city brain", which helps to ensure that public resources are reasonably allocated based on urgency and priority. The chief engineer of the Informatization Department in Wuhu introduced the main functions of the BDRC to achieve this goal:

> *"First, the research center is devoted to improving the quality of existing data and exploring data that have the potential to promote city development. Furthermore, the members of the center continued trying to do the innovation work, which they called 'data collision'. 'Data collision' here means to collide data from different sources in different fields, some of which are seemingly unrelated, to detect emerging issues in the city and discover novel solutions."*

Furthermore, cutting-edge technologies have also been used in Wuhu's smart city development to exploit and fully use the value of big data. An engineer of government-related products from iFlyTek explained,

> *"City governors emphasized the great potential of big data to make the city smarter and believed that introducing more advanced technologies would help to maximally excavate the potential. Thus, in cooperating with the government, we have tried to utilize AI in city management. The big data with machine learning algorithms are expected to support decision making and predict important patterns… We have also developed government robots for Wuhu, and in 2017, the government allocated them to the citizen services centers as receptionists to communicate with and assist citizens in handling their applications… In the same year, based on AI, we helped the government launch a smart education project and a smart healthcare project for balancing educational resources and healthcare resources within the city, aiming to pursue citizen equality in the future."*

Through constant trials with big data, Wuhu has grown from a third-tier city to one of the reference models of smart cities in China for other cities pursuing smart city development.

A Wuhu citizen commented on its development performance in achieving its original citizen-centric objective:

> *"As a citizen, I can see great changes that happened here due to its smart city development in these years. It made Wuhu more modernized, or in other words, more high-tech. The most important is that our lives have become much more convenient, and I feel safer and happier living in this city. This is actually what I imagined a smart city should be."*

5. Case Analysis – Big Data Orchestration

The three phases identified were further analyzed to identify data resources and how they were orchestrated for smart city development. The resource orchestration perspective suggests that the environment influences the orchestration of related resources, based on which capabilities are developed to achieve specific outcomes (Sirmon, Hitt, & Ireland, 2007; Sirmon et al., 2011).

Given our research question, a framework focusing on the orchestration of big data resources for the development of smart cities was developed (Figure 1). In the framework, ***data issues*** in city management motivate the orchestration of big data from different sources. Based on various data-focused actions, three types of ***data orchestration*** are identified, including *data sourcing*, *data processing*, and *data utilizing*. Furthermore, data orchestration and its ***interactions with other resources*** collectively lead to several ***focal capabilities*** for development. The conceptual framework details how big data from different sources are integrated in different phases of smart city development and is useful to smart cities in other countries attempting to use big data. The framework does not make assumptions about how data are collected and how a country is governed. Instead, it is organized around data issues commonly experienced in the development of smart cities, such as data silos and inconsistency. Therefore, the framework is applicable to other countries to the extent that they encounter similar data issues.

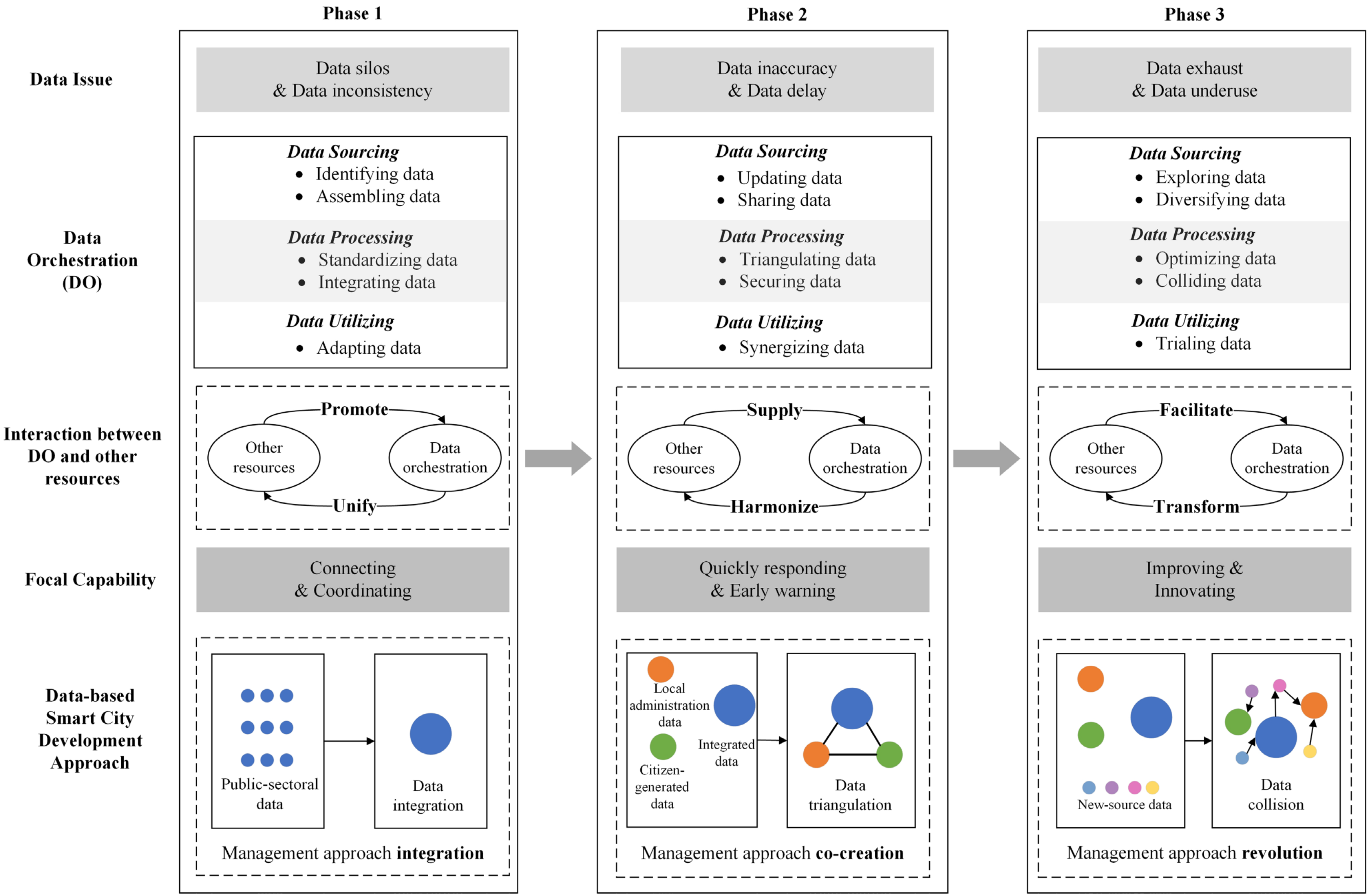

Figure 1. Big data orchestration in the development of smart cities

5.1. Data orchestration to address data issues

We observed that the obstacles to developing a smart city in Wuhu's case were all related to data management. In response, the Wuhu government orchestrated big data and related resources to address the issues. Specifically, we identified various data-focused actions leading to three types of data orchestration processes, namely, ***data sourcing***, ***data processing***, and ***data utilizing***.

In phase 1, at the beginning of the development, low-efficiency public services caused low citizen satisfaction, which impeded the achievement of the citizen-centric objective. The city issue was due to ***data silos*** and ***data inconsistency*** in separated departmental systems. As the head of the Governmental Administration Office stated:

> *"Different (governmental) departments had their own systems, which were not connected, and they stored the data in different forms based on their own standards. The resulting 'isolated data islands' hindered the departmental connection for providing better public services."*

To break down data silos and solve data inconsistency, in the process of ***data sourcing***, the data required for public services were first *identified* from each department by comprehensively sorting out the processes of public services, which were further *assembled* by the BDC. As the collected data were provided by different departments, they contained a variety of types with diverse forms. For ease of data management and use, in the process of ***data processing***, the data were first *standardized* through cleaning and filtering. Then, they were *integrated* into the database to support the operation of the unified public-service system. The head of the BDC highlighted the importance of this action in phase 1:

> *"The key to realizing the 'one-stop' public services is breaking down data silos for data integration. Thus, we can let the integrated data run more (for processing the public services), but let our citizens run less (for applying the public services)."*

Then, in the process of ***data utilizing***, the integrated data were iteratively *adapted* to the unified public-service system to ensure the smooth and sustainable running of the system.

In phase 2, although the integrated data included some types of real-time data from sensors (e.g., smart meters), the majority of them were relatively static, structured, and internal administrative data. The main data issues were related to ***data inaccuracy*** and ***data delay***. As the chief engineer of the Informatization Department explained:

> *"Some of the administrative data could not be updated in a timely manner, which makes it impossible to accurately reflect the current situation of city operation. Without*

such a sufficient understanding, it was passive for the city government to respond to the continuously emerging problems."

To address the data issues in this phase, in the process of ***data sourcing***, situational data about the city were *updated* and *shared* regularly through video cameras in public spaces, local administrators and citizens. In the process of ***data processing***, the data from multiple sources were *triangulated* to inform, verify, and improve the city government's understanding of current needs and demands. Data were also *secured* through technical and regulatory measures to protect citizens' privacy, build trust, and promote citizen participation. In the process of ***data utilizing***, relevant data were *synergized* with one another to detect and predict emerging risks and problems and to mobilize resources to address them in a timely manner.

In phase 3, the two main obstacles regarding public services and governmental responses were addressed based on big data accumulated in the preceding phases. The city government paid specific attention to maximizing the value of big data in promoting innovations for smart cities. It was found that the existing data issues became ***data exhaust*** caused by the accumulation of historical data and ***data underuse*** due to the lack of application. The city government recognized big data as a "pool of treasure" that can be explored for innovations.

To address these issues, in the process of ***data sourcing***, the data were *explored* using advanced technologies (e.g., Internet of Things (IoT), AI, and social media), leading to further *diversification* in the types and sources of data. A staff member of the BDC explained the reason for doing so:

"Acknowledging the great potential of big data, we wanted to build this 'pool of treasure' by adopting new technologies. We believed that richer data would promote innovations in improving citizens' lives."

In the process of ***data processing***, by establishing professional technical support organizations (i.e., the Could Computing Center) and research institutions (i.e., BDRC) on big data, the data were *optimized* and further *collided* to develop new products and services. The head of the BDC stated that:

"More adequate, diverse, high-quality data provide more opportunities to realize data value. Tentatively colliding cross-domain data is expected to find some distinctive ways for viewing, analyzing, and managing the city."

Thus, in the final process of ***data utilizing***, the optimized data with new technologies and the novel data-based products and services created through the collision were further *trialed* in diverse aspects of city development (e.g., city administration, public services, education, healthcare, and finance). All these efforts were made to achieve the citizen-centric objective, which is providing citizens a more convenient, sustainable, safer, and happier life.

Synthesizing the process of data orchestration in the three phases, the government encountered different data issues for different types of data and used different ways to address them. In phase 1, although some real-time sensor data were included, the majority of the data were static, structured, internal administrative data that had already been collected and stored in separate departmental databases. Accordingly, the main task was to make full use of the existing data in a unified way. The consistency of the data was emphasized, and thus, the focus was more concerned with the technologies and relevant designs to standardize and integrate the existing data to break down the data silos. In this phase, power and political concerns were the key causes of data silos and inconsistencies. A bottom-up approach was used to persuade the different departments to share data by highlighting the expected benefits. At the same time, a top-down approach was imposed on the different departments by clarifying the political consequences of uncooperativeness. As a result, sufficient (though limited) data were obtained for initial development, and the shared data gradually increased as the different departments experienced value added and weighed the risks accordingly. Different from the data in phase 1, the data in phase 2 were mainly focused on camera data and user-generated data from local administrators and citizens. Comparatively, the data were more fluid, unstructured, and included more external data. Thus, the accuracy and security of the data were emphasized. The task focus was more on designing a proper way to triangulate the data and providing a regulated approach for process management. In addition, there was a strong privacy concern that must be addressed to improve data accuracy and delay in this phase. Other than limiting the data gathered to those of utmost necessity, the government also took a socio-technical approach to manage the concern and build trust over time. Role-based access control was implemented, and regular security and privacy trainings were conducted for system administrators. For citizens, the nature of the data collected and approaches taken to protect them were communicated through websites and campaigns. These measures reduced the resistance encountered to the extent that the project moved forward unimpeded. In phase 3, the data involved were more diversified for innovations. The usefulness of the data was more highlighted, and thus, the task's focus was more on tentatively introducing advanced technology to trial novel data-based products and services to explore the data value.

5.2. Capability development through data orchestration and interactions with other resources

This study identifies the focal capability for smart city development in each phase. We found that the development of such capabilities is based on both data orchestration and its interaction with other resources. This finding not only highlights the significance of orchestrating data in development but also reveals the relationship between data orchestration and other resources. On the one hand, other resources support the achievement of data orchestration; on the other hand, data orchestration influences other resources to develop the focal capability in the three phases.

In phase 1, the focal capabilities were ***connecting capability*** and ***coordinating capability***, with which the previously separated governmental departments could be closely connected and effectively coordinated for delivering better public services. To develop the focal capability, the data orchestration correspondingly focused on integrating the separated data as the input of the unified public-service system. Other resources first ***promoted*** this process of data orchestration. Specifically, for data sourcing, knowledge resources from related governmental departments were deployed to analyze existing public-service procedures for identifying relevant data. Then, the leadership resources from city governors "push" the departments, while the knowledge resources from the BDC "pull" them to hand in the identified data for data assembling. For further data processing, the technological resources and knowledge resources from the cooperating IT company iFlyTek mainly standardized the data by cleaning and filtering them and integrated the data into the database for the unified system. Then, for data utilizing, the integrated data were adapted to the system by coordinating all the relevant sources, including the system, knowledge, and technological resources. In turn, the achieved data orchestration ***unified*** the key resources in this phase to create the connecting capability and coordinating capability for the development. As a staff member of the Governmental Administration Office explained:

> *"The integrated data enable the city government to combine the tedious (public-service) procedures, downsize redundant workload and manpower, and merge the originally separated systems into a unified one."*

In phase 2, when the public services had been dramatically improved based on data integration, the focal capability for smart city development became ***quickly responding*** and ***early warning*** to preempt and minimize risks and problems. A staff member of the City Management Department stated:

> *"Large amounts of governmental resources were occupied to address emerging city problems. The government was in a passive position, and we wanted to change this through increasing our proactiveness."*

To develop the focal capability, other resources first ***supplied*** data orchestration with either data sources or processing capability. For data sourcing, cameras, as an equipment resource, were installed in public spaces to collect real-time situational data. Human resources included local administrators and citizens participating in city management. For data processing, technological resources and knowledge resources offered support for triangulating multisource data and securing them for sustainable use. For data utilizing, system resources, technological resources and knowledge resources furnished the approaches for synergizing data for emergency detection and risk prediction. In turn, the data orchestration was an asset that ***harmonized*** other resources, which ultimately led to the focal capability of quick responding and early warning. The head of the Governmental Administration Office explained:

> *"With the help of* local administrators*, the resources that had been previously occupied by passively addressing problems could be reallocated. This means more resources could be used for the development…The local administrators were empowered to directly respond to certain issues, especially those reported by citizens. They could reconcile the stakeholders involved and coordinate related resources by gathering, verifying, and conveying the relevant information."*

In phase 3, as the main obstacles were addressed, the city government started bold attempts. The focal capability in this phase was the ***improving capability*** to make the city smarter and ***innovating capability*** to create more novel products and services. Thus, other resources first ***facilitated*** data orchestration. For data sourcing, technological and equipment resources (e.g., IoT, AI, and social media) helped the government explore more data and diversify them. Then, for data processing, R&D resources, technological resources, and knowledge resources assisted in optimizing and colliding data to develop innovations. For data utilizing, all possible resources (e.g., human resources, financial resources, leadership resources, system resources, technological resources, knowledge resources, infrastructure resources, policy resources, etc.) were coordinated for trialing the data, which is applying data-based products and services to various aspects of a city. Data orchestration, in turn, ***transformed*** the existing resources in the city to be more intelligent, valuable, and cooperative for collectively improving the city and creating innovations for smart city development.

Further synthesizing the process of capability development in the three phases, we found that smart city development requires not only data orchestration but also interactions with other resources as well as collaboration among stakeholders. Two types of collaboration are highlighted in the study. One is the collaboration between the government and the IT company that provides technical support. The difficulty of collaboration is due to the knowledge and organizational boundaries existing between them. The majority of the staff in governmental departments were not familiar with the concepts and uses of big data, algorithms and systems. The IT company also did not know much about the governmental terminology, policy, and working processes. Thus, to facilitate their collaboration, a boundary spanner was required. The BDC, established by the government, has played such an important role in the relationship as a "*concentrator*", a "*translator*", and a "*supervisor*". As a concentrator, the BDC is responsible for gathering and storing all the data from different departments of the government and then providing the database to the IT company to produce innovative products and services. As a translator, on the one hand, the BDC needs to explain technology-related issues to the staff members in the government. On the other hand, the BDC is also responsible for delivering knowledge of governmental policies and working procedures to the IT company. As a supervisor, the BDC needs to supervise the IT company's process of accessing and using governmental data to provide technical support to ensure data security. In summary, the BDC facilitates collaboration between the government and the IT company by managing data resources, promoting smooth communication, and enforcing security.

The other type of collaboration highlighted in the study is that between the government and citizens. During development, the role of citizens gradually changed from being passive evaluators to active participants. With a citizen-centric objective, the government addressed complaints from citizens related to public services. The unified system based on the integrated database allowed citizens to track the progress of the public services they requested, which not only enhanced government transparency but also empowered citizens to stay updated on the service processes. The introduction of the local administration system further extended this collaboration. On the one hand, citizens were encouraged to participate in city management by reporting issues (e.g., public facilities and public cleanliness), supervising and providing feedback to the issue solution. On the other hand, the local administrators, who have direct contact with citizens, were empowered to coordinate stakeholders and resources to meet citizen demands in a timely manner. The smooth functioning of this collaboration depends on prompt communication and the deployment of multiple resources based on appropriate data orchestration. Moreover, citizen participation is premised on the effective protection of privacy and data security, as the chief engineer of the Informatization Department called it "*the key to the success or failure of the entire system*".

5.3. Data-based smart city development approaches

By further synthesizing the outcomes of the process, three major approaches for realizing the data value for smart city development have been identified:

In phase 1, the existing *public-sectoral data* were originally separated in the departments that had seriously impeded the efficient delivery of public services. Through *data integration*, a unified information system was launched and smoothly operated to support public services. Thus, the data integration enabled the ***integration*** of prior management approaches in the city, which had been previously diverse and disconnected. Accordingly, the joined-up process of public services based on the integrated data and the unified system greatly simplified the application and approval procedures of public services to shorten processing time and increase citizens' satisfaction.

In phase 2, the local administration system was introduced, based on which more sources of data became available for updating the integrated data. Moreover, as citizen-provided data were shared, citizen participation was achieved. In this case, the *data acquired from the local administrators*, the *citizen-generated data*, and the already *integrated data* from governmental departments were triangulated with one another to form, verify, and modify the understanding of the real-time situation of the city, which aimed to quickly respond to and provide early warnings for city problems. Therefore, the ***co-creation*** *management approach* is enabled by *data triangulation*.

In phase 3, the value of big data was confirmed in the previous two phases and was highly emphasized by the government at the time. As a result, more big data from novel sources were obtained. To fully use the *existing data* and the *new-source data*, data-focused centers were established, which tentatively collided data to develop new products and services for city development. Through the application of the innovations to various aspects of the city, smart education, smart healthcare, and smart transformation enabled the city to be smarter. Thus, in this phase, *data collision* is a key enabler of the ***revolution*** management approach.

Analyzing the three phases has revealed that the value of big data for smart city development has been gradually accepted, realized, and accumulated over time. The achievements of the previous phase drive the planning and implementation of the subsequent phase. At the beginning, although the government acknowledged the potential of big data, it was still uncertain about the actual results caused by the data-based development. Thus, utilizing existing data in a novel way was relatively conservative and cost-effective. Until the integration of previous management approaches was achieved by data integration, the government witnessed the effects of data-based development and affirmed its feasibility and usability. The government then started a relatively bolder attempt in phase 2, which was to introduce a local administration system. For this attempt, the integrated data and system achieved in phase 1 were regarded as the foundation, based on which new-source data from local administrators and citizens were used as its supplement and extension. Thus, through the triangulation among these data, co-creation was achieved, which dramatically enhanced both the efficiency and the responsiveness of the government. As a result, the city has become a reference model for smart cities. The local government could release more resources that were occupied by emerging city issues and gain more support from the national government. Accordingly, in phase 3, large-scale investment was made in introducing advanced technologies and acquiring diversified data to create more innovations. Although the management approach revolution based on data collision made significant breakthroughs for the development, it was still based on the realization of data value (i.e., integration and co-creation) in previous phases.

6. Discussion

This study set out to address the research question: How can different data sources be orchestrated to facilitate the development of a smart city? Our analyses of the highly successful case of Wuhu's smart city development indicate three key phases, each requiring a different approach. In the first phase, the focus should be on addressing data silos and inconsistency when identifying useful data, which are likely to be collected from diverse sources and stored in different forms and locations. The key approach to managing data in this phase is integration, which involves the development of connecting and coordinating capabilities through data sourcing, processing, and utilizing and its interaction with other resources. The case indicates that a key socio-technical concern in this phase is the political power play affected by changes in the ownership and sharing of data across governmental departments.

In the second phase, the key focus becomes tackling data inaccuracy as citizens' lives evolve and the city develops, as well as minimizing the delay in data updates. Our case study indicates that co-creation involving local administrators and citizens is an effective approach to managing data. The approach emphasizes data-enabled quickly responding and early warning of risks and problems via data orchestration and its interaction with other resources. It is important to note that the success of developing these capabilities depends much on citizens' trust in the government with regard to data security and privacy. The case suggests that clear rules, regulations, and policies helped to instill confidence in citizens, while regular training of system administrators and users ensured the continuous effectiveness of security and privacy safeguards.

The third phase builds on the preceding phases to develop innovative data applications for a smarter city. The key data issues to address in this phase are to minimize data exhaust, such as the detailed traffic data not used for actual analysis, and identifying useful applications to extract value from underused data. We found that the revolution approach to sourcing, processing, and utilizing data helps to improve and innovate data use. In Wuhu, new insights about urban management emerged through data collision, leading to ground-breaking applications such as blockchain-based financial platforms and the "City Brain" that automates many daily urban operations. The involvement of technology providers in innovations is critical in this phase. In Wuhu's case, technology providers design the software, but the city owns the data to prevent commercial exploitation. The theoretical and practical contributions of these findings are discussed next.

6.1. Theoretical contributions

This study makes three significant theoretical contributions. First, for the body of research on how data can be managed in the development of smart cities to improve government resource management and services (Al Nuaimi et al., 2015; Allen et al., 2020; Ismagilova, Hughes, Dwivedi, & Raman, 2019; Lim et al., 2018), we have identified three phases of smart city development, delineated the focal capability to develop in each phase (e.g., connecting and coordinating, improving and innovating), and conceptualized the management approach needed (i.e., integration, co-creation, and revolution). Identifying the capabilities extends Chong et al. (2018)'s attempt to redefine a smart city with dynamic capabilities. The process framework can be used as a conceptual basis in future research seeking to design smart cities, compare smart cities, or understand the progress of a specific smart city development. As an empirical case study, the findings also offer rich insights into data issues (e.g., data silos) and how they can be overcome with different data orchestration processes. This adds to the findings of prior studies that indicate handling of imperfections in data represents the main challenge encountered by smart cities (e.g., Ben, 2017). Furthermore, the findings also reveal how data orchestration interacts with other resources (e.g., human resources, leadership resources, knowledge resources, policy resources) in the development of capabilities. The political power and privacy concerns arising from the socio-technical interactions identified in this study can be the focus of future research examining the critical aspects of smart city development. As suggested by Meijer and Thaens (2018), more studies taking the socio-technical perspective are needed.

Second, this study responds to the general call by Sirmon et al. (2011) for conducting more empirical studies on resource orchestration in different contexts by adopting it within the smart city context. Furthermore, this study extends the resource orchestration perspective by narrowing down its scope from all possible resources into big data resources. Accordingly, the specific processes of data orchestration are identified and categorized into data sourcing, data processing, and data utilizing processes. Each process contains its specific data-focused actions in three phases. Moreover, based on the initial logic of the perspective from resource orchestration to capability development and ultimately to outcomes (Cui & Pan, 2015; Sirmon et al., 2011), this study adds an aspect of the interaction between data orchestration and other resources. This modification extends the resource orchestration framework by not only focusing on big data but also further clarifying how focal capability can be developed through data orchestration.

Third, this study contributes to the big data literature by shifting emphasis from the glamor of big data itself to orchestrating data and realizing data value in response to the call for rethinking big data strategies (Grover, Chiang, Liang, & Zhang, 2018; Ross et al., 2013). The findings reveal the internal mechanisms of the value realization of big data through data orchestration (i.e., sourcing, processing, and utilizing data), extending other researchers' argument that owning big data can create only very little value (e.g., Foster et al., 2018). Although the development of Wuhu into a smart city is overall successful, the process has not been perfect. This empirical case study offers rich insights into data issues (e.g., silos, inconsistency, inaccuracy, delay) as well as socio-technical issues (e.g., power and privacy concerns) that can plague smart-city projects (Ben, 2017), and how they could be managed to allow reasonable progress, even if they could not be completely resolved in time. The overall process indicates that the grand vision of developing a smart city based on big data requires small steps rather than bold leaps and sweeping changes to manage unforeseen resistance and challenges. Future research can deepen our understanding and inform practice by studying these and other socio-technical risks and critical considerations of smart city development based on big data (Meijer & Thaens, 2018).

6.2. Practical contributions

This study also makes three usable suggestions for city governments embarking on smart city development (Pan & Pee, 2020). First, based on the case study, three phases of development were delineated. Each phase differs in terms of focal data issues (e.g., data silos), and this understanding can be used to plan the development of smart cities. More importantly, this allows governments to allocate resources incrementally and demonstrate intermediate success before investing further. Small successes also help build confidence among stakeholders and citizens that fuel more explorations and innovations in later phases. An incremental approach appears to be more realistic considering that many ambitious smart city proposals have been abandoned even before commencing (e.g., Mulholland, 2019).

Second, this study has detailed useful approaches for managing diverse sources of big data throughout the process of smart city development, namely, integration, co-creation, and revolution. These data management approaches hold the key to the success of Wuhu and provide valuable insights into how big data should be orchestrated through souring, processing, and utilizing to create value in each phase. For instance, after the integration of data in phase 1, phase 2 should espouse co-creation to involve citizens in updating, triangulating, and synergizing data for quickly responding and early warning of risks and problems. The participation of citizens in this approach is foundational in establishing trust and confidence for more ambitious innovations in the next phase.

Third, the case study has highlighted several critical socio-technical concerns in Wuhu's development that are likely to also be relevant to other countries. In phase 1, it is necessary to manage the political concerns around the ownership and sharing of data across government departments. As our case demonstrates, this is a major hurdle to the integration of data and the development of practically useful data applications. More generally, it is important to be aware of the local political climate and formulate appropriate strategies to allow integration. In phase 2, privacy concerns must be acknowledged and proactively addressed. Our case illustrated how Wuhu successfully managed the concerns and earned the social capital necessary for taking the smart city to the next level. In phase 3, public-private partnerships with technology providers become a crucial element of innovation. In this case study, we elaborated how a successful smart city works together (in design) yet apart (in data ownership) with private-sector technology providers to revolutionize data applications while ensuring responsible data use.

7. Conclusion

Cities worldwide are pursuing the goal of becoming smarter as part of innovative strategic urban agendas that aim to address existing urban issues and threats (Chong et al., 2018). Thus, there is a need to better understand both the theoretical and practical aspects of this field. As big data have been considered to have great potential to promote smart city development (Al Nuaimi et al., 2015), this study focuses on the use of big data to make a city smarter. By investigating the case of Wuhu, the study proposes a framework to illustrate the process of orchestrating big data for development. This study provides innovative insights into the use of big data for smart city development that benefit both researchers and practitioners by contributing to theoretical developments and providing practical insights.

This study also has some limitations requiring future studies. First, as a single-case study, our findings have limited statistical generalizability compared to other methods, such as surveys (Yin, 1994). To generalize the findings to a population, future research could collect more data from other smart cities when they become more established. For example, future studies could compare different development paths with paths based on the use of big data. Second, we identified three phases in smart city development based on the case study. As smart cities mature, it is possible that a fourth phase could emerge. Case studies of successful smart cities should be conducted regularly in the future to reflect new knowledge and update the framework as necessary.

Appendix A. Examples of the coding in Phase 1

Example of Raw Data	1st Order Concept	2nd Order Theme	Aggregate Dimension
"Each governmental department, such as the Education Department, the Police Department, and the Finance Department had its own system to support its daily operation. To meet different needs, different departments stored the related data from different sources in different forms separately in their own systems." (interview with the chief engineer of the Informatization Department)	Data were stored separately in different governmental departments	Data silos	Data Issue
"There was no connection interface between departmental systems and databases. Data in each department was like an isolated island, which could not be directly connected with other departments." (interview with the chief engineer of the Informatization Department)	Data were accessible by one department but isolated from the rest of the government		
"To complete a public service task, the relevant departments required the citizen who applied the service to provide materials for verification and passed the verified data between departments." (interview with the staff member of the Public Service Center) *"At that time, when I applied for a settling-in allowance as an overseas returnee, I went to several governmental departments at different sites for different certificates required for the application…The whole tedious process made me feel frustrated then and took almost two months for the final approval."* (interview with a Wuhu citizen)	Data could not easily pass between departments		
"The types of data were diversified in departments as data were collected and captured by different tools. For instances, the Ecology and Environment Department captured real-time data on air quality by sensors while the Culture and Tourism Department collected the data on tourist satisfaction by questionnaires." (interview with the head of the BDC)	Data were collected by different tools in different departments	Data inconsistency	
"To meet different needs, different departments stored the related data from different sources in different forms separately in their own systems…Each departmental system had its own requirements about the standards of data storage." (interview with the chief engineer of the Informatization Department)	Data were stored with different forms and standards in different departments		
"Sometimes, the data about the same information provided by different departments were not matched. This is because the data might be collected from different sources, by different tools, and in different time intervals." (interview with the staff member of the BDC)	The same data from different departments were conflicting		

Example of Raw Data	1st Order Concept	2nd Order Theme	Aggregate Dimension
"We needed to sort out the existing public-service processes first… Finally, collaborating with other governmental departments, we identified 398 types of services which cover 54 departments made up of 218 governmental entities." (interview with the head of the BDC)	Sorting out the processes of public services	Data Sourcing	Data Orchestration (DO)
"Corresponding to each public-service process, we then identified what types of data would be involved to support the proper functioning of the process." (interview with the head of the BDC)	Identifying the data involved in the processes		
"We labeled the data involved in the particular public-service process with the responsible departments and required them to hand in the relevant data to us." (interview with the head of the BDC)	Labeling the involved data with the responsible departments		
"In the meetings, we were told that if the department heads would not hand in the data to the BDC, they may need to hand in their resignations to the government instead." (interview with the chief engineer of the Informatization Department) *"We went to the governmental departments to persuade them to hand in their data by explaining the expected benefits of breaking down the data silos…Gradually, the departments started to provide their data to us."* (interview with the staff member of the BDC)	Assembling the required data from each department		
"The data gathered from different departments were not 'clean' enough to be directly used. Thus, we collaborated with the center (BDC) to use our technology for automatically identifying the data that were incomplete or with obvious errors. To ensure the data quality, we selectively clean off the identified data." (interview with the staff member of iFlyTek's government collaboration department)	Standardizing the collected data through cleaning off the incorrect or incomplete data	Data Processing	
"As the data were provided by a variety of departments using different standards for data collection and storage, some of them were repetitive or irrelevant. Thus, we filtered out these data to keep the rest of them 'clean' enough." (interview with the staff member of iFlyTek's government collaboration department)	Standardizing the collected data through filtering out the repetitive or irrelevant data		
"We finally aggregated the data into 1,011 major categories and then stored all of them in an integrated database. This unified database contains 17 subject sub-databases, involving the domains of demographic, corporation, housing, etc." (interview with the staff member of the BDC)	Integrating the data into the unified database		
"Based on the unified database, we also integrated the functions of the original systems existed in governmental departments. Accordingly, a unified information system comprising all public services were created in 2013." (interview with the head of the BDC)	Integrating the systems into a unified system		

Example of Raw Data	1st Order Concept	2nd Order Theme	Aggregate Dimension
"The processes of city operation and management are extremely complex, filled with uncertainty. Thus, we could not directly implement the (unified) system in the whole city. We needed a 'testing-bed' to pilot our system and we selected the Jinghu District to do the test." (interview with the head of the Governmental Administration Office)	Testing the unified system supported by the integrated data	Data Utilizing	
"During the test, some run-time errors of the unified system and the problems in the system operation were detected. Majority of these issues was related to the quality of data, as data were the input of the system and determined the output quality." (interview with the staff member of the BDC)	Detecting run-time errors and problems		
"To support the practical operation of the system and address errors, we did a lot of work to adapt the data to the system by improving the data quality, for examples, supplementing data, increasing data standards, accelerating data updates, verifying the associated data and so on." (interview with the staff member of the BDC)	Adapting the data to the unified system for error correction		
"To analyze the public service processes and identify the data involved in each process, we had to closely collaborate with other departments, such as the police, civil administration, industrial and commercial departments, health departments, and so on. They used their professional knowledge and practical experience to help us understand the relevant processes." (interview with the head of the BDC)	Using knowledge resources to analyze service processes to identify required data	Other resources promote data orchestration	Interaction between DO and other resources
"The task was stuck at the very beginning, as no department handed in its data to us. Through further communication with department heads, some expressed their concerns on the security of data sharing and the possible changes in their operation processes." (interview with the head of the BDC) *"In the meetings, we were told that if the department heads would not hand in the data to the BDC, they may need to hand in their resignations to the government instead."* (the chief engineer of the Informatization Department) *"We went to the governmental departments to persuade them to hand in their data by explaining the expected benefits of breaking down the data silos…Gradually, the departments started to provide their data to us."* (interview with the staff member of the BDC)	Using leadership resources and knowledge resources to assemble data		

Example of Raw Data	1st Order Concept	2nd Order Theme	Aggregate Dimension
"It is a quite difficult work to process and integrate the massive and multi-source data. We needed professional IT support to complete the related tasks and we selected iFlyTek for the collaboration… iFlyTek truly did a good job by providing professional technology and knowledge support on the data standardization and the data integration." (interview with the head of the BDC) *"Thus, we collaborated with the center (BDC) to use our technology for automatically identifying the data that were incomplete or with obvious errors…We also communicated with the center and the relevant departments frequently to understand their requirements for integrating the data."* (interview with the staff member of iFlyTek's government collaboration department)	Using technological resources and knowledge resources to standardize and integrate data		
"It was even harder to adapting the integrated data to the unified system. We needed the governmental staff with professional knowledge and experience to assist us and we provided them the advanced technologies and systems. This task could only be done through collaboration." (interview with the staff member of iFlyTek's government collaboration department)	Coordinating system, knowledge, and technological resources to adapt data		
"Supported by the integrated data and the unified system, the previous redundant procedures of public services were combined into the unified and simplified procedures." (interview with the head of the Public Service Center)	Combining the public-service procedures	Data orchestration unify other resources	
"The public-service system based on integrated data also helped to join the professional knowledge together. The knowledge had been scattered in different departments previously, which was difficult to be collectively used for providing services." (interview with the staff member of the Public Service Center)	Joining knowledge		
"The required labor for supporting the delivery of public services was also significantly reduced. Previously, the staff members of the governmental departments needed to verify and process the information passed by the citizens who applied for the public services. Now, the integrated data and the system do this job in a more effective and efficient way." (interview with the head of the Public Service Center)	Reducing labor		
"Based on the integrated data, the fundamental functions of the separated systems in governmental departments were merged into a unified system to support all the public services." (interview with the head of the Governmental Administration Office)	Merging the departmental systems		

Example of Raw Data	1st Order Concept	2nd Order Theme	Aggregate Dimension
"Previously, the governmental departments were to some extent separated and it was hard for them to collectively work together for one task… Currently, by using the unified system, all the relevant departments can be easily connected for the collaboration to complete a task." (interview with the head of the BDC)	Connecting governmental departments for collaborative work	Connecting	Focal Capability
"The staff members in different departments, their knowledge and experiences were also connected based on the integrated data to provide public services… Moreover, the internal governmental resources and external technology support were connected for collectively completing the tasks." (interview with the head of the BDC)	Connecting resources for collaborative work		
"It (the unified system) also helped to assign the relevant departments subtasks. The departments were coordinated for collectively providing one-stop public service. The (unified) system not only promoted the interdepartmental collaboration but also made each department more responsible as it enabled the service processes traceable." (interview with the head of the Public Service Center)	Coordinating governmental departments to provide one-stop public service	Coordinating	
"The (unified) system made the available resources more visible. The resource could be reasonably allocated for offering one-stop public service, which simplified the service processes and maximized the utilization of resources." (interview with the head of the Public Service Center)	Coordinating resources to provide one-stop public service		
"We finally aggregated the data into 1,011 major categories and then stored all of them in an integrated database." (interview with the staff member of the BDC)	Data integration	Integration	Management Approach
"Based on the unified database, we also integrated the functions of the original systems existed in governmental departments. Accordingly, a unified information system comprising all public services were created in 2013." (interview with the head of the BDC)	System integration		
"The original processes of public services had been scattered and tedious. Through breaking down data silos and developing the unified system, the original processes were merged and simplified." (interview with the head of the Public Service Center)	Process integration		
"The integrated data and the unified system simplified the processes of public services, which further made the city management more consolidated and harmonious. It shortened the time for approving and delivering services and improving citizens' satisfaction." (interview with the staff member of the City Management Department)	Management integration		

References

Al Nuaimi, E., Al Neyadi, H., Mohamed, N., & Al-Jaroodi, J. (2015). Applications of big data to smart cities. *Journal of Internet Services and Applications,* 6(1), 1-15.
Albino, V., Berardi, U., & Dangelico, R. M. (2015). Smart cities: Definitions, dimensions, performance, and initiatives. *Journal of Urban Technology,* 22(1), 3-21.
Allen, B., Tamindael, L. E., Bickerton, S. H., & Cho, W. (2020). Does citizen coproduction lead to better urban services in smart cities projects? An empirical study on e-participation in a mobile big data platform. *Government Information Quarterly,* 37(1), 101412.
Anthopoulos, L., Janssen, M., & Weerakkody, V. (2016). A Unified Smart City Model (USCM) for smart city conceptualization and benchmarking. *International Journal of Electronic Government Research (IJEGR),* 12(2), 77-93.
Axelsson, K., & Granath, M. (2018). Stakeholders' stake and relation to smartness in smart city development: Insights from a Swedish city planning project. *Government Information Quarterly,* 35(4), 693-702.
Bach, B., & Loibl, W. (2016). European research and innovation for smart cities. *International Issues & Slovak Foreign Policy Affairs,* 25, 39-52.
Baert, C., Meuleman, M., Debruyne, M., & Wright, M. (2016). Portfolio entrepreneurship and resource orchestration. *Strategic Entrepreneurship Journal,* 10(4), 346-370.
Bakici, T., Almirall, E., & Wareham, J. (2013). A smart city initiative: the case of Barcelona. *Journal of the Knowledge Economy,* 4(2), 135-148.
Batty, M. (2013). Big data, smart cities and city planning. *Dialogues in Human Geography,* 3(3), 274-279.
Batty, M., Axhausen, K. W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., et al. (2012). Smart cities of the future. *The European Physical Journal Special Topics,* 214(1), 481-518.
Belanche-Gracia, D., Casaló-Ariño, L. V., & Pérez-Rueda, A. (2015). Determinants of multi-service smartcard success for smart cities development: A study based on citizens' privacy and security perceptions. *Government Information Quarterly,* 32(2), 154-163.
Ben, S. H. (2017). Quality and the efficiency of data in "Smart-Cities". *Future Generation Computer Systems,* 74, 409-416.
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.
Caragliu, A., Del Bo, C., & Nijkamp, P. (2011). Smart cities in Europe. *Journal of urban technology,* 18(2), 65-82.
Carnes, C. M., Chirico, F., Hitt, M. A., Huh, D. W., & Pisano, V. (2017). Resource orchestration for innovation: Structuring and bundling resources in growth-and maturity-stage firms. *Long Range Planning,* 50(4), 472-486.
Chan, C. M., Hackney, R., Pan, S. L., & Chou, T.-C. (2011). Managing e-Government system implementation: a resource enactment perspective. *European journal of information systems,* 20(5), 529-541.
Chong, M., Habib, A., Evangelopoulos, N., & Park, H. W. (2018). Dynamic capabilities of a smart city: An innovative approach to discovering urban problems and solutions. *Government Information Quarterly,* 35(4), 682-692.
Chourabi, H., Nam, T., Walker, S., Gil-Garcia, J. R., Mellouli, S., Nahon, K., et al. (2012, January). *Understanding smart cities: An integrative framework.* Paper presented at the System Science (HICSS), 2012 45th Hawaii International Conference on, TBD Maui, HI, USA.
Cui, M., & Pan, S. L. (2015). Developing focal capabilities for e-commerce adoption: A resource orchestration perspective. *Information & Management,* 52(2), 200-209.
Cui, M., Pan, S. L., Newell, S., & Cui, L. (2017). Strategy, Resource Orchestration and E-commerce Enabled Social Innovation in Rural China. *The Journal of Strategic Information Systems,* 26(1), 3-21.

Dameri, R. P., & Rosenthal, C. (2014). *Smart city: How to create public and economic value with high technology in urban space*. Cham: Springer.
Desouza, K. C., & Flanery, T. H. (2013). Designing, planning, and managing resilient cities: A conceptual framework. *Cities,* 35, 89-99.
Desouza, K. C., & Jacob, B. (2017). Big data in the public sector: Lessons for practitioners and scholars. *Administration & Society,* 49(7), 1043-1064.
Díaz-Díaz, R., Muñoz, L., & Pérez-González, D. (2017). Business model analysis of public services operating in the smart city ecosystem: The case of SmartSantander. *Future Generation Computer Systems,* 76, 198-214.
Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *Academy of management journal,* 50(1), 25-32.
Foster, J., McLeod, J., Nolin, J., & Greifeneder, E. (2018). Data work in context: Value, risks, and governance. *Journal of the Association for Information Science and Technology,* 69(12), 1414-1427.
Gascó-Hernandez, M. (2018). Building a smart city: lessons from Barcelona. *Communications of the ACM,* 61(4), 50-57.
Gascó, M., Trivellato, B., & Cavenago, D. (2016). How Do Southern European Cities Foster Innovation? Lessons from the Experience of the Smart City Approaches of Barcelona and Milan. In J. R. Gil-Garcia, T. A. Pardo & T. Nam (Eds.), *Smarter as the New Urban Agenda: A Comprehensive View of the 21st Century City* (pp. 191-206). Cham: Springer.
Giest, S. (2020). Do nudgers need budging? A comparative analysis of European smart meter implementation. *Government Information Quarterly,* 37(4), 101498.
Giffinger, R., Fertner, C., Kramar, H., & Meijers, E. (2007). *Smart Cities: Ranking of European medium-sized cities*. Vienna: Centre of Regional Science.
Gil-Garcia, J. R., Pardo, T. A., & Nam, T. (2016). *Smarter as the new urban agenda: a comprehensive view of the 21st century city*. Cham: Springer.
Gil-Garcia, J. R., Zhang, J., & Puron-Cid, G. (2016). Conceptualizing smartness in government: An integrative and multi-dimensional view. *Government Information Quarterly,* 33(3), 524-534.
Grover, V., Chiang, R. H., Liang, T.-P., & Zhang, D. (2018). Creating strategic business value from big data analytics: A research framework. *Journal of Management Information Systems,* 35(2), 388-423.
Gummesson, E. (2000). *Qualitative methods in management research*. Thousand Oaks, California: Sage.
Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J., et al. (2010). Foundations for smarter cities. *IBM Journal of Research and Development,* 54(4), 1-16.
Hashem, I. A. T., Chang, V., Anuar, N. B., Adewole, K., Yaqoob, I., Gani, A., et al. (2016). The role of big data in smart city. *International Journal of Information Management,* 36(5), 748-758.
Ismagilova, E., Hughes, L., Dwivedi, Y. K., & Raman, K. R. (2019). Smart cities: Advances in research—An information systems perspective. *International Journal of Information Management,* 47, 88-100.
Johnson, P. A., Robinson, P. J., & Philpot, S. (2020). Type, tweet, tap, and pass: How smart city technology is creating a transactional citizen. *Government Information Quarterly,* 37(1), 101414.
Kar, A. K., Ilavarasan, V., Gupta, M. P., Janssen, M., & Kothari, R. (2019). Moving beyond Smart Cities: Digital Nations for Social Innovation & Sustainability. *Information Systems Frontiers,* 21(3), 495-501.
Kitchin, R. (2014). The real-time city? Big data and smart urbanism. *GeoJournal,* 79(1), 1-14.
Klein, H. K., & Myers, M. D. (1999). A set of principles for conducting and evaluating interpretive field studies in information systems. *MIS Quarterly,* 23(1), 67-93.
Kuk, G., & Janssen, M. (2011). The business models and information architectures of smart cities. *Journal of Urban Technology,* 18(2), 39-52.
Lee, J. H., Hancock, M. G., & Hu, M.-C. J. T. F. (2014). Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco. *Technological Forecasting and Social Change,* 89, 80-99.
Lim, C., Kim, K.-J., & Maglio, P. P. (2018). Smart cities with big data: Reference models, challenges, and considerations. *Cities,* 82, 86-99.

Liu, X., & Zheng, L. (2018). Cross-departmental collaboration in one-stop service center for smart governance in China: Factors, strategies and effectiveness. *Government Information Quarterly,* 35(4, Supplement), 54-60.
Matheus, R., Janssen, M., & Maheshwari, D. (2020). Data science empowering the public: Data-driven dashboards for transparent and accountable decision-making in smart cities. *Government Information Quarterly,* 37(3), 101284.
Medaglia, R., & Zheng, L. (2017). Mapping government social media research and moving it forward: A framework and a research agenda. *Government Information Quarterly,* 34(3), 496-510.
Meijer, A. (2018). Datapolis: A Public Governance Perspective on "Smart Cities". *Perspectives on Public Management and Governance,* 1(3), 195-206.
Meijer, A., & Bolívar, M. P. R. (2016). Governing the smart city: a review of the literature on smart urban governance. *International Review of Administrative Sciences,* 82(2), 392-408.
Meijer, A., & Thaens, M. (2018). Urban technological innovation: Developing and testing a sociotechnical framework for studying smart city projects. *Urban Affairs Review,* 54(2), 363-387.
Mulholland, J. (2019). *Waterfront Toronto Smart City Plans Raise Privacy Concerns*, from https://www.govtech.com/smart-cities/Waterfront-Toronto-Smart-City-Plans-Raise-Privacy-Concerns.html
Nam, T., & Pardo, T. A. (2011, June). *Conceptualizing smart city with dimensions of technology, people, and institutions.* Paper presented at the Proceedings of the 12th Annual International Digital Government Research Conference, College Park, MD, USA.
Ndofor, H. A., Sirmon, D. G., & He, X. (2011). Firm resources, competitive actions and performance: investigating a mediated model with evidence from the in-vitro diagnostics industry. *Strategic Management Journal,* 32(6), 640-657.
Neirotti, P., De Marco, A., Cagliano, A. C., Mangano, G., & Scorrano, F. (2014). Current trends in Smart City initiatives: Some stylised facts. *Cities,* 38, 25-36.
Nograšek, J., & Vintar, M. (2014). E-government and organisational transformation of government: Black box revisited? *Government Information Quarterly,* 31(1), 108-118.
Pan, S. L., Cui, M., & Qian, J. (2020). Information resource orchestration during the COVID-19 pandemic: A study of community lockdowns in China. *International Journal of Information Management,* 54, 102143.
Pan, S. L., & Pee, L. G. (2020). Usable, in-use, and useful research: A 3U framework for demonstrating practice impact. *Information Systems Journal,* 30(2), 403-426.
Pan, S. L., & Tan, B. (2011). Demystifying case research: A structured–pragmatic–situational (SPS) approach to conducting case studies. *Information and Organization,* 21(3), 161-176.
Paroutis, S., Bennett, M., & Heracleous, L. (2014). A strategic view on smart city technology: The case of IBM Smarter Cities during a recession. *Technological Forecasting and Social Change,* 89, 262-272.
Pee, L., Pan, S. L., & Cui, L. (2019). Artificial intelligence in healthcare robots: A social informatics study of knowledge embodiment. *Journal of the Association for Information Science and Technology,* 70(4), 351-369.
Pee, L. G., Kankanhalli, A., & On Show, V. (2010). Bridging the digital divide: Use of public internet kiosks in Mauritius. *Journal of Global Information Management (JGIM),* 18(1), 15-38.
Ross, J. W., Beath, C. M., & Quaadgras, A. (2013). You may not need big data after all. *Harvard Business Review,* 91(12), 90.
Sanchez, L., Muñoz, L., Galache, J. A., Sotres, P., Santana, J. R., Gutierrez, V., et al. (2014). SmartSantander: IoT experimentation over a smart city testbed. *Computer Networks,* 61, 217-238.
Schaffers, H., Komninos, N., Pallot, M., Trousse, B., Nilsson, M., & Oliveira, A. (2011, May). *Smart cities and the future internet: Towards cooperation frameworks for open innovation.* Paper presented at the The Future Internet Assembly, Berlin, Heidelberg.
Silverman, D. (2011). *Interpreting qualitative data: A guide to the principles of qualitative research*. London: SAGE.

Sirmon, D. G., Hitt, M. A., & Ireland, R. D. (2007). Managing firm resources in dynamic environments to create value: Looking inside the black box. *Academy of management review,* 32(1), 273-292.
Sirmon, D. G., Hitt, M. A., Ireland, R. D., & Gilbert, B. A. (2011). Resource orchestration to create competitive advantage: Breadth, depth, and life cycle effects. *Journal of Management,* 37(5), 1390-1412.
Stone, D. (2012). *Policy paradox. The art of political decision making*. New York: W.W. Norton & Company.
Symeonidou, N., & Nicolaou, N. (2018). Resource orchestration in start-ups: Synchronizing human capital investment, leveraging strategy, and founder start-up experience. *Strategic Entrepreneurship Journal,* 12(2), 194-218.
Timmermans, S., & Tavory, I. (2012). Theory construction in qualitative research: From grounded theory to abductive analysis. *Sociological theory,* 30(3), 167-186.
van Zoonen, L. (2016). Privacy concerns in smart cities. *Government Information Quarterly,* 33(3), 472-480.
Walsham, G. (2006). Doing interpretive research. *European Journal of Information Systems,* 15(3), 320-330.
Wang, C., Medaglia, R., & Zheng, L. (2018). Towards a typology of adaptive governance in the digital government context: The role of decision-making and accountability. *Government Information Quarterly,* 35(2), 306-322.
Wixom, B., Ariyachandra, T., Douglas, D., Goul, M., Gupta, B., Iyer, L., et al. (2014). The current state of business intelligence in academia: The arrival of big data. *Communications of the Association for information Systems,* 34(1), Article 1.
Wu, Y. J., & Chen, J.-C. (2021). A structured method for smart city project selection. *International Journal of Information Management,* 56, 101981.
Yin, R. K. (1994). Discovering the future of the case study. Method in evaluation research. *Evaluation Practice,* 15(3), 283-290.
Yin, R. K. (2003). *Case study research: Design and methods*. Beverly Hills, Calif.: Sage.
Zhang, D., Pan, S. L., Yu, J., & Liu, W. (2019). Orchestrating big data analytics capability for sustainability: A study of air pollution management in China. *Information & Management*, 103231.
Zhu, S., Li, D., & Feng, H. (2019). Is smart city resilient? Evidence from China. *Sustainable Cities and Society,* 50, 101636.
Zygiaris, S. (2013). Smart city reference model: Assisting planners to conceptualize the building of smart city innovation ecosystems. *Journal of the Knowledge Economy,* 4(2), 217-231.