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Understanding the relationships between information architectures and business models: An empirical study on the success configurations of smart communities

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ABSTRACT

With the development of Internet of Things (IoT) and big data, many smart city and smart community projects bloomed in recent years. Following the two approaches of smart city development from Kuk and Janssen (2011), the study proposed a synergetic framework for understanding the relationship between information architectures and business models. Since community is a basic unit of a city, the development goals of a smart city are needed to be implemented at the level of communities. The development path of smart community is a configuration set including both information architecture factors and business model patterns. Based on the cases of 69 communities from Beijing, China, we explored successful configurations based on the framework. Using the Qualitative Comparative Analysis (QCA) method, we found that a successful smart community depends on the integration between information architectures and business models, and different business models rely on different information architectures elements. Networking, terminals, and sensors are key information architecture elements that are used more frequently in business models.

1. Introduction

Mahizhnan (1999) puts forward the concept of smart city in which enhancement of urban residents' life quality serves as a development goal. In 2008, the IBM Corporation's proposal of the concept of "Smart Planet" unlocks the door of practical exploration into smart city, and many countries started to build smart cities since then (IBV, 2009). A general definition of smart city encompasses "the implementation and deployment of information and communication technology (ICT) infrastructures to support social and urban growth through improving the economy, citizens' involvement and government efficiency" (Yeh, 2017). Thanks to the rapid development of ICTs like Internet of Things (IoT) and big data, different types of data become available, and they could be exploited to increase the transparency and promote the actions of the local government toward the citizens, enhance the awareness of people about the status of their city, stimulate the active participation of the citizens in the management of public administration, and also stimulate the creation of new services (Zanella, Bui, Castellani, Vangelista, & Zorzi, 2014).

Many regions and countries in the world have developed smart city policies and projects, such as Europe Union's "Living Lab", British "Smart Bay" Project, "I-Japan Strategy 2015", and "U-Korea Development Strategy". China is also not lagging. In China, the development path of smart city is generally top-down. In 2013, The Ministry of Housing and Urban-Rural Development announced 93 pilot smart cities. To date, the Ministry of Housing and Urban-Rural Development and Ministry of Science and Technology have announced 290 pilot smart cities in total. In August 2014, National Development and Reform Commission (NDRC) published the Guidelines for Smart City Development (NDRC, 2014). With the promotion of the central government and the rapid development of technologies, many cities listed "smart city construction" into their strategic plans, including Beijing, Shanghai, Nanjing, Guangzhou, Ningbo, and Shenzhen. In many ways China is "at the global vanguard" of constructing smart cities (Parasol, 2018, p. 71).

However, compared with increasingly enriched practices of smart cities and communities, theoretical explorations and empirical studies still remain limited, especially on how to select an effective smart city development path when resources are scarce (Chong, Habib, Evangelopoulos, & Park, 2018; Dameri, Benevolo, Veglianti, & Li, 2019;

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Shen, Huang, Wong, Liao, & Lou, 2018). According to Chong et al. (2018), "extant smart city research does not sufficiently reflect the ongoing practice of how cities are actively reconstructing themselves and their growing worldwide movement toward smart cities" (p.683). Comparing cases from two Holland cities, Kuk and Janssen (2011) discuss two development paths of smart city: business models and information architecture. One approach has business models preceding information architecture and the other takes an opposite direction. They also demonstrate that the two approaches have different influences on smart city development, for example, the types and sustainability of services. Kuk and Janssen (2011)'s work lays a foundation for understanding the relationship between information architectures and business models in smart cities.

Based on multi-case studies of smart community development in China, this study attempts to further the research on smart city by exploring the relationship between information architectures and business models and developing configurational theories of smart city. Smart cities start with smart communities (Chong et al., 2018). Employing Qualitative Comparative Analysis (QCA) method, the article explores configurations of conditions leading to smart city based on 69 pilot smart communities in Chaoyang District, Beijing, which also provides an opportunity to test the external validity of propositions proposed by Kuk and Janssen (2011). We found that a successful smart community depends on the integration between information architectures and business models, and different business models rely on different information architectures elements. Networking, terminals, and sensors are information architecture factors that are used more frequently in various business models.

2. Literature review

2.1. Success factors of smart cities

As a product of information technology and urbanization, smart city provides a new perspective for urban management and innovation. Smart city services are increasingly becoming "a norm rather than exception in developing and managing city services for citizens" (Lee & Lee, 2014, p. 93). Gil-Garcia, Zhang, and Puron-Cid (2016) argued that every city could attain a different level of smartness within a range instead of "falling in black and white categories of smart or not" (p.524). Hollands (2008) contends that "one of the key elements which stands out in the smart (intelligent) city literature is the utilization of networked infrastructures to improve economic and political efficiency and enable social, cultural and urban development" (p. 307). Caragliu, Bo, and Nijkamp (2011) argue that a city to be smart "when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance" (p. 70).

The Centre of Regional Science at the Vienna University of Technology identified six main components of a smart city: a smart economy, smart people, smart governance, smart mobility, a smart environment, and smart living (Giffinger, 2007). The Intelligent Community Forum defined critical success factors for the creation of intelligent communities: broadband, knowledge workforce, innovation, digital equality, sustainability, and advocacy. Gil-Garcia, Pardo, and Nam (2015) proposed a comprehensive conceptualization of smart city and identified ten core components: (1) public services, (2) city administration and management, (3) policies and other institutional arrangements, (4) governance, engagement and collaboration, (5) human capital and creativity, (6) knowledge economy and pro-business environment, (7) built environment and city infrastructure, (8) natural environment and ecological sustainability, (9) ICT and other technologies, and (10) data and information. Technology is a component that "enables the development and progress in other smart city components, becoming a means and not an end in itself" (Gil-Garcia et al., 2015, p. 69).

Linking key actors (universities, industry, government, and civil society) to the above-mentioned main dimensions of a smart city (smart economy, smart mobility, smart environment, smart people, smart living and smart governance), Lombardi, Giordano, Farouh, and Yousef (2012) proposed five clusters of smart city performance indicators: smart governance (related to participation); smart human capital (related to people); smart environment (related to natural resources); smart living (related to the quality of life); and smart economy (related to competitiveness). In summary, these studies all suggest developing smart economy and smart governance based on smart people, thereby efficiently utilizing resources and achieving smart life (Kourtit & Nijkamp, 2012; Mahizhnan, 1999).

2.2. The information architectures and business models of smart cities

Although smart city and community projects have different focuses, they are developed mainly through two approaches: information architectures and business models (Kuk & Janssen, 2011). Kuk and Janssen (2011) contend that there are two ways cities acquire the smart city status: information architectures and business models. While the approach of business models is to improve and increase front-end services to achieve rapid accumulation of commercial value, the approach of information architectures primarily aims to improve rear-end services for processing information with low cost and high efficiency. The first case accumulated business value faster with more new services made available to the public. In contrast, the second case was more resource-intensive and relatively slower in bringing new services to the general public, but the services were much improved and sustainable over time (Kuk & Janssen, 2011).

The approach of information architectures emphasizes that IT infrastructure is the foundation of smart city and community (Bartlett, Harthoorn, Hogan, & Kehoe, 2011; Gann, Dodgson, & Bhardwaj, 2011). It generally integrates a variety of information service resources and establishes unified data and service platform to make each department and system connected. On the other hand, the approach of business models focuses on the role of the human being. It believes that the construction of smart cities is not all about investing and upgrading infrastructures, but exploring and utilizing human's wisdom to improve urban management. The approach of business models takes full advantage of ICT technology and public data, and provide one-stop service to enhance the value of service provision and political participation (IBV, 2009).

In short, countries have started the development of smart city or community through the approaches of information architectures and business models, but there isn't a unified and effective development path of smart city (Dameri et al., 2019; Li, Liu, Dai, & Zhao, 2019), especially on how to choose and combine the factors of the two approaches (business models and information architectures) to become smart cities. According to Kuk and Janssen (2011), "any realistic understanding of what it means to be a smart city needs to specify the type of business models being used and ensure that the information architecture is able to support the desired business models" (p.41). In addition, extant smart city studies mainly focus on the level of cities, and there are few smart community studies. A community is a basic unit of a city, and development goals of a smart city need to be implemented at the level of communities. Smart community studies will enrich our understanding of the implementation of smart city projects. The framework we introduce in this paper will explore how to combine the approaches of business models and information architectures in the process of implementing smart city programs. The framework is presented in the next section.

3. Analysis framework

3.1. A framework of smart city/community development

According to Kuk and Janssen (2011), public sector managers should have a clear idea what it is they hope to achieve with limited resources at their disposal and select appropriate transformation strategy. Rational governors tend to process a few issues in a serial rather than parallel fashion based on their resource views, attending to some issues before moving on to others (Jones, 1994). This study also follows the logic of limited resources when discussing successful strategies of smart city or smart community development.

In 2012, the government of Beijing published *Smart Beijing Action Plans* and identified basic characteristics of Smart Beijing: ubiquitous infrastructure, intelligent and integrative IT applications, and innovative and sustainable development environment. Based on the approaches proposed by Kuk and Janssen, *Smart Beijing Action Plans*, and relevant studies, this study proposed an analysis framework for understanding the relationship between information architectures and business models in smart cities. Following Reimers and Johnston's (2008) top-down and bottom-up patterns, five elements of information architectures and five types of business models in smart cities are identified. The five factors of information architectures include networking, data warehouse, terminals, sensors, and interaction and payment. The five types of business models include public information, facilities management, healthcare service, education service, and accessibility service. We discuss the details of the elements of information architectures and business models as follows.

3.2. Elements of information architectures

- Networking: The most important feature of smart city is connection. Both the physical world and the virtual world need a powerful network to connect (Dijkman, Sprenkels, Peeters, & Janssen, 2015). Networking infrastructure connects digital devices and builds the foundation of fast and timely data communication and resource sharing. Internet broadband and wireless network can transmit massive data and information, enabling community residents to enjoy the convenience of Internet all the time.
- Data warehouse: The development of IoT and big data technologies has made massive data available and played an important role in smart city initiatives (Hashem et al., 2016). The establishment of databases (for example, population database, social media database, and administration database) in the city/community can meet the needs of city/community managers and residents for information and communication. Multiple users can share data resources in the database at the same time, which can save the time and enhance efficiency of community managers and government employees. In addition, open databases also provide an opportunity for residents to participate in the decision-making process and strengthen community management.
- Terminals: Following traditional computer terminal definition (Kim, Nam, Park, Park, & Hyun, 2007; Schicker & Duenki, 1978), terminals are considered as electronic hardware devices for inputting and displaying information in this study. In the context of smart city and smart community, terminals refer to computers, mobile phones, tablets, and public display screens.
- Sensors: Sensor is a device, module, or subsystem whose purpose is to detect events or changes in its environment and send the information to other terminals. As entrances to the physical world, billions of sensors are the foundations of smart cities (Yan, Lee, & Lee, 2015). As the public's demand for quality life increased, air quality monitor, fire smoke detector, high concentration gas alarm, toxic and hazardous substances monitor, and other sensors have been used in the smart city plans in China (Zhang, Chen, & Song, 2015).
- Interaction & Payment: The potential of smart cities lies in the interaction among nodes working together toward value co-creation (Ghanbari, Laya, Alonso-Zarate, & Markendahl, 2017). While the core spirit of Internet changes from Web 1.0 to Web 2.0, the interactive functions of terminals attract more attention. In the context of smart city and smart community, mobile payment functions are of great importance to citizens.

3.3. Types of business models

- Public Information: Janssen, Kuk, and Wagenaar (2008) contend that one of the e-government business models is “content provider”, that is, governments provide “static and dynamic content, including contact information, organization information, product and service information, and news” (p.209). Smart cities and communities provide information about public policy, safety, and job, improving transparency and enhancing interaction between community managers and residents.
- Facilities management: Based on technologies such as IoT and cloud computing, smart cities and communities can realize remote facility management through wireless terminal equipment. IoT is already delivering benefits to cities like Los Angeles and Oslo, which have experienced energy savings of more than 60 percent by moving to smart street lighting. Other cities have seen similar significant savings by deploying smart waste management solutions, reducing CO2 emissions, and increasing citizen satisfaction through smart parking and traffic management (Zanella et al., 2014). For example, smart parking system enables residents to complete the process of locating parking spaces, parking cars, and retrieving them by accessing mobile phone apps.
- Healthcare service: Cities could benefit from and harness the power of ICTs to improve the health and well-being of their local populations (Kamel Boulos & Al-Shorbaji, 2014). Smart community can improve health service through establishing electronic medical records system, providing online appointment system, and offering online health consultation for community residents. Monitoring sensors and devices can transmit alerts and other relevant data over the Internet, and therefore patients can stay less in hospitals and more at home (Kamel Boulos & Al-Shorbaji, 2014).
- Education service: Many smart city initiatives list education as one of the most important areas (Díaz-Díaz, Muñoz, & Pérez-González, 2017). Using IT technologies and means, smart communities build lifelong online learning platform, distance education platform, and Internet library. In addition, some communities provide Internet skills training and professional training for community residents.
- Accessibility service: Many scholars contended that smart cities need to be designed to improve accessibility and allow the inclusion of all kinds of citizens. For instance, motor disabled people like wheelchair users may have problems to interact with the city. Based on latest communication and positioning technologies for smart sensing, such as Augmented Reality (AR) and RFID technologies, smart cities and communities are able to allow the inclusion of all kinds of citizens (Mora, Gilart-Iglesias, Pérez-del Hoyo, & Andújar-Montoya, 2017; Rashid, Melià-Seguí, Pous, & Peig, 2017).

Janssen et al. (2008) identified different business models for e-government, including content provider, direct-to-customer, value-net-integrators, full-service provider, infrastructure service provider, market, collaboration, and virtual communities. These five types of business models we proposed may seem different from Kuk and Janssen’s business models, but they are not contradictory and actually consistent. Take public information for example. Communities use the Internet and electronic screens to disseminate important and useful information to residents’ phone, computer, and TV, which is consistent with Kuk and Janssen’s model of “content provider”. When it comes to the areas of healthcare and education, residents of smart communities can enjoy services like online appointment, online consultation, Internet library, and distance training at home. These services are all "direct-to-customer". That is, not only information is made available, but also transaction functionality is provided to residents (Janssen et al., 2008). Moreover, some communities employed the model of "full-service provider" in facility management and accessibility service, offering one-stop shop to residents through "bundling information and services" provided by a number of organizations. For example, in terms of accessibility, services like haircutting, housekeeping, and dining are directly provided to seniors and the disabled in the communities. With regard to facility management, thanks to the collaboration of remote meter company, electricity company, and communities, residents can pay electricity bills online. In the model of "full service provider", "customers do not directly deal with individual organizations and the identities of the organizations are often hidden"(Janssen et al., 2008, p. 209). In summary, the five elements we proposed are basically in accordance with Kuk and Janssen (2011)'s three models: "content provider", "direct-to customer", and "full-service provider" (see Table 1), which are the most-used business models in smart cities (Janssen et al., 2008; Kuk & Janssen, 2011).

3.4. The relationship between information architectures and business models in smart cities

The approach of information architectures refers to "a realignment of the relationships between various information systems" by governments' increase in infrastructure investment, integration of information platform, and development of a unified database (Kuk & Janssen, 2011, p.50). The approach of business models includes governments' activities such as providing personalized services, developing smart applications, and creating new services through information infrastructure and intelligent platform. Kuk and Janssen (2011) argue that the two approaches (business models and information architectures) are not mutually exclusive and should be considered complementary. New business models and supporting information architectures should be developed in parallel with an approach involving both the front-end and the back-end. Therefore, the development of smart cities relies on the integration of information architectures and business models.

Moreover, different business models are established on different combinations of information architectures. Information infrastructures are the foundation of smart community development, and to a certain degree influence business models. Developing a business model requires "a solid and relevant information architecture" that makes it possible to acquire, process, and disseminate information (Kuk & Janssen, 2011, p.47). The development of smart communities and the accompanying business rationales "require working in tandem with the underlying information architecture" (Kuk & Janssen, 2011, p.40). Constrained by financial resources and leader's awareness level, the readiness of information architectures varies in cities and communities. Distinct configurations of information architecture elements might lead to different types of business models. In addition, one specific type of business model might be based on multiple combinations of information architecture elements, which is consistent with the equifinality assumption of Qualitative Comparative Analysis. The analysis framework is summarized in Fig. 1.

4. Research methods

4.1. Qualitative Comparative Analysis

Firstly proposed by Ragin (1987), Qualitative Comparative Analysis (QCA) is a case-oriented research method. With iterative dialogue between theories and cases, QCA is an effective method for analyzing small and medium size data (Ragin, 1987, 2000). Compared to conventional quantitative analysis, the QCA method has different analytical logic. QCA conveys "a particular conception of causality ('multiple conjunctural causation') that stresses "equifinality, complex combinations of conditions, and diversity" (Berg-Schlosser, Meur, Rihoux & Ragin, 2008, p. 17). That is, different combinations of causes may lead to the same result. For example, in this study, we assume that there are multiple factors that influence smart community development, and they can be simultaneously present or be combined to improve smart community development level. And a given causal combination may not be the only route to smart community; other combinations also may be able to produce it.

This study aims to explore the relationship between information architecture and business models and different configurations of factors influencing the development of smart community. Prior findings based on case studies of smart cities and smart communities are enlightening, but their external validity is compromised. Another problem is that configurational theories of smart community development are still in the nascent stage and conventional regression models are limited in testing complex interactions between explanatory variables (Wang, 2016). The use of QCA enables us to identify under what (combinations of) conditions communities acquire the smart community status.

Fuzzy set QCA and Software FsQCA 2.5 is utilized. Fuzzy set QCA not only uses set-theoretic reasoning but also enables fine gradations in degree of membership (Ragin, 2008). Fuzzy sets "allow researchers to calibrate partial membership in sets using values in the interval between 0.0 (nonmembership) and 1.0 (full membership) without abandoning core set-theoretic principles and operations" (Ragin, 2008, p. 29).

4.2. Data, operationalization, and calibration

Most of the data used in this study are obtained from Information Network Center of Chaoyang District, Beijing (INCCD). Chaoyang District is the largest and the most modern urban district in Beijing. According to the most recent data of Beijing Municipal Bureau of Statistics, between 2013 and 2017, its average GDP per capita was around 124,789 yuan (about 17,827 US dollars) and it had a permanent population of 3.9 million, making it also the most populous district.[1] As seen in Fig. 2, Chaoyang District has more than 40 subdistricts both in the downtown area within the 2nd Ring Road and in rural area out of the 5th Ring Road in Beijing. [2]

Chaoyang District is one of the first 93 pilot smart cities nationwide. INCCD is the principal agency responsible for smart community development in Chaoyang District. To promote the development of smart community, INCCD organized a smart community star rating in 2013 (one star is the lowest rating, and five stars is the highest score), and communities are required to submit files, pictures, and videos of smart community development before December 2013. These self-reporting data were checked and confirmed by INCCD before the evaluation. INCCD went to these communities to check the validity and reliability of data on the spot. Finally, the sample size is 69 communities. The data were then coded and categorized based on the 10 elements and factors of information architectures and business models: networking, data warehouse, terminals, sensors, interaction and payment, public information, facilities management, healthcare service, education service, and accessibility service (see Table A4 in the Appendix A).

To measure smart community development level, due to data availability, we used the results of 2013 subdistrict performance evaluation conducted by the Social Construction Office of the Chaoyang district, which is another agency relevant to smart community

[1] http://tjj.beijing.gov.cn/nj/main/2018-tjnj/zk/indexeh.htm. From 2013 to 2017, GDP of the Chaoyang District was 420.81, 449.54, 482.39, 517.1, and 563.55 billion yuan respectively.

[2] The city of Beijing is served by five completed ring roads. From the center of the city outward, they are: 2nd Ring Road, 3rd Ring Road, 4th Ring Road, and 5th Ring Road.

Table 1
Kuk and Janssen's business models and the business models we proposed.

Kuk and Janssen's business models	The business models we proposed
1. Content provider: Providing static and dynamic content, including contact information, organization information, product and service information, and news.	Public information
2. Direct-to-customer: Directly providing services to customers and/or businesses.	Healthcare service; Education service
3. Full-service provider: Enabling interaction through directly providing information and services. This involves the collaboration of several departments and/or organizations to create a one-stop shop.	Facility management; Accessibility service

Source: Kuk and Janssen (2011).

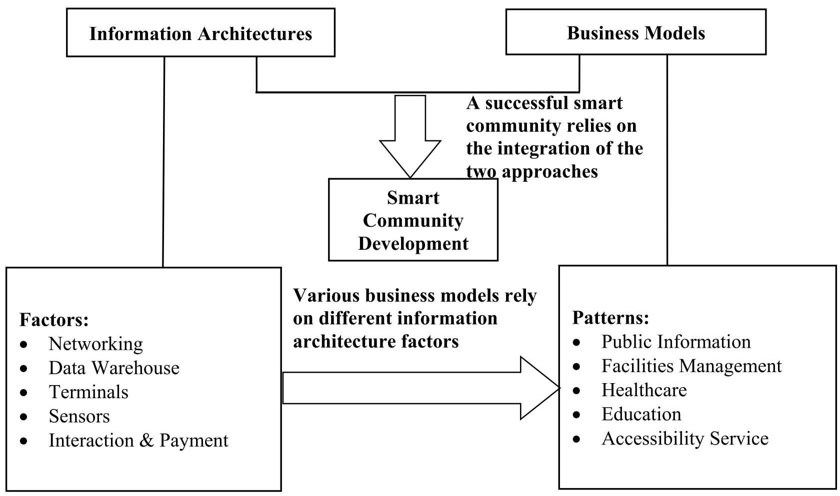

Fig. 1. Analysis Framework

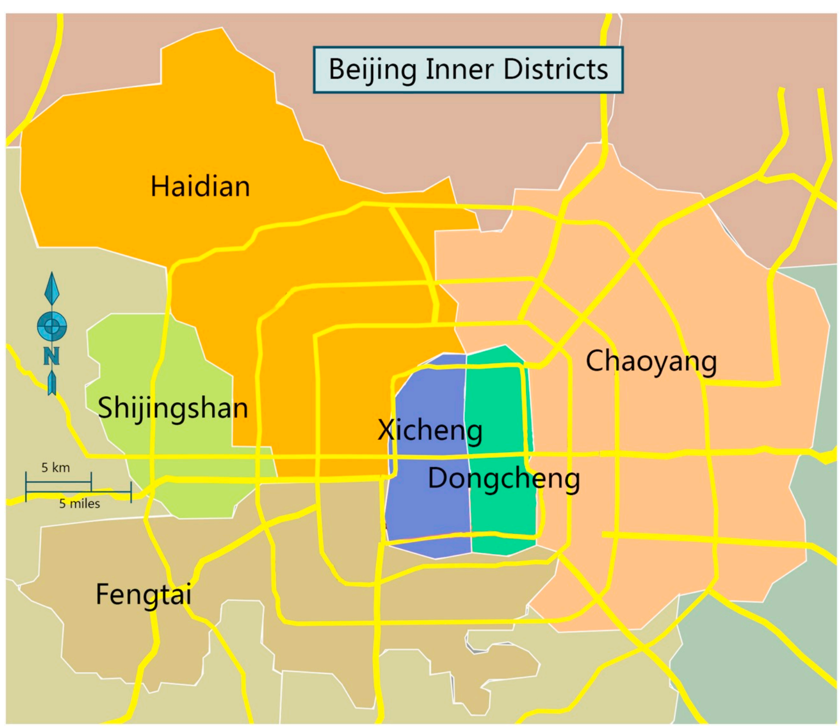

Fig. 2. Map of Beijing Inner Districts (https://en.wikivoyage.org/wiki/User:Renek78/Sandbox/Beijing)

development. In China, a subdistrict is an administrative unit that is one level higher than community. 27 subdistricts were included in the evaluation. The performance evaluation was based on in-depth interviews and a survey of the public and smart community experts in Chaoyang District. The public and experts were asked to rate the development level of individual subdistricts on a scale of zero to ten (zero is the lowest level and ten is the highest level, see Table 2). To explore the relationship between smart community development level and information architectures and business models, ten indexes of information architectures and business models serve as explanatory

Table 2
Subdistricts' development level (Performance) of smart community.

Subdistricts	Score	Subdistricts	Score
Anzhen	8.33	Xiangheyuan	8.67
Aoyuncun	9.33	Maizidian	9.67
Chaowai	6.00	Tuanjiehu	9.00
Jianwai	9.33	Yayuncun	6.67
Shuangjing	8.67	Hepingjie	6.00
Jingsong	7.67	Hujialou	9.33
Fatou	5.67	Zuojiazhuang	9.33
Jichang	8.00	Panjiayuan	9.33
Xiaoguan	8.33	Datun	5.67
Wangjing	9.00	Donghu	6.33
Sanlitun	9.00	Taiyanggong	5.67
Liulitun	6.67	Jiangtai	6.00
Balizhuang	8.67	Laiguangying	8.33
Jiuxianqiao	6.00		

variables. In terms of the influence of different information architectures on business models, information architecture factors are applied as explanatory variables, and various business model patterns are applied as outcomes.

Calibration is a key step of the QCA process. Transforming raw data to fuzzy sets allows for the variables match or conform to external standards. Calibration should use "theoretical and substantive criteria" and consider "researcher's conceptualization, definition, and labeling of the set in question" (Ragin, 2008, p. 85). Software FsQCA provides the function *calibrate (x,n1,n2,n3)*, where x is an existing interval or ratio scale variable, n1 is the value of x that corresponds to the threshold for full membership in the target set (fuzzy score = 0.95), n2 is the value of x that corresponds to the cross-over point (fuzzy score = 0.5) in the target set, and n3 is the value of x that corresponds to the threshold for nonmembership in the target set (fuzzy score = 0.05). Ragin (2008) argued that "the collective knowledge base of social scientists should provide the basis for the specification of precise calibrations…However, the social sciences are still in their infancy, and this knowledge base does not exist" (p.86). There are hardly any theories that set specific criteria of smartness of communities, so the calibration was mainly based on substantive knowledge of each community or subdistrict. To explore the relationship between smart community development level and information architectures and business models, 27 subdistricts were included in the sample, the 4th highest value was set as the threshold of full membership; the median of the 27 subdistricts was regarded as the crossover point; and the 24th highest value was set as the full nonmembership threshold. In terms of the influence of different information architecture on business models, 69 communities were included in the sample, the 5th highest value was set as the threshold of full membership; the median of the 69 communities was considered as the crossover point; and the 65th highest value was used as the full nonmembership threshold. Finally, membership scores are assigned to each case, which ranges from 0.0 to 1.0 (see Tables A5 and A6).

4.3. Validity and reliability

To ensure internal validity, this study uses multiple sources to obtain material during data collection and sorting phase (Yin, 2003). The primary evidence is from documents, interviews, and direct observations. The hypothetical proposition which can be derived from cases is first analyzed via QCA, and the proposition is then applied back to the original cases.

In terms of external validity, as Berg-Schlosser, Meur, Rihoux, and Ragin (2008) contend, "a well-executed QCA should go beyond plain description and consider 'modest generalizations': QCA results may be used in support of 'limited historical generalization'" (p.12). This type of generalization is "much more modest than statistical inference" (Berg-Schlosser et al., 2008, p. 12), and therefore it is "limited," "historical," "modest", or "contingent" generalization (Rihoux & Ragin, 2008; Thomann & Maggetti, 2017). However, it is possible to formulate propositions that can be applied to cases that "share a reasonable number of characteristics with those that were the subject of the QCA" (Berg-Schlosser et al., 2008, p. 12). To enhance external validity, we specified the background information of the communities in Chaoyang based on government statistics, star rating materials, and relevant reports.

With regards to reliability, on one hand, we established a case database of smart communities in Chaoyang district, Beijing, which could be provided for readers for independent evaluation. On the other hand, to prevent subjective judgment, this study formulated specific valuation principle and standards to code the data (see Appendix A) and modified the standards for multiple rounds (Yin, 2003).

Table 3
Configurations leading to smart community.

Configuration		A	B
Information architectures	Networking	⊗	•
	Data warehouse	⊗	⊗
	Terminal	●	●
	Sensors	●	●
	Interaction & payment	•	⊗
Business models	Public information	●	⊗
	Facility management	•	⊗
	Healthcare	•	●
	Education	⊗	●
	Accessibility service	⊗	⊗
Key indexes	Consistency	0.93	0.90
	Raw coverage	0.25	0.20
	Unique coverage	0.13	0.08
	Overall solution consistency	0.93	
	Overall solution coverage	0.33	

Notes: Black circles indicate the presence of a condition, and circles with "X" indicate its absence. Large circles indicate core conditions; small ones, peripheral conditions. Blank spaces indicate "don't care."

5. Results and discussions

Tables 5 and 6 present the results. We only report complex solutions here, which is the most conservative approach to deal with logical remainders that have no empirical cases. Logical remainders may be included in the Boolean minimization (Rihoux & Ragin, 2008). Complex solutions do not rest on any assumption about the logical remainders (Schneider & Wagemann, 2012).

5.1. Information architectures, business models, and smart community development

Five elements of information architectures and five type of business models are selected as the causal conditions, and the level of smart community development is used as the outcome. Following Fiss (2011)'s work, we demonstrate the results by using symbols rather than mathematical formulas (see Table 3).

There are two causal paths leading to high development level of smart community. Both of these paths are combinations of information architectures and business models, which are consistent with Kuk and Janssen (2011)'s argument that business models and information architectures are not mutually exclusive and should be considered complementary. In terms of information architectures, terminals and sensors are important causal conditions for high development level of smart communities while data warehouse is not. With regard to business models, healthcare and ~accessibility service presented in both of the causal paths, indicating that successful smart communities did a good job in providing healthcare services instead of accessibility services.

The overall solution consistency is 0.93, indicating that 93% of the

Table 4
Configurations leading to different business models.

Kuk and Janssen's business models	The business models we proposed	Networking	Data warehouse	Terminals	Sensors	Interaction and payment	Consistency and coverage
Content provider	Public information	●		●		●	Solution consistency:
		●	●	●	⊗		0.91;
		●	●		⊗	⊗	Solution coverage: 0.52
		●	●	⊗		⊗	
			⊗	●	●	⊗	
		⊗	⊗		⊗	●	
Direct-to- customer	Healthcare service	●	⊗			●	Solution consistency:
				●	●	●	0.85;
			⊗	●	●		Solution coverage: 0.75
		⊗		●	●		
		●		⊗	⊗	●	
		⊗	●	●		●	
		⊗	●		●	●	
		●	●	⊗	●	⊗	
	Education service	●		●	⊗	⊗	Solution consistency:
		●	⊗	●	●		0.94;
			⊗	●	●	⊗	Solution coverage: 0.44
Full service provider	Facility management	●	●	⊗	●	⊗	Solution consistency: 0.91; Solution coverage: 0.29
	Accessibility service		●	●	●	●	Solution consistency:
		●	⊗	⊗	⊗	●	0.90; Solution coverage: 0.48

Notes: Black circles indicate the presence of a condition, and circles with "X" indicate its absence. Blank spaces indicate "don't care."

communities with the two configurations were "smart". The overall solution coverage is 0.33, suggesting that these two paths could explain 33% of all the smart communities. It may be restricted by the sample size and there might be other factors influencing smart community development level.

5.2. Relationship between information architecture and business model

Five factors of information architectures are used as causal conditions, and five elements of business models are used as outcomes respectively. It can be seen from Table 4 that five business models rely on different combinations of information architectures. In terms of public information service, a combination of networking, data warehouse, and terminals plays important roles in improving public information service. Anzhenxili and Qingyuanlu (No.1) are such communities that offered excellent public information services through means of networking, data warehouse, and terminals. For example, multiple broadband access options were provided and high-definition interactive TVs were installed with set-top boxes (the coverage rate was 100%). The communities are fully covered by wireless network, and there is an Internet Café free for residents in each community.

With respect to facility management, only one combination is supplied by QCA, which includes networking, data warehouse, and sensors. As seen in the XY plot in Fig. 3, most of the fuzzy membership scores in causal combination of "networking, data warehouse, and sensors" (X Axis) are less than or equal to fuzzy membership scores in the outcome of "facility management" (Y Axis). Therefore, it is possible to argue that instances of the cause are a subset of instances of the outcome. That is to say, the combination of networking, data warehouse and sensors is sufficient for building model of facility management in communities. For example, the communities of Fenglinlvzhou, Shuangquan, and Wankexingyuan provided free Wi-Fi in public space and installed environment monitoring systems. Moreover, these communities also established comprehensive information management system and resident database. The information architecture laid solid foundation for facility management. Based on IoT and cloud computing applications, the communities realized remote meter reading and electronic payment of water, electricity, and gas. Vehicle intelligent management system was also installed, residents can easily find a parking spot with the help of

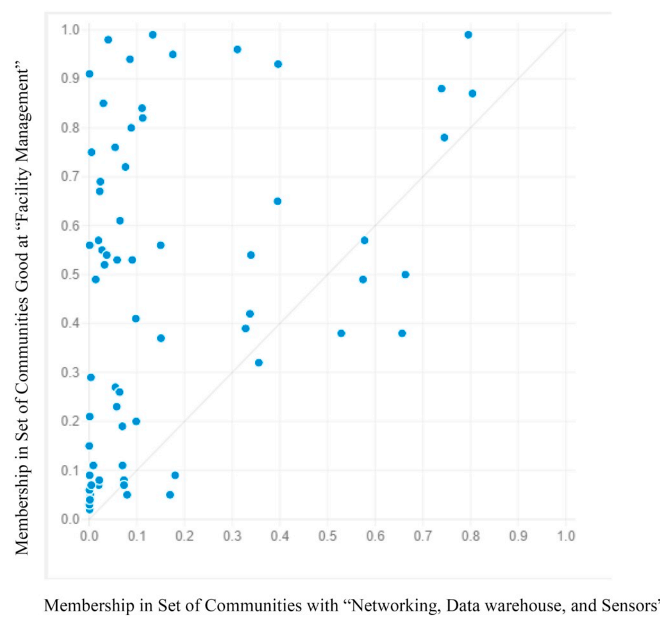

Fig. 3. Plot of "Facility Management" against "Networking, Data warehouse, and Sensors"

parking space screen.

With regard to healthcare services, there are eight causal paths. Sensors and interaction and payment are the information architectures that are used more often by communities. Healthcare services in smart communities mainly include electronic health records management, telemedicine, and online appointment registration. Dawang, Guanghuan, and Nanlang are such communities with valuable healthcare services. These communities installed online interaction and payment equipment and emergency facilities, and 100% of residents have electronic medical records.

When it comes to education service in communities, there are three causal paths. Networking, terminals, and sensors are crucial for improving education services, especially terminals. It is found that terminals exist in all three combinations. Fangyuanli, Nongzhannanli, and

Zaoyingbeili are such communities that introduced online learning platforms to residents through providing multiple terminals including computers, book vending machines, and electronic newspaper display screens.

Finally, for accessibility service, there are two combinations of information architectures. Interaction and payment appear in both combinations and it seems that it is a prerequisite for excellent community service for vulnerable groups. It is also interesting to note that these two configurations display the same outcome while having contradictory combinations of data warehouse, terminals, and sensors. It reflects the two schools of thoughts on improving accessibility in smart city projects. The first path focuses on developing network environment and solving challenges based on external resources via the Internet. This is the case for Yiertiao and Songyuxili, which built network infrastructure and aimed to provide online services for vulnerable groups. The second supports building terminals and facilities and providing services based on internal capacities. Anzhenli, Beilangdong, and Yonganli are such cases trying to provide services for seniors and the disabled directly from the communities through establishing vulnerable group database, providing computer terminals, and installing visual doorbells and sensors.

In terms of Kuk and Janssen (2011)'s categorization, the communities in the study mainly employed three business models: content provider, direct-to-customer, and full-service provider (see Table 4). The model of content provider is mostly used in public information, which is supported by the information architecture combination of networking, data warehouse, and terminals. Direct-to-customer is one of the popular models in smart communities in the Chaoyang District, and we can see it in two of the five elements we proposed: healthcare service and education service. Information architectures like terminals and sensors are essential for communities to provide direct-to-residents services. The model of full-service-provider appeared in facility management and accessibility service. Information architectures including networking, data warehouse, sensors, and interaction and payment all played an important part in offering one-stop services to community residents.

6. Conclusion

Based on Kuk and Janssen (2011)'s study, this article aims to explore successful smart city strategies and more specific, how to combine the factors of the two approaches (business models and information architectures) to become smart cities. According to the QCA results of 69 communities in Chaoyang district, Beijing, smart community development level is jointly influenced by information architectures and business models. A successful smart community depends on the integration between information architectures and business models, which corroborated Kuk and Janssen (2011)'s propositions. The advent of new technologies including IoT, cloud computing, big data, and artificial intelligence provided new opportunities for urban development. However, policy-makers should never forget that the opportunities could be turned into realities only when technologies integrated with business models and the public's needs.

Second, in a limited resources context, prioritizing different issues is important for the development of smart cities. This study also explores successful strategies of smart city development. Based on QCA results, we found that five business models rely on different combinations of information architectures. Networking, terminals, and sensors are information architecture factors that are used more frequently in various business models. Communities should pay more attention to these information architectures. In addition, communities should develop their business models in accordance with their own comparative advantage and existing information architectures, just coping other communities' ideas and models is not enough.

This study also has limitations. The cases are all from the Chaoyang District, Beijing, as we mentioned above, whose development level of smart community is relatively high. However, it confirmed Kuk and Janssen (2011)'s study from a configurational perspective and provided invaluable experiences for other cities and areas (for example, with a similar population and GDP per capita). Future research could empirically explore successful factors of smart city or community development using a large-N sample or include more cases of smart city or community from other areas in China or even other countries. For example, the data in this study were collected about 5 years ago and the material doesn't include enough information that we could tell if the communities used the business models of value-net-integrators, infrastructure service provider, market, collaboration, and virtual communities (Janssen et al., 2008; Kuk & Janssen, 2011). We would like to also collect more data on these models in subsequent studies.

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Authors' statement

Nan Zhang: Conceptualization, Methodology, Writing – Original Draft, Visualization, Supervision, Funding acquisition.

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Appendix. Coding

In order to avoid subjective judgment and discretion, this paper formulates unified valuation principles and standards for evaluation and endows scores and weight to text data. Subsequently, a number of specialists are invited to score the reorganized text material as a function of the valuation principle and revise the scores with great difference for multiple times so as to eventually obtain the scores of respective analysis variables in each community.

The unified valuation principle for all indexes include: (1) valuation field of all indexes is set as an interval [0, 10], and grades are scored from 0, the worst, to 10, the best. (2) As for the valuation principle employed for the index which is directly determined by "yes" or "none", "none" corresponds to 1, and "yes" corresponds to 10. (3) If there is merely qualitative material, the start score for the index is 1; if there is merely quantitative material, the start score for the index is 3; if quantitative material and qualitative material appear simultaneously, the start score for the index is 5. (4) All evaluation indexes are positive indexes, and the valuation level represents advantages and disadvantages of the smart community construction. (5) All secondary indicators have equal weight in this paper.

A.1. Scoring principle for quantitative data

Based on the above scoring principle, this paper intends to use a deviation method to set estimation scale, and assignment is performed as a function of data value of a single index, i.e., calculating all numerical mean value (standard value) and standard deviation of the single index. The bonus points of 1–5 are determined from the multiple relation between data value and standard deviation (see Table A1), and the summed scores are no more than 10.

Table A1
Assignment principle of quantitative data.

Less than 1 times standard deviation	Less than 0.5 times standard deviation	Standard value	More than 0.5 times standard deviation	More than 1 times standard deviation
+1	+2	+3	+4	+5

For example, upon indexes of hardware infrastructure-resident-specific computer, there are totally 31 numerical data whose average is 8.26 and standard deviation is 7.02. By taking the average 8.26 as the standard deviation in combination with actual conditions of 69 communities, estimation scale scores are set with more than 0.5 times and 1 times standard deviation and less than 0.5 times and 1 times standard deviation respectively (see Table A2).

Table A2
Scoring principle of resident-specific computer index.

Grade	Number of computers for residents' exclusive use	Reference assignment
More than 1 times standard deviation	15.28	+5
More than 0.5 times standard deviation	11.77	+4
Standard value	8.26	+3
Less than 0.5 times standard value	4.75	+2
Less than 1 times standard deviation	1.24	+1

A.2. Scoring principle for qualitative data

A large proportion of the material from 69 communities arranged in this paper is qualitative. In order to facilitate quantifying the qualitative material, this paper endows marks according to two dimensions, i.e., clarity degree and execution level of the index.

(1) The clarity degree of the single index becomes gradually clear with the promotion of the smart community construction. Various clarity degrees are divided into a fuzzy phase and a distinct phase in this paper (see Table A3).

Table A3
Scoring principle for clarity degree of qualitative data.

Clarity degree	Specific performance	Scoring
Fuzzy phase	The community does not think deeply according to the index description in guidance standard for the smart community of Beijing city, or does not redefine the index.	+1
Distinct phase	The community specifies the standard indexes in view of its own actual situations and stores them with the material of language and character so as to facilitate instructing development of the smart community construction	+2

(2) Execution level endows marks according to actual implementation of the index to indicate the extent to which the index is executed. According to the execution level of the index, the material of the smart community construction is divided into low execution phase and high execution phase. The valuation is assigned with 1 mark in the low execution phase, and the high execution phase is endowed with 1 mark for an increase of 1–2 items each based on refined execution projects upon the single index, with the summed scores no more than 10. Based on the above-mentioned scoring principles, we coded the data and assigned scores for each variable (see Table A4).

Table A4
Outcomes and conditions measurement.

Outcomes/Conditions		Indicators
IA 1: Networking	High-definition interactive TV	0: No High-definition interactive TV; 1: High-definition interactive TV installed; 3. High-definition interactive TV installed with set-top boxes; 5: High-definition interactive TV installed with a coverage rate of less than 60%; 7: High-definition interactive TV installed with set-top boxes, and the coverage rate ≤90.17%; 9: High-definition interactive TV installed with set-top boxes, and the coverage rate ≥97%; 10: High-definition interactive TV installed with set-top boxes, and the coverage rate = 100%.
	Internet broadband	0: No broadband access; 1: Internet broadband access capacity ≤10 Mbs; 3: Internet broadband access capacity > 10 and ≤100 Mbs; 5: Internet broadband access capacity > 10 and ≤100 Mbs, and the coverage rate ≤76.45%; 7: Internet broadband access capacity > 10 and ≤100 Mbs, and the coverage rate > 76.45 and ≤86.8%, and there are at least 4 types of broadband access options; 9: Internet broadband access capacity > 10 and ≤100 Mbs, and the coverage rate > 86.8 and ≤97.58%, and there are at

(*continued on next page*)

Table A4 (*continued*)

Outcomes/Conditions		Indicators
		least 7 types of broadband access options; 10: Internet broadband access capacity = 100 Mbs (community ≥ 1000 Mbs), and the coverage rate of fiber broadband = 100%, and there are at least 8 types of broadband access options.
	Wireless network	0: No wireless network; 1: Expanded wireless network coverage; 3: Has a wireless network; 5: Full coverage of 2G/3G networks in the community; 7: Wireless network is provided in the community office and shops; 9: Full coverage of 2G/3G networks in the community, and wireless network is provided in the community office and shops; 10: Full coverage of 2G/3G network and wireless network in the community.
IA 2: Data warehouse,	Basic database	0: No community basic information database; 1: Basic information database established; 3: Clearly propose to establish basic information database or comprehensive information management system; 5: Basic information database or comprehensive information management system established (at least 2 types of information or data); 7: Basic information database or comprehensive information management system established (at least 4 types of information or data); 9: Basic information database or comprehensive information management system established (at least 6 types of information or data); 10: Basic information database or comprehensive information management system established (at least 7 types of information or data, such as population, geographic information, medical treatment and service.
	Basic service platform	0: No basic service platform; 1: Basic service platform established; 3: The basic service platform to be built is clearly proposed; 5: At least 2 basic service platforms established; 7: At least 4 basic service platforms established; 9: At least 6 basic service platforms established; 10: At least 7 basic service platforms established.
IA 3: Terminals	Computers for community workers	0: No computers in the community office; 8: One computer per person in the community office; 9: One computer per person in the community office and the total number is specified; 10: One computer per person in the community office, and there are also tablet computer, printer and other equipment.
	Computers for residents	0: No computers for residents use in the community; 1: There is an Internet Café free for residents in the community; 3: There are computers with Internet access for residents use in the community; 5: There is an Internet Café free for residents in the community, and there is at least 1 computer with Internet access for residents; 7: There is an Internet Café free for residents in the community, and there are 2-4 computers with Internet access for residents; 9: There is an Internet Café free for residents in the community, and there are 12-15 computers with Internet access for residents; 10: There is an Internet Café free for residents in the community, and there are at least 16 computers with Internet access for residents.
	Electronic information display screen	0: No electronic information display screen; 3: Electronic information display screen installed (≥1 and < 3); 5: Electronic information display screen and LED display screen both installed; 7: Electronic information display screen installed (≥3 and < 21); 9. Electronic information display screen installed (≥21 and < 30); 10: Electronic information display screen installed (≥30).
IA 4: Sensors	Environment monitoring system	0: No environment monitoring system; 1: Sensors installed; 3. Environment monitoring system installed; 5. Environment monitoring system installed and it is in use for real-time monitoring of the community; 7: Environment monitoring system installed and it is in use for real-time monitoring of the community (number of sensors < 56); 9. Environment monitoring system installed and it is in use for real-time monitoring of the community (number of sensors ≥443); 10: Environment monitoring system installed and it is in use for real-time monitoring of the community (number of sensors ≥637).
	Smoke and fire alarm system	0: No smoke alarm facilities; 1: Smoke alarm facilities installed; 3: Smoke alarm facilities installed as a pilot community; 5: Smoke and fire alarm facilities installed, and the name of the facility specified; 7: Smoke and fire alarm facilities installed, and the name of the facility specified, and the facilities are connected to fire departments; 9: Smoke and fire alarm facilities installed, and the name of the facility specified, and the facilities are connected to fire departments, and the coverage rate and number of facilities also specified; 10: Smoke and fire alarm facilities installed, and the name of the facility specified, and the facilities are connected to fire departments, and the coverage rate of the facilities is 100%.
IA 5: Payment	Electronic payment terminal	0: No electronic payment terminals; 1: Electronic payment terminals installed; 3: There are 2 types of electronic payment terminals; 5: There is one type of electronic payment terminal, and the number of electronic payment equipment is between 1-7; 7: There are 4 or more types of electronic payment terminals (or there are 2 types of electronic payment terminals and the

(*continued on next page*)

Table A4 (*continued*)

Outcomes/Conditions		Indicators
		number of electronic payment equipment is between 1-7); 9: There are 6 or more types of electronic payment terminals (or there are 2 types of electronic payment terminals and the number of electronic payment equipment is more than 23); 10: There are 7 or more types of electronic payment terminals (or there are 2 types of electronic payment terminals and the number of electronic payment equipment is more than 32).
BM 1: Public information	Channels	0: No community information dissemination channel; 1: There is only one information dissemination channel (brief description); 3: There is only one information dissemination channel (detailed description); 5: There are at least 3 information dissemination channels (< 5); 7: There are at least 5 information dissemination channels (< 7); 9: There are 7 information dissemination channels; 10: There are 8 information dissemination channels with the number of messages published.
	Daily life	0: No daily life information (e.g. weather forecast, farmers market, payment notice, etc.) published; 1: There is only one type of daily life information (brief description); 3: There is only one type of daily life information (detailed description); 5: There are 3 types of daily life information; 7: There are 5 types of daily life information and a list of contracted service providers and services; 9: There are 7 types of daily life information and a list of contracted service providers and services; 10: There are 9 types of daily life information and a list of contracted service providers and services.
	Public policy	0: No information on community policy; 1: There is only one type of information on community policy (brief description); 3: There is only one type of information on community policy (detailed description); 5: There are over 2 types of information on community policy (< 4); 7: There are over 4 types of information on community policy (< 6); 9: There are over 6 types of information on community policy (< 8); 10: There are over 8 types of information on community policy.
	Occupation	0: No information on employment and career; 3: Employment information provided; 5: Job referral services provided; 7: Employment information and job referral services provided; 9: Employment information platform established to provide employment information, job referral services, and related consulting services; 10: Employment information platform and localized employment website established to provide employment information, job referral services, related consulting services, and training for unemployed people.
	Safety	0: No security warning messages and notifications; 3: One type of safety warning provided; 5: 2 types of safety warning provided; 7: 3 types of safety warning provided; 9: 4 types of safety warning provided; 10: Information on extreme weather warning, emergency shelters, civil defense facilities, emergency evacuation is provided and emergency management plans and solutions provided.
BM 2: Facilities management	Applications of IoT and cloud computing	0: No IoT or cloud computing related applications; 1: IoT or cloud computing applications mentioned, but no further implementation; 3: There is one IoT or cloud computing application; 5: There are 2 IoT or cloud computing applications; 7: Remote meter reading and electronic payment of water, electricity, and gas; 9: Remote meter reading and electronic payment of water, electricity, and gas, and there are 2 IoT or cloud computing applications; 10: Remote meter reading and electronic payment of water, electricity, and gas; smart home appliance control; use new technology to improve garbage removal efficiency; and intelligent adjustment of street lamps.
	Vehicles management	0: No vehicle intelligent management system; 1: Vehicle intelligent management mentioned without further implementation; 3: There is one vehicle intelligent management system; 5: There are 2 vehicle intelligent management systems; 7: There are 4 vehicle intelligent management systems; 9: There are 6 vehicle intelligent management systems; 10: Vehicle intelligent management; automatic identification device installed; parking space screen installed; and electronic parking card in use.
BM 3: Healthcare service	Electronic health records and medical records	0: No residents' electronic health records and electronic medical records; 3: The community is promoting the use of residents' electronic health records and medical records; 5: There are electronic health records and medical records for residents; 7: There is information on electronic health file registration number and filing rate; 9: Personal health records, family health records, and electronic medical records are established, and there is information about the number of registered persons and filing rate; 10: Personal health records, family health records, and electronic medical records are established, and the filing rate is 100%.
	Medical services	0: No community medical services (such as online appointment and online referral); 3: Online registration available; 5: 2 types of medical services are provided; 7: 4 types of medical services are provided; 9: 6 types of medical services are provided; 10: 7 types of medical services are provided.
BM 4: Education service	Online education platform	0: Online learning platform (e.g. National Digital Culture Network) is not provided; 3: Online learning platform is provided;

(*continued on next page*)

Table A4 (*continued*)

Outcomes/Conditions		Indicators
		5: 2 types of online learning platforms are provided; 7: 4 types of online learning platforms are provided; 9: 6 types of online learning platforms are provided; 10: A diversified and lifelong online learning platform for community residents is established with over 6 types of online learning platforms accessible.
BM 5: Accessibility service	Community service for vulnerable groups	0: No services provided for vulnerable groups in the community (such as dining, haircutting, housekeeping, and maintenance); 1: Only one type of service provided for vulnerable groups in the community (brief description); 3: Only one type of service provided for vulnerable groups in the community (detailed description); 5: 3 types of services provided for vulnerable groups in the community; 7: 5 types of services provided for vulnerable groups in the community; 9: 7 types of services provided for vulnerable groups in the community; 10: Over 7 types of services provided for vulnerable groups in the community.

Table A5
Membership scores (level of subdistricts).

Subdistricts	Information architectures					Business models					Development level of smart community
	Networking	Terminals	Data warehouse	Payment	Sensors	Healthcare service	Education service	Public information	Accessibility service	Facilities management	
Anzhen	0.99	0.99	1	0.98	0.95	0.95	0.62	0.98	0.97	0.87	0.5
Aoyuncun	0.93	0.14	0.98	0.04	0.68	0.54	0.89	0.17	0.12	0.86	0.95
Chaowai	0.02	0.66	0.77	0.81	0.04	0.6	0.98	0.91	0.94	0.45	0.05
Jianwai	0.48	1	0.94	0.84	1	0.71	0.34	0.78	0.5	0.73	0.95
Shuangjing	0.44	0.95	0.18	0.98	0.92	0.53	0.5	0.97	0.83	0.76	0.73
Jingsong	0.88	0.4	0.18	0.57	0.97	0.96	0.96	0.96	0.95	1	0.3
Fatou	0.85	0.45	0.96	0.57	0.97	0.96	0.95	0.95	0.95	0.98	0.03
Jichang	0.26	0.86	0.65	0.45	0.67	0.5	0.9	0.95	0.95	0.91	0.4
Xiaoguan	0.08	0.22	0.77	0.04	0.83	0.05	0.47	0.68	0.93	0.95	0.5
Wangjing	0.42	0.9	0.29	0.97	0.5	0.58	0.05	0.7	0.01	0.78	0.88
Sanlitun	0.05	0.03	0	0.07	0.05	0.2	0	0.04	0.08	0.02	0.88
Liulitun	0.02	0.03	0.84	0.45	0.02	0.01	0.35	0.56	0.17	0.01	0.11
Balizhuang	0.24	0.86	0.86	0.22	0.83	0.5	0.02	0.39	0.28	0.05	0.73
Jiuxianqiao	0.99	0.86	0.43	0.75	0.55	0.98	0.84	0.93	0.61	0.99	0.05
Xiangheyuan	0.99	0.53	0.83	0.04	0.08	0.01	0.95	0.03	0.67	0.17	0.73
Maizidian	0.8	1	0.04	0.61	0.95	0.89	0.95	0.5	0.47	0.7	0.98
Tuanjiehu	0.83	0.03	0.05	0.19	0.16	0.23	0	0.15	0.05	0.91	0.88
Yayuncun	0.95	0.66	0.13	0.95	0.64	0.69	0.93	0.13	0.98	0.5	0.11
Hepingjie	0.95	0.35	0.62	0.92	0.15	0.69	0.09	0.82	0.87	0.1	0.05
Hujialou	0.02	0.86	0.52	0.05	0.05	0.33	0.09	0.01	0	0.14	0.95
Zuojiazhuang	0.73	0.05	0.95	0.45	0.22	0.5	0.06	0.06	0	0.09	0.95
Panjiayuan	0.8	0.08	0.43	0.8	0.67	0.33	0.6	0.23	0.76	0.05	0.95
Datun	0.38	0.1	0.75	0.05	0.14	0.44	0.81	0.41	0.72	0.35	0.03
Donghu	0.08	0.5	0.22	0.5	0.09	0.21	0.17	0.1	0.09	0.55	0.07
Taiyanggong	0.5	0.23	0.01	0.82	0.02	0.03	0.37	0.05	0.09	0.09	0.03
Jiangtai	0.95	0.54	0.49	0.29	0.12	0.31	0.55	0.62	0.85	0.3	0.05
Laiguangying	0.8	0.71	0.5	0.85	0.94	0.93	0.85	0.94	0.38	0.93	0.5

Table A6
Membership scores (level of communities).

Communities	Information architectures					Business models				
	Networking	Terminals	Data warehouse	Payment	Sensors	Healthcare service	Education service	Public information	Accessibility service	Facilities management
Anhuali	0.92	0.74	0.92	0.92	0.95	0.04	0.79	0.62	0.85	0.87
Anhuaxili	0.95	0.95	0.97	0.95	0.72	0.96	0.46	0.98	0.98	0.5
Anzhenli	0.82	0.66	0.98	0.99	0.92	0.73	0.69	0.95	0.99	0.88
Anzhenxili	0.91	0.82	0.89	0.95	0.92	0.95	0.2	0.97	0.95	0.78
Huangsi	0.95	0.89	0.96	0.92	0.72	0.95	0.4	0.97	0.96	0.38
Yuminlu	0.95	0.89	0.96	0.94	0.58	0.95	0.4	0.93	0.51	0.38
Beishatan	0.73	0.09	0.86	0.12	0.24	0.56	0.47	0.22	0.12	0.37
Dayangfang	0.39	0.38	0.79	0.05	0.36	0.5	0.7	0.18	0.12	0.84
Fenglinlvzhou	0.92	0.08	0.91	0.29	0.69	0.68	0.7	0.31	0.16	0.57
Guoaocun	0.44	0.69	0.08	0.05	0.39	0.5	0.95	0.18	0.12	0.49
Kexueyuan	0.88	0.08	0.92	0.08	0.08	0.5	0.47	0.07	0.57	0.61
Lincui	0.48	0.38	0.92	0.05	0.34	0.56	0.92	0.33	0.32	0.56

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Table A6 (*continued*)

Communities	Information architectures					Business models				
	Networking	Terminals	Data warehouse	Payment	Sensors	Healthcare service	Education service	Public information	Accessibility service	Facilities management
Longxiang	0.2	0.38	0.76	0.22	0.74	0.5	0.7	0.19	0.14	0.82
Lvsejiayuan	0.93	0.6	0.73	0.05	0.5	0.5	0.8	0.33	0.14	0.54
Nanshatan	0.5	0.19	0.85	0.05	0.93	0.5	0.96	0.07	0.5	0.65
Shuangquan	0.87	0.08	0.93	0.05	0.71	0.5	0.37	0.23	0.33	0.49
Wankexingyuan	0.92	0.08	0.95	0.04	0.91	0.5	0.92	0.81	0.62	0.99
Zongzhuang	0.95	0.38	0.86	0.04	0.12	0.5	0.79	0.06	0.14	0.41
Jixiangli	0.03	0.61	0.63	0.77	0.07	0.56	0.96	0.85	0.9	0.21
Beilangdong	0.43	0.91	0.92	0.84	0.9	0.5	0.58	0.86	0.71	0.32
Nanlang	0.16	0.92	0.15	0.79	0.98	0.65	0.37	0.56	0.05	0.69
Yonganlidong	0.39	0.92	0.85	0.7	0.99	0.74	0.14	0.75	0.5	0.39
Dawang	0.44	0.81	0.25	0.98	0.82	0.6	0.64	0.94	0.82	0.53
Guanghuan	0.17	0.72	0.25	0.88	0.76	0.4	0.23	0.9	0.63	0.52
Jinsongzhong	0.6	0.48	0.25	0.57	0.89	0.88	0.92	0.91	0.91	0.99
Cuichengyayuan	0.55	0.52	0.81	0.57	0.89	0.88	0.9	0.9	0.91	0.93
Nanpingli	0.18	0.69	0.56	0.5	0.54	0.5	0.8	0.89	0.9	0.76
Huixinbeili	0.07	0.32	0.63	0.07	0.68	0.14	0.37	0.68	0.88	0.85
Furongjie	0.2	0.5	0.25	0.94	0.39	0.35	0.08	0.31	0.08	0.57
Wangjingyuan	0.35	0.86	0.43	0.94	0.39	0.69	0.3	0.89	0.21	0.53
Xingfuyicun	0.05	0.08	0.01	0.11	0.08	0.31	0.07	0.05	0.22	0.03
Daojiayuan	0.03	0.08	0.67	0.5	0.05	0.05	0.33	0.61	0.26	0.02
Yuanyangtiandijiayuan	0.17	0.69	0.69	0.29	0.68	0.5	0.11	0.5	0.29	0.05
Yisiyuan	0.95	0.69	0.43	0.71	0.43	0.92	0.7	0.87	0.47	0.95
Xibahedongli	0.95	0.56	0.67	0.07	0.11	0.05	0.9	0.04	0.54	0.11
Chaoyanggongyuan	0.5	0.99	0.1	0.86	0.54	0.78	0.8	0.79	0.12	0.55
Nongzhannanli	0.75	0.97	0.1	0.15	0.93	0.78	0.94	0.42	0.12	0.19
Xiaguangli	0.48	0.91	0.1	0.9	0.77	0.78	0.9	0.55	0.68	0.54
Zaoyingbeili	0.58	0.95	0.1	0.29	0.95	0.78	0.88	0.22	0.39	0.27
Zaoyingnanli	0.26	0.5	0.1	0.29	0.86	0.8	0.94	0.67	0.51	0.67
Nanbeili	0.8	0.21	0.25	0.15	0.2	0.85	0.05	0.23	0.34	0.98
Sansitiao	0.82	0.05	0.05	0.15	0.12	0.14	0.07	0.09	0.58	0.75
Shuiduizi	0.69	0.05	0.13	0.53	0.85	0.69	0.03	0.17	0.05	0.72
Yiertiao	0.67	0.05	0.13	0.57	0.02	0.89	0.03	0.72	0.33	0.56
Zhonglubei	0.19	0.21	0.13	0.15	0.15	0.01	0.02	0.1	0.1	0.56
Zhonglunan	0.3	0.05	0.08	0.15	0.05	0.01	0.47	0.05	0.1	0.56
Anhuili	0.84	0.61	0.21	0.91	0.56	0.62	0.95	0.31	0.96	0.2
Huanyanbeilixi	0.66	0.61	0.21	0.91	0.46	0.62	0.63	0.08	0.95	0.26
Shisiqu	0.78	0.44	0.55	0.87	0.17	0.62	0.2	0.78	0.79	0.08
Jintaili	0.03	0.69	0.5	0.09	0.08	0.4	0.2	0.01	0.09	0.09
Sanyuanli	0.44	0.1	0.79	0.5	0.21	0.5	0.17	0.07	0.05	0.07
Huaweixili	0.3	0.08	0.82	0.87	0.69	0.4	0.4	0.1	0.5	0.05
Songyuxili	0.79	0.27	0.01	0.59	0.35	0.4	0.47	0.57	0.76	0.05
Anhuidongli	0.16	0.08	0.67	0.15	0.54	0.5	0.87	0.46	0.58	0.23
Huizhongli (No.2)	0.77	0.08	0.37	0.07	0.07	0.4	0.7	0.2	0.64	0.07
Yayunxinxinjiayuan	0.09	0.6	0.71	0.07	0.06	0.5	0.37	0.74	0.57	0.29
Nanhudongyuanbei	0.23	0.05	0.21	0.61	0.44	0.4	0.51	0.54	0.52	0.08
Wanghu	0.03	0.38	0.37	0.53	0.05	0.1	0.26	0.08	0.05	0.03
Wangjingxiyuan	0.05	0.97	0.31	0.35	0.05	0.54	0.09	0.03	0.33	0.91
Shizikou	0.23	0.27	0.08	0.84	0.09	0.01	0.05	0.08	0.52	0.04
Taiyanggong	0.1	0.82	0.04	0.95	0.03	0.5	0.87	0.17	0.08	0.15
Xiajiayuan	0.89	0.05	0.03	0.15	0.02	0.14	0.5	0.01	0.21	0.06
Fangyuanli	0.63	0.77	0.14	0.15	0.1	0.33	0.76	0.31	0.52	0.11
Fangushuijun	0.51	0.66	0.22	0.29	0.04	0.33	0.44	0.6	0.88	0.07
Shuianjiayuan	0.95	0.21	0.74	0.61	0.48	0.5	0.19	0.85	0.81	0.42
Qingniancheng	0.4	0.96	0.23	0.29	0.93	0.98	0.63	0.52	0.16	0.94
Xiujuyuan	0.81	0.72	0.4	0.98	0.96	0.91	0.69	0.93	0.82	0.96
Lianpayuan	0.31	0.08	0.57	0.07	0.5	0.62	0.4	0.9	0.05	0.8
Qingyuanlu (No.1)	0.53	0.5	0.54	0.96	0.63	0.4	0.95	0.96	0.42	0.09

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