smart cities

Article

People-Centric Service Intelligence for Smart Cities

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Abstract: In the era of big data, smart cities have become a promising prospect for governments, citizens, and industrials. Many ideas and their derived systems for smart cities depend on big data for achieving a goal of data intelligence. However, there is an urgent transformation trend from data intelligence to service intelligence in the vision of smart cities due to the living requirements of citizens. People-centric service intelligence in smart cities has to support the realization of people's needs within urban and social domains. This paper introduces a concept of people-centric service intelligence, defines the level of it and its challenges in the aspect of infrastructure, human dynamics, human understanding and prediction, and the human–machine interface. Then, this paper proposes the theoretical framework and technical frameworks of people-centric service intelligence, and the service intelligence schemas for future construction of smart cities. It will be helpful for governments and industries to design people-centric service intelligence for improving the quality of life, the capabilities of good sustainability, and better development.

Keywords: smart city; data intelligence; service intelligence; people-centric service

1. Introduction

The magnificent goals of smart cities include quality of life, sustainability, and development [1], which have already attracted a great deal of attention from researchers in an array of disciplines, such as urban planning [2–4], transportation [5–7], civil engineering [8], information science [9–13], surveying and mapping [14,15], commercial and logistics [16], energy [17,18], atmosphere and environment [19], society [20,21], tourists [22], governance [2,23], and industry in recent years. Although the proper definition of smart cities are still lacking [2], smart cities' goals are consistent to include smart living, smart people, smart environment, smart mobility, smart economy, smart governance [24], smart services, and smart infrastructure [25]. To achieve these goals, government and industry create and collect plenty of information related to smart cities' core components (land, infrastructure, people, and government) by using earth observation (EO) and information and communication technologies (ICT). Therefore, it launched an era of urban big data, which provides a promising vision of supporting smart cities.

By using urban big data, artificial intelligence (AI), and machine learning (ML), governments and industries built up many department-driven data engines to transform data, mash-up flows, accelerate data delivery, and develop augmented analytics for local governance or running business. They could be called as data intelligence for future endeavors. Data intelligence has become the primary facet of big data due to ambitiously powerful capabilities of descriptive, prescriptive, diagnostic, predictive, and decisive techniques. Thus, these works built up various kinds of information infrastructure to construct or practice smart cities.

The urban environment is designed for human beings. Although current department-driven data engines could provide work or living-related services to government, employees, or individuals under the framework of data intelligence, there still needs to be a drive for people-centric service intelligence due to the human demands for urban functions (residence, work, recreation, and transportation) according to The Charter of Athens (1933). Therefore, people-centric service intelligence is a natural paradigm shift in the era of big data. People-centric service intelligence is different from business intelligence (BI). BI comprises strategies and technologies used by enterprises for data analysis of business information, while people-centric service intelligence compromises the theories, strategies, and technologies deriving from and complying with the requests and demands of urban citizens. Their requests or demands may involve the authorized scopes of more than one department or company. Eventually, the intelligence in smart cities could evolve to civic intelligence [26]. Figure 1 provides the paradigm shifts of smart cities, which could be concluded as from data-driven intelligence to people-centric service intelligence and even to civic intelligence.

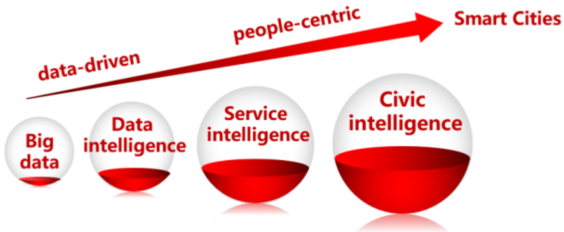


Figure 1. The paradigm shifts of smart cities.

People-centric service intelligence in smart cities has to support the realization of people's needs within urban and social domains (see Figure 2), for example, physiological, safety, love/belonging, esteem, and self-actualization needs according to Maslow's theory [27]. City provides critical resource services (i.e., environments, techniques, and infrastructure) to people, while the society support the mental needs of interaction, ethic, and culture. Both of them need to be designed and constructed with an appropriate level of service intelligence suitable to developed or developing cities.

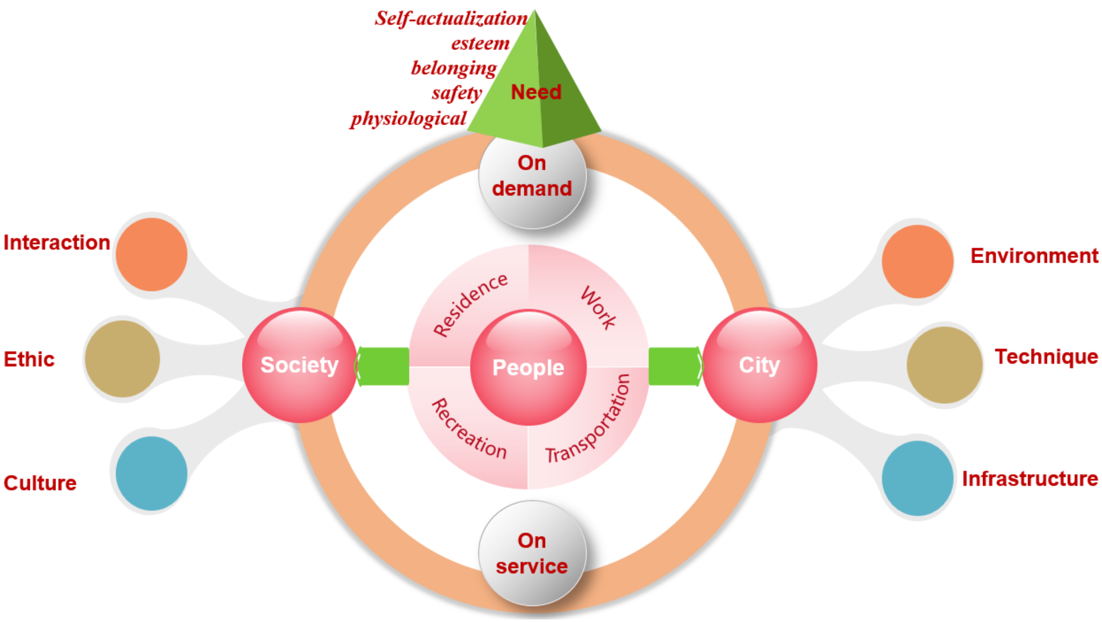


Figure 2. People-centric service intelligence within urban and society domains.

2. Related Works

Smart cities have been studied by a broad of disciplines, such as urban planning, transportation, civil engineering, information science, surveying and mapping, commercial and logistics, energy, atmosphere and environment, society, tourists, governance, and industry. Many researchers have reviewed the literature related to smart cities [1–10,28–37]. It could be summarized as three important aspects, namely, infrastructure, service, and culture.

In the aspect infrastructure, developing countries like China [38], Brazil, India, and others still have huge demand for designing and constructing basic hard infrastructure like buildings, city facilities (e.g., roads bridges, subways), and utilities (e.g., water, energy, waste, heat, etc.) [25,39,40]. Because smart cities try to address the challenges of growth, sustainability, and safety [41] the hard infrastructure in cities does not follow the same development path for cities all over the world. However, developed countries have moved to technology-enhanced infrastructure, which consists of array of physical assets, inventory of embedded, attached, and remote sensors, robust communication and data storage networks, and cohorts of asset managers [42]—for example, fiber Bragg gratings, self-monitoring materials, ground penetrating radar systems, active thermographic systems, and embedded electrical sensors—that allow users to monitor data from structures several hundred miles away. Also, many smart devices within detecting infrastructure, like street quality identification devices, support the novel monitoring workflow of maintaining infrastructure [42,43].

In the aspect of service in smart cities, information centric service supported by pervasive Information and Communication Technology (ICT) and Internet of Things (IoT) systems is a basic main feature in the current stage. For example, Piro et al. [11] summarized the information-centric service in smart cities, which embraces all available and upcoming wireless technologies and enforces ubiquitous and secure applications such as government and public administration, intelligent transportation systems, public safety, social, health-care, educational, and building and urban planning application domains. These information centric services will benefit the future internet-enabled services in open innovation environments [44]. Information infrastructure are also very important for the support of information centric services in smart cities, for example, Maas [45]. Many researchers studied the components of information infrastructure, for example, public–private partnership model based on OneM2M and OSGi solutions, eIDAS public digital identity systems, knowledge management perception systems, cold chains and shelf life of refrigerated foods, HCE-based authentication approach for multi-platform mobile devices, and cloud networking for IoT [46]. From the viewpoint of service architecture in smart cities, a three-layer architecture for smart cities was proposed [14]; namely, information layer, interface layer, and interaction layer. Similar works also were introduced by Anthopoulos et al. [47] and Su et al. [48]. A powerful architecture named ADAPCITY, which is a self-adaptive system for smart cities, includes physical, grid, management, and control layers. These service architectures could be built based on service-oriented architecture and event driven architecture [49,50]. In addition, smart city decision management or urban planning [51] could be empowered by real-time data (i.e., telemetry of smart-cities [52,53]) processing using big data analytics [54]. Most service platforms in smart cities are viewed as a new service economy [55] for supporting sustainable urban development [56].

In the aspect of culture in smart cities, Allam and Newman [2] reviewed the literature about the smart cities in terms of culture. They suggest a citizen-centered outcome-oriented approach rather than a technology-based, corporate-centered solution for smart cities, which is so-called 'smart culture' including urban culture heritage, urban creative industries, or the needs of citizens by promoting livability within cities. Currently, culture-led urban regeneration has become a prominent feature of cites in China, many characteristic towns or culture creation industrial zones have been built to drive economic development like industry, tourism, and so on. Therefore, the cultural and historical urban fabrics are respectful of urban culture. Cultural policy is also an important factor to keep urban culture [57–59], even the illness culture prevention [60].

The literature in the above three aspects of smart cities shows that current stage of smart city is very close to the approach of data intelligence, which needs a transformation to the approach of service intelligence in visions of smart cities. Importantly, there are several critical and emergent requirements [1,6–8] for assessing the intelligence level of smart cites and defining theoretical and technical frameworks [11,17,18] for the constructing smart cities, which are helpful to guide the construction of smart cities. These works have not been investigated very clearly in literature.

3. Levels and Challenges of People-Centric Service Intelligence

There are two important questions that need to be answered for the participation of research works and industrial development of people-centric service intelligence in smart cities. For example, how to define the levels of people-centric service intelligence, and what their research challenges are. The first question help us to judge the development level of service intelligence, and the second question is related to the challenge of creation in research and innovation in industry.

The levels of people-centric service intelligence could be categorized as seven classes listed in Table 1. Their narrative definitions are given in this table according to three basic rules, how they operate automatically, what the complexity and difficulty of services are, and what the hierarchy of needs they could meet is. Here, the service intelligence evolution from a low to high level indicates the transformation from sensing awareness to unawareness, from data-sensitivity to behavior sensitivity, from physiological needs to mental needs. The higher level of people-centric service intelligence, the more challenges exist in its realization.

Table 1. Levels of people-centric service intelligence

Intelligence Level	Name	Narrative Definition
Level 0	Without sensing	All service is artificial service. It does not involve the presents and helps of computers and any network of sensors.
Level 1	Sensing with awareness	Services with some observation and sensing technologies which people could feel the process of sensing.
Level 2	Sensing without awareness	Services with some observation and sensing technologies, but people could not feel the process of sensing
Level 3	Automatic services sensitive to behavior	Automatic services with sensitive sensing of and coordinating with human behaviors.
Level 4	Automatic services sensitive to preference	Automatic services with the cognizing of and coordinating with human preferences.
Level 5	Automatic services with mental esteem	Automatic services without the feeling of being tracked, used, unsafe, and others.
Level 6	Automatic services with self-actualization	Automatic services helpful to realize people's full potential, like perceptions, creativity, knowledge, spiritual enlightenment, transforming society and others.

To achieve people-centric service intelligence, researchers need to address challenges in the aspects of infrastructure, human dynamics, human understanding and prediction, human–machine interface.

Infrastructure is the basic support resource of people-centric service intelligence. Smart cities need user-friendly and intelligently physical, digital, and cultural infrastructure to facilitate people-centric services. The challenges of intelligence on infrastructure are human behavior-sensitive content by infrastructure, and the crowdsourcing information connection and integration among infrastructures. For example, how to design adaptive infrastructure for professional or business scenarios. How to assign spatiotemporal infrastructure resources for labor-, energy-, environment-, and cost-savings. How to connect crowdsourcing sensed information by infrastructure efficiently, and how to integrate this crowdsourcing information for promoting the intelligence level of services.

Human dynamics is the basic surrounding conditions on service intelligence. Shaw and Sui [61] conclude the core elements should be considered in human dynamics are from physical space to virtual space, from the historical to real-time, from the human to context, and which are changed by modern technologies, human-technology relationships and interactions. The intelligence challenge of human dynamics in smart cities includes the multi-space interactions (absolute space, relative space, relational space, and mental space) [61], aggregation effects of individuals and their spatiotemporal variation of components, cultures, and forces. For example, how to model human dynamics on the spatial structures of infrastructure. How to assess the aggregation effect of dynamic directionality and regularity, and how to model the effect of human dynamics on the service target.

Human understanding and prediction is an important dimension of people-centric service intelligence. The understanding and prediction of human behavior, called the next frontier by *Science* [62], could lead to a friendly on-demand service. However, current prediction models and approaches still need full understanding [63] of human behaviors. The understanding of human behavior is related to a broad spectrum of social, biological, health, physical, and spatial science disciplines. The intelligence challenge of human understanding and prediction includes (1) the perception, thinking, feeling, deciding, interacting, and acting of human beings; (2) the differences among individuals, groups, and cultures; (3) the influence of other human beings and environment; and (4) the explanation mechanism of prediction theories.

Human–machine interface (HMI) is the key approach to improving the satisfaction of people-centric service intelligence because intelligent HMI could reduce the interaction load of people in motion understanding and service recommendation. Current HMI is already improved by modern information and communication technologies (ICT), and some promising and innovative HMI approaches (i.e., eye motion [64], brain–machine interface systems [65,66]) are investigated by researchers in multi-disciplines. The intelligence challenges of HMI for smart cities include (1) the low-cost and ubiquitous HMI technologies within the urban environment; (2) people motion-driven and content-oriented HMI services based on multi-source information integration; and (3) transparent and culture friendly HMI with less media.

4. People-Centric Service Intelligence Framework

This section will introduce the theoretical and technical frameworks of people-centric service intelligence. These frameworks are obviously dependent on the people-related theories, which totally builds up the foundations of people-centric service intelligence in smart cities.

4.1. Theoretical Framework

Figure 3 illustrates the theoretical framework of people-centric service intelligence. This framework include six layers. The layer 0 is the computational intelligence in information and computer sciences, which provides the basic theories for implementing the top five layers. Layers 1 to 5 are corresponding hierarchies according to Maslow's theory [67]. The detailed theories could be explained as follows:

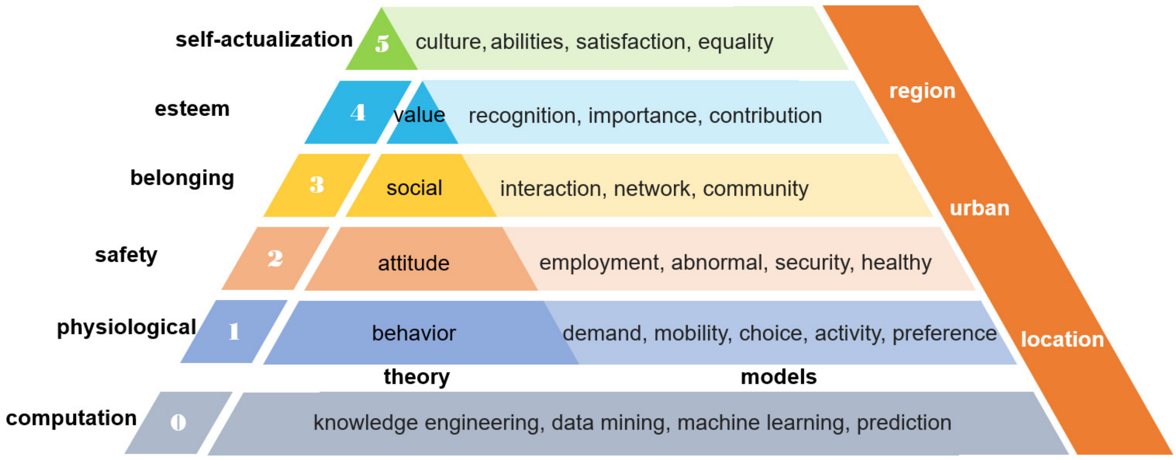


Figure 3. Theoretical framework of people-centric service intelligence.

The computation layer 0 is highly related to the computational implementation of people-centric service intelligence, for example, the knowledge engineering, data mining, artificial intelligence and machine learning, and prediction theories. These theories provide convenient, efficient, and powerful computational capabilities to define, code, embed, generate service intelligence from people-, society-, and environment-related big data.

The layer 1 is about the theory of behavior. Understanding human behavior is the first step to service intelligence. The models of demand, mobility, choice, activity, and preference are all related to the learning theory, cognitive theory, and reasoning theory of human behavior. Four most widely-used theoretical models of social and behavior theories include the health belief model (HBM) [68], the transtheoretical model/stages of change (TTM) [69], social cognitive theory (SCT) [70], and the social ecological model [71].

The layer 2 is about the theory of attitude. Safety is an important attitude for people's living. The theory of functional attitude [72] explains that the changing attitudes may involve generalization of change of belief and feeling. The evaluation of effective, behavioral, and cognitive components [73] of attitude is helpful to analyze attitude. Employment ensures a feeling of economic safety. Abnormal events in everyday situations and the security policies and actions formulate the feeling of environmental safety. Healthy attitude is derived from healthy living behaviors. Attitudes limit the effectiveness and practicability of service intelligence.

The layer 3 is about social theory. Social phenomena are also an important aspect of people's lives. Social theory examines how humans relate to each other and the society they find themselves in. Social interaction, social networks, and social community are some common concepts to understand the social instincts of human beings. Social belonging places limitations on the scope of service intelligence.

The layer 4 is about the theory of value. Personal values are investigated by value theory, which might changes under different situations. The value in the context of psychology and sociology, perceived by people have a great influence on their behaviors. The recognition of value is vital to applicability of service intelligence. The perception of importance and contribution to other people or society lead to feeling of esteem, which are necessary dimensions of constructing service intelligence. Most current studies depend on questionnaire surveys and participant observation, which could develop innovative approaches with the help of big data.

The layer 5 is about the theory of self-actualization. Self-actualization is the highest need in the hierarchy of Maslow's theory. Service intelligence includes the related theory of discovering and learning people's culture, defining their abilities, potential, aspirations, reaching equality in surrounding relationships and in society. To achieve these goals, the theory of self-actualization should be dependent on the integration and innovation of multiple disciplines. It is a promising paradigm for service intelligence, but it is still very difficult to define and realize it so far.

Besides the above layers, spatial thinking theory is also an important dimension to service intelligence. Every service relies on physical and virtual space to service people. Location, place, city, and region are critical spatial elements to support service intelligence. The manner of spatial thinking leads to the degree of acceptance of service intelligence, because effective matching between it and people's spatial thinking patterns is easy for people to follow up.

4.2. Technical Framework

Figure 4 illustrates the technical framework of people-centric service intelligence. It includes three layers, namely, infrastructure, data, and service layers. They could be called 'digital city', 'open city', and 'intelligent city'. All of them totally build up the prospect of a smart city.

The first layer of this technical framework is the digital city as an infrastructure layer. The digital city is viewed as critical infrastructure for a smart city. The key technologies of the digital city include soft infrastructure and hard infrastructure. (1) Soft infrastructure consists of people observation systems (POS), ICT and cloud infrastructure [74–76], professional processing systems [54,57,58,77,78], and others. People observation systems (i.e., closed circuit television; mobile phones; wearable devices like wristbands, glasses, helmets; eye-catching, ubiquitous approaches; etc.) observe activities and behaviors within outdoor or indoor environments. The ICT and cloud infrastructure provide powerful abilities for collecting, communicating, storing, and mining people-related data. The professional processing systems usually are designed for the time- or cost-saving of professional workflows, or the historical documentation of important information. (2) The hard infrastructure consists of earth observation systems, transport, and logistic systems [45], BIM (building information modeling) for buildings, facilities, and utilities. Earth observation systems (EOS) (i.e., camera systems, wave, light detection and ranging (LiDAR), and thermal imaging equipment in satellites, airships or airplanes, and unmanned aerial vehicles) and global positioning and communication systems (i.e., China BeiDou satellite navigation guiding and positioning system, US Global Positioning System) facilitate the ability to observe georgraphic changes such as land-use, atmosphere, landscape, and others. BIM is a process involving the generation and management of digital representations of physical and functional characteristics of buildings, facilities and utilities. BIM technology is an important profiling approach for a digital city. By using on the people observation system, the earth observation system and ICT, the infrastructure layer could observe earth changes, human dynamics including the people, social and political things. Importantly, the space-time and real-time GIS can play important roles of digitalizing, organizing, achieving cities, and providing fundamental space–time analytic functions for servicing cities.

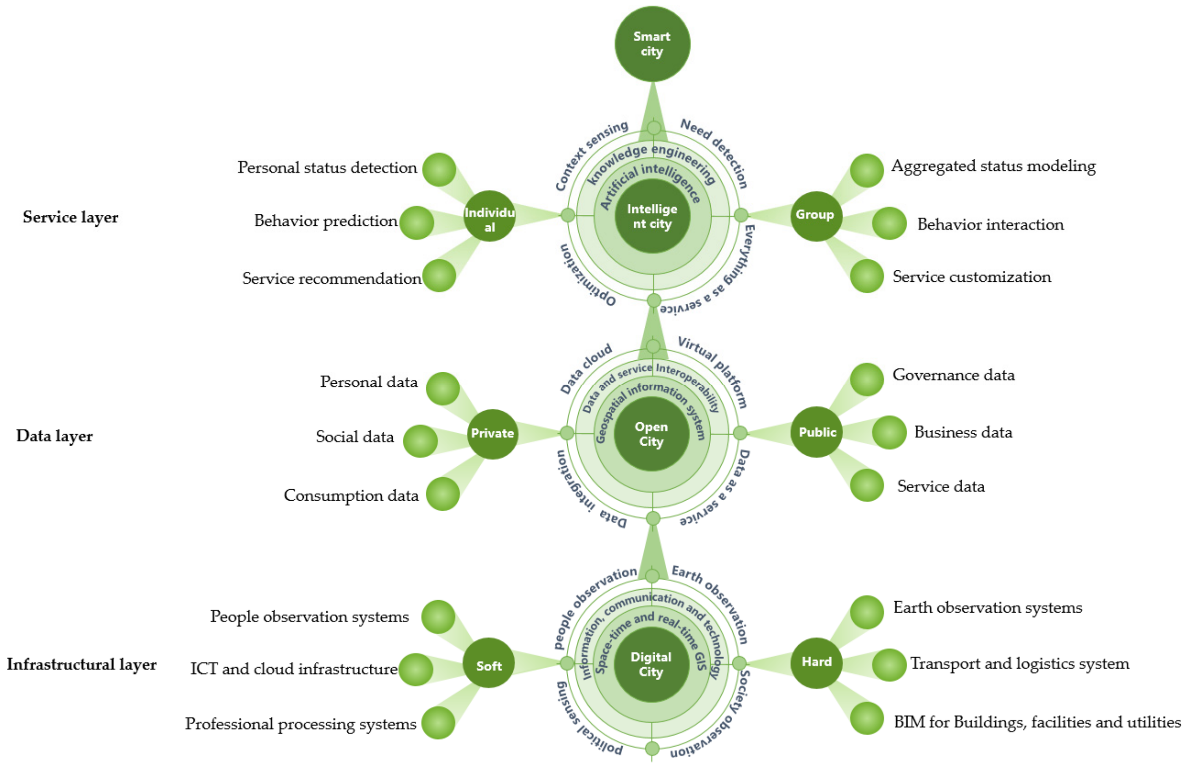


Figure 4. Technical framework of people-centric service intelligence.

The second layer of this technical framework is the open city as a data layer. Usually, the level of service intelligence is highly dependent on the openness of private and public data. However, openness and privacy are two instinct and opposite issues of service intelligence. How to balance the two issues is the most crucial research question for smart cities. For the perspective of the private or individual personal devices like smart phones and pads, wearable glasses, eye-motion devices, and so on, could help sense individual activities, schedules, and social interactions. Actually, many apps are collecting the individuals' data with the permission of users at the installation of them. Many CCTV cameras record individuals along the road or within indoor environments for the primary purpose of safety. Short-range internet service (i.e., Wi-Fi) at stores, restaurants, shopping malls, and hotels in cities also collects the appearance of individuals with Wi-Fi sensing devices for the purpose of providing data services. Mobile communication technologies record the trajectories of individuals at all times for the purpose of providing communications services. These technologies provide powerful sensing technical systems able to generate more and more personal, social, and consumption data. For the perspective of the public, government sectors, industries, and businesses build many governance or business systems which are based on geospatial information systems, because they need to relate the people and business to location or place. These systems create daily logs of the public. However, the independence of different sectors, departments, companies leads to a lack of data and service interoperability. Modern technologies like data clouds and virtual platforms facilitate a potential of implementing interoperability easily; meanwhile, it could also create powerful data integration technologies to support Data as a Service (DaaS).

The third layer of this technical framework is the intelligent city as a service layer. The intelligence of a city is not only dependent on the previous two layers, but also highly dependent on the intelligence mechanism for individuals and groups in the service layer. In the aspect of individuals, service intelligence needs to answer questions like, what about the individuals now? What they will do in the next period? What they will choose in their lives? Answering these questions requires solid support of sensing and analyzing technologies, such as personal status detection, behavior prediction and service recommendation. In the aspect of groups, service intelligence needs to answer questions like, what are the aggregated dynamics of groups? How do groups interact within different environments? How can we implement accurate customized services? The answering of these questions needs the solid support of aggregated status modeling, behavior interaction modeling, and differential service customization technologies. Basically, the foundation of these technologies for individuals and groups are spatial behavior theory, artificial intelligence theory, and knowledge engineering modules. The techniques could be summarized as context sensing, need detection, optimization, and Everything as a Service (XaaS).

The technique trajectory from digital city, to open city, to intelligent city actually builds up the three layers and their fundamental technique requirements. It will be a feasible approach to create service-on-demand technical systems for smart cities. The theoretical and technical frameworks could help the frameworks of smart cities to become more powerful [28–32,39,40,49,51].

4.3. Smart City Practices in Wuhan City: Linking of Theoretical and Technical Frameworks

This section uses the smart city practices in Wuhan city to explain the linking of theoretical and technical frameworks (Table 2). The infrastructural layer in Wuhan used camera, IoT, RFID, IC card, mobile internet, GPS/GIS and some other dedicated short-range communication technologies to build up people observation systems, integrates the ICT and cloud computing platforms to support the administrative service, medical and pension service, smart home and intelligent community management systems, and others. Many professional processing systems—for example, smart decision-making systems for governance, meat quality safety traceability information systems, sewage treatment operation management platforms, urban road and bridge non-parking charge systems—were built on a foundation of ICT and cloud infrastructure. The data layer collects many data sources related to people's living and mobility. The service layer provides administrative service, urban management service, health care service, safe food service, non-parking sensing service, campus education service, and so on. However, Wuhan city is only in the digital city stage, it still could not be called an 'open city' or 'intelligent city' according to the smart city criteria of the proposed framework. Current smart city practices in Wuhan city only cover the theoretical layer of computation, physiological, and safety conditions. There is a big gap to support the theoretical practices of belonging, esteem, and self-actualization.

Table 2. Smart city practices in Wuhan.

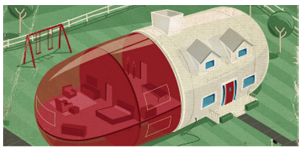
Projects	Functions	Components/Layers in People-Centric Service Intelligence Framework
 Administrative Service Center Information System (Wuhan)	Administrative Service Center Information System is developed by using IoT and cloud computing technologies to provide uniform, modern, and convenient administrative services for enterprises and the public. It realizes a modern comprehensive administrative service system that integrates various administrative services such as administrative examination and approval, public services, public resource transactions, government information release, and political administration.	Within theoretical framework: computational capabilities in layer 0, demand, mobility, activity in layer 1, Interaction in layer 3. Within technical framework: digital city, open city.
 Smart decision-making system for governance (JiangXia, Wuhan)	A digital governance platform is constructed under the framework of public geographic data platform is developed to provide integrated and intelligent services for government organizations and management, which also improves government decision-making ability by introducing e-government.	Within theoretical framework: computational capabilities in layer 0, demand, choice in layer 1. Within technical framework: digital city.
 Wuhan Digital City Management Public Service Platform	Wuhan Digital City Management Public Service Platform is built upon the idea of “everyone is a city manager”. A digital public service platform was built to form a model for discovering urban management problems based on professional grid supervisors and citizens. This system strengthens the interaction between the government and the citizens, improve the quality of urban management and services, and enhances the public's satisfaction with urban management.	Within theoretical framework: computational capabilities in layer 0, demand, activity, preference in layer 1. Within technical framework: digital city.
 Smart hospital (The Central Hospital of Wuhan) and intelligent medicine logistics	Modern communication technologies, such as, IoT, mobile internet, tri-network integration (telecommunications networks, cable tv networks, and the internet) are used to create new applications such as ward multimedia self-service information, mobile ward, medical internet of things, medical cloud computing platform, and medicine e-commerce project. The medicine e-commerce project used RFID, GPS/GIS, and cold chain logistics to full-time intelligent real-time tracking and management of drug procurement, storage, sales, and distribution.	Within theoretical framework: computational capabilities in layer 0, demand, choice, preference in layer 1, healthy in layer 2. Within technical framework:digital city.
 Smart Fisheries Pilot Project (Hannan District Animal Husbandry and Veterinary Bureau, Wuhan)	IoT sensing technology is integrated into the whole process of aquaculture production, management, and service, also the cloud computing platform is built to support the unified fine dynamic management of aquaculture. It represents the development direction of ‘smart agriculture’.	Within theoretical framework: computational capabilities in layer 0, demand, choice, preference in layer 1. Within technical framework: digital city.

Table 2. *Cont.*

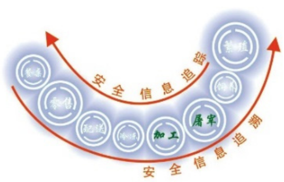
Projects	Functions	Components/Layers in People-Centric Service Intelligence Framework
 Meat quality safety traceability information system (Wuhan)	Meat quality safety traceability information system used IoT, RFID, IC card, mobile internet to track the production, processing, wholesale and retail of pork, through the collection, integration, processing, and storage of relevant data. It has formed a whole process from pig slaughtering, meat wholesale to retail terminals, and comprehensive safety supervision information network. It also sets up an information tracing system inquiry terminal in the hypermarkets, supermarkets, and bazaars of the city to provide 24/7 real-time service to the public.	Within theoretical framework: computational capabilities in layer 0, demand, activity, preference in layer 1, Healthy in layer 2. Within technical framework: digital city.
 "Wireless Guanggu" project (Guangu, Wuhan)	This project will achieve the goal of full area coverage of Wi-Fi in the main function zones like Optical Valley Software Park, Optics Valley Bio City, Optics Valley Financial Port, Optics Valley Pedestrian Street, Optics Valley Venture Street, International Student Pioneer Park, Optics Valley Creative Industry Base, International Enterprise Center, Ramada Optics Valley Hotel. This project demonstrates the potential value of a wireless city.	Within theoretical framework: computational capabilities in layer 0, demand, preference in layer 1, Interaction in layer 3. Within technical framework: digital city,open city.
 Urban Road and Bridge Non-Parking Charge (ETC) System (Wuhan)	Urban Road and Bridge Non-Parking Charge (ETC) System uses dedicated short-range communication technologies, including on-board units and roadside units, to realize charging information exchange between vehicles and bollards. The ETC system is also connected to more than 10 banks, 3 major communication operators, the Traffic Management Bureau, the Public Security Bureau, and the Finance Bureau. This system played an important role in tracking stolen vehicles, vehicles involved, and combating deck vehicles. Also, it provides real-time, massive traffic flow information for smart transportation.	Within theoretical framework: computational capabilities in layer 0, demand, mobility, choice, activity, preference in layer 1, abnormal, security in layer 2; network in layer 3within technical framework: digital city,open city.
 Intelligent parking lot management system (Wuhan)	Intelligent parking lot management systems will manage ETC vehicle owners' vehicle information, account information, and parking consumption information, released parking space information of the city's parking lot, which is not only convenient for vehicles to enter the parking lot to achieve non-stop traffic, but also it improves parking space utilization.	Within theoretical framework: computational capabilities in layer 0, demand, choice, preference in layer 1, security in layer 2, community in layer 3. Within technical framework: digital city,open city.
 Vehicle Network Public Service Platform Project	In the vehicle network public service platform project, the passive UHF RFID, ground coil, camera, floating car, and SOA+PaaS technologies are used to provide infrastructure-as-a-service (IaaS), software-as-a-service (SaaS), or platform-as-a-service (PaaS) to enable resource-based applications for car-related and driving-related information.	Within theoretical framework: computational capabilities in layer 0, demand, mobility, activity, preference in layer 1, employment in layer 2; network in layer 3. Within technical framework: digital city, open city.

Table 2. *Cont.*

Projects	Functions	Components/Layers in People-Centric Service Intelligence Framework
 "Wings travel" project (China Telecom Wuhan Branch)	"Wings travel" project releases traffic conditions of main and secondary classes of roads within the Third-Ring Road of Wuhan City. This system integrates 256 real-time videos and road condition sources to provide 24/7 transportation information releasing via computer screen, mobile phone screen, and TV screen.	Within theoretical framework: computational capabilities in layer 0, demand, activity, preference in layer 1, security in layer 2. Within technical framework: digital city, open city.
 Wuhan Geospatial Cloud Information Platform	Wuhan Geospatial Cloud Information Platform provides a three-dimensional digital map of the city's mega-city for supporting provincial and municipal geographic information services, forming a complete geospatial information cloud platform for construction standards. It is a critical component of Smart Wuhan.	Within theoretical framework: computational capabilities in layer 0, choice, preference in layer 1, abnormal in layer 2. Within technical framework: digital city.
 Intelligent weak current project (Yong Qing commercial zone, Wuhan)	Intelligent weak current project provides integrated security system, video intercom access control system, background music and economic broadcasting system, parking lot vehicle management system, smart home, and intelligent community management systems. It provides residents with an advanced, comfortable, safe, and reliable living environment.	Within theoretical framework: computational capabilities in layer 0, demand in layer 1, community in layer 3. Within technical framework: digital city.
 Sewage treatment operation management platform (Wuhan)	Sewage treatment operation management platform support automatic acquisition, real-time remote transmission and online display of SCADA data and video surveillance system data, combines expert experience and computer technology to achieve local optimization targets such as pump unit coupling optimization scheduling and aeration tank energy saving optimization control, and uses artificial intelligence and data mining technology to achieve optimal control and refined management of water enterprises.	Within theoretical framework: computational capabilities in layer 0, demand, activity, preference in layer 1, security in layer 2. Within technical framework: digital city.
 Intelligent pension platform (Wuchang, Wuhan)	Intelligent pension platform provides old person with a series of 60 services including housekeeping service, electrical maintenance, food purchase, humane care, entertainment learning, escrow and custody, and emergency assistance. This platform innovated the service model, technical model, and management model of old people, especially the elderly people over 60 years old, special care recipients, and difficult disabled people. Finally, it improved the level of socialized aged care services.	Within theoretical framework: computational capabilities in layer 0, demand, choice, preference in layer 1, health and security in layer 2. Within technical framework: digital city.

Table 2. *Cont.*

Projects	Functions	Components/Layers in People-Centric Service Intelligence Framework
 Smart Campus (Wuhan No. 2 Middle School)	Smart campus project provides education and teaching content information service, gate control channel management information service, social identification and service of student identity, campus security prevention and control, electronic student card campus card (including payment function), electronic student ID student location service (LBS), home-school education contact through internet and mobile terminal. This project aims to minimize the burden on teachers and education administrators, and pays close attention to solving people's major livelihood issues such as fair enrollment and balanced education that people care about.	Within theoretical framework: computational capabilities in layer 0, demand, mobility, choice, activity, preference in layer 1, security and health in layer 2. Within technical framework: digital city.
 "I show China" location-based service platform (Wuhan LiDe company)	"I show China" location-based service platform uses advanced air-ground integrated data acquisition technology, mobile measurement technology, real-time mapping technology based on cloud storage and cloud computing to create a real-time map big data service platform, which provides location search, environmental navigation, simulated driving, virtual tourism, and other location services and professional measurement service. This plafrom solves the problems of the accuracy, completeness, and intuition of geographic information in the construction of "smart city".	Within theoretical framework: computational capabilities in Layer 0, Mobility and activity in layer 1, Interaction in layer 3. Within technical framework: digital city, open city.

The image source in table is from the website: Http://Www.Wrisc.Cn/Wrisc/Demoproject/Projects.

5. Service Intelligence Schemas for Smart City

Schema usually describe the pattern of though or behavior that organizes categories of information and the relationships among them [59]. Schema thinking is decisive to computer-based learning theory and technologies especially in the era of big data. This paper concludes the schema thinking for smart cities as a series of evolution from database schema, mining schema, and knowledge schema to collective schema (Figure 5).

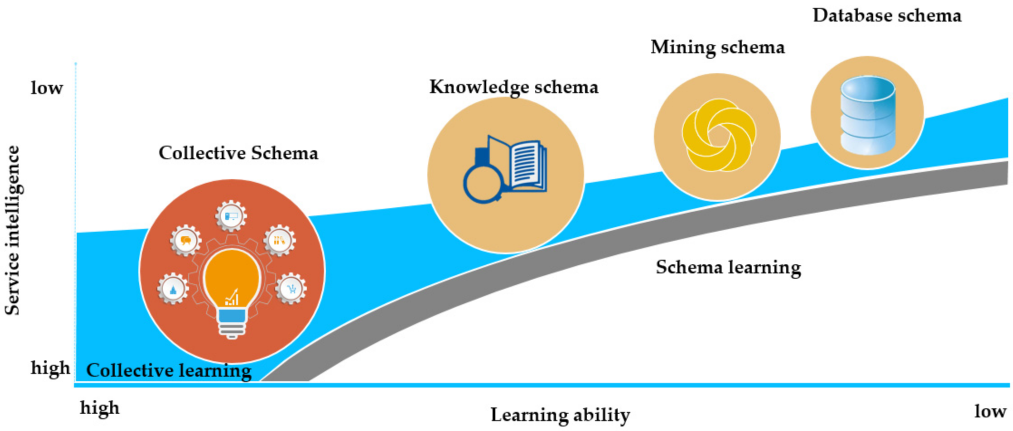


Figure 5. Research schemas of people-centric service intelligence.

The database schema is the lowest level of schema thinking, which is popularly used in all kinds of information management systems for sectors or companies. This schema defines all elements in database. These elements play roles in organizing the understanding of data, which naturally services end-users. This learning ability of this schema is the easiest one of four schemas. For example, the Administrative Service Center Information System in Wuhan city focuses on the data collection and administrative flow of government, which directly services the citizens with a powerful database engine and does not include more complicated service requirements.

The mining schema is relatively higher than the database schema. The most used technique is called as data mining. It involves related fields of machine learning, statistics, and databases, and includes the tasks of anomaly detection, association rule learning, clustering, classification, regression, summarization, and so on [27]. The mining schema could extract previously unknown, interesting patterns with a good learning ability to support service intelligence. For example, smart hospital project (The Central Hospital of Wuhan) and intelligent medicine logistics implement full-time intelligent real-time tracking and management of drug procurement, storage, sales, and distribution, which needs to mining the demand of drug according to the seasonal rhythms.

The knowledge schema is higher than the previous schemas. This schema focuses on the mathematical logic of problems or phenomena, and the deriving, maintaining, and development of knowledge about problems or phenomena. It is very helpful for problem solving methods. Knowledge involves the domain, inference, and task of problems. The intelligence of deriving, maintaining, and developing structured or non-structured knowledge is decisive to the solving quality of problems. For example, vehicle network public service project in Wuhan needs to know the driving behaviors within different routes, and the knowledge of adapting these behaviors and some abnormal vehicle behaviors and road-crossing behavior of pedestrians.

The future schema for smart cities is the collective schema. It focuses on the collective perceiving, processing, learning, and deciding of human beings in a pattern of collective thinking. The collective schema not only has influence on individual memories, consciousness, individual reasoning, but also plays an important role in collective intelligence of cognition, identity, localization, sensemaking, action, and capabilities. The schema matching or mapping and assembling are crucial processes to intelligent learning process even for machine deep learning, which could improve the level of service intelligence in applications of smart cities. For example, all of the above smart city practices in Wuhan city need to share their data and services to collectively contribute to the implementation of esteem and self-actualization.

6. Conclusions

This paper proposes the theoretical frameworks and technical frameworks of people-centric service intelligence, a promising concept for smart city research and applications. In these frameworks, all people's needs are classified as six layers (computational implementation, theory of behavior, theory of attitude, social theory, theory of value, and theory of self-actualization) according to the Maslow's theory. The implementation techniques of smart cities are organized in levels of 'digital city', 'open city', and 'intelligent city' according to the function divisions in computational implementation. Furthermore, this paper concludes the four service intelligence schemas for future construction of smart cities, namely, the database schema, mining schema, knowledge schema, and collective schema. The easiest approach is the database schema, and the most difficult approach is the collective schema. This paper suggests a promising collective schema for smart cities which focuses on the collective perceiving, processing, learning, and deciding of human beings in a pattern of collective thinking. It will be helpful for governments and industries to design people-centric service intelligence for improving the quality of life, capabilities of good sustainability, and better development.

The proposed concept of people-centric service intelligence and its implementation routes could change the current circumstance of data intelligence to meet the human demands on urban functions. It could enhance the capability of constructing smart cities in the aspect of infrastructure, human dynamics, human understanding and prediction, and human–machine interfaces. It will be a promising direction for smart city research and industrial developments. However, there are still some challenges in the implementation of the people-centric service intelligence in current stage. Multi- and crossing disciplines (urban planning, transportation, civil engineering, information science, surveying and mapping, commercial and logistics, energy, atmosphere and environment, society, tourists, governance, and others) should be involved together to solve its challenges.

We plan to improve our approach in several directions. First, the lack of detailed criteria or tools in classifying the level of people-centric service intelligence makes the assessment of smart cities more difficult. It should be carefully defined and validated in the future. Second, it would be valuable to implement and demonstrate this proposed frameworks by a real smart city case. Third, it would be valuable to develop practical service techniques to service urban planning, transportation, civil engineering, information science, surveying and mapping, commercial and logistics, energy, atmosphere and environment, society, tourism, and governance under the framework of the proposed theory.

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