

Article

How Do Smart Villages Become a Way to Achieve Sustainable Development in Rural Areas? Smart Village Planning and Practices in China

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Abstract: The sustainability of rural areas is facing numerous challenges in China. The Chinese government has chosen the construction of smart villages as an important strategy to realize the sustainable development of rural areas. In this paper, we define a smart village as a rural development model that fully utilizes the solutions provided by the information and communication technology (ICT) to promote the sustainable development of the village on the basis of clarifying the characteristics and needs of rural development. Combined with general system theory, we propose a theoretical framework of the smart village system. Based on the theoretical framework of the smart village system, we analyzed the smart village strategic planning and smart village practice in China. The results of the study showed that the construction and development of smart villages in disadvantaged rural areas is the correct choice for sustainable rural development according to the current situation in China. The Chinese government's role in promoting smart village construction has been to promote the smart village system's strategic subsystem to enhance smart rural areas' development through a unified overall plan and related supporting policies. The top-down smart village construction model currently adopted by China is determined by China's political and economic system, which is mainly reflected in the centralization of power and the public economy's dominance.

Keywords: smart village; sustainability; smart village system; rural areas; ICT; smart development

1. Introduction

The application of the concept of “smart” development in rural areas has gradually received increased attention. Although smart villages and their practices have received late attention compared with smart cities [1], people have many expectations for the sustainable development of rural areas through the smart village initiative and practice, especially in China. The concept of sustainable development originated from the need to stop the degradation of the natural environment and very soon was transferred to social and economic aspects of development [1]. Therefore, the connotation of sustainable development is usually linked with the sustainable development of the economy, society, and environment. When the concept of sustainable development refers to rural areas, the Chinese government defines it as “strong agriculture, beautiful villages and rich farmers” in response to the challenges faced by rural areas in China. The Chinese government proposed the implementation of the Rural Revitalization Strategy in 2017 and formulated the “National Rural Revitalization Strategic Plan (2018–2022)” in 2018 [2], and the “Outline of the Smart Village Development Strategy” in 2019 [3]. These plans intend to achieve sustainable development in rural areas by promoting informatization in various fields of villages, such as the rural economy, society, culture, and ecological

civilization, through overall planning. Furthermore, by exploring the large potential of information and communication technology (ICT), the Chinese government seeks to attain the result of upgrading agriculture, the progress of rural areas, and the overall development of farmers.

Can the sustainable development of rural areas be realized by villages becoming smart villages? Some studies mentioned that ICT and its components are not the only strategies and are not necessarily the most important in self-sustaining rural villages [4]. However, other studies have concluded that the smart village concept can be useful in facilitating the sustainable development of rural areas in Poland [1]. In China, different types of smart village practices have emerged. The Chinese government has also formulated strategic plans to ensure that the initiative and practice of smart villages can truly help villages achieve sustainable development. The main objective of this paper is to show how sustainable development can be achieved in rural areas through smart village strategic planning and practice in China. In order to understand the importance of smart village planning and practice, the problems and challenges in achieving sustainable development in rural areas in China are analyzed first. Later, a theoretical framework of the smart village system is established to help analyze the planning and practice of smart villages in China.

2. Challenges for Rural Areas to Achieve Sustainable Development in China

The urbanization rate in China reached 60.6% by 2020, which means that there are currently 551.62 million people in China still living in rural areas, and there are also 236 million people who live and work in cities while their household registration is still in rural areas [5]. The quality of life of nearly half of the people in China depends on the quality and level of rural development. Currently, the sustainable development of rural areas in China is facing several important challenges.

Firstly, there is a large gap in the level of economic development between urban and rural areas, and rural areas are trapped in poverty. Data show that the income growth rate of rural residents in China has slowed down, and the income gap between urban and rural areas has been widening. In addition, it is more difficult to reverse this course. In 2012, the per capita disposable income of urban residents in China was CNY 16,630.1 more than that of rural residents. However, by 2019, the gap widened to CNY 26,338, and the income gap between urban and rural residents had widened by 58.45% [6], as shown in Figure 1. The decrease in rural residents' income reflects the lagging development of agriculture and related industries in rural areas. Rural areas in China are dominated by traditional agricultural operations with relatively low production efficiency and economic benefits. In the process of China's industrialization, the countryside has gradually become a source of raw materials for industrial development in urban areas. In the process of China's rapid urban development, social resources such as capital, technology, knowledge, and talent have all flowed into cities, and the rural areas in China have declined under the pressure of cities [7].

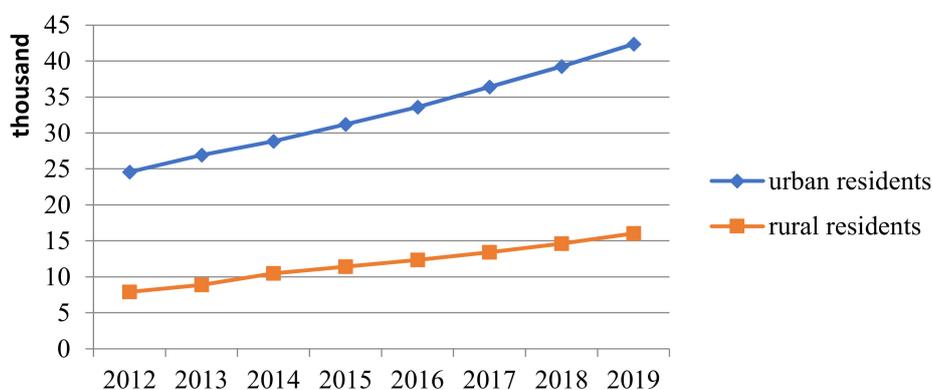


Figure 1. The per capita disposable income of urban and rural residents in China. Source: The Statistical Communiqué on National Economic and Social Development in China from 2012 to 2019.

Secondly, in terms of the quantity and quality of the public services available, there is a large gap between China’s urban and rural areas, especially in the fields of medicine and education [8]. In terms of basic living facilities, the gap in the living and environmental public facilities between urban and rural areas is all-encompassing. The gap between the rural and urban water penetration rates is 20.67%, the gas penetration rate gap is 68.11%, the sewage treatment rate gap is 76.74%, and the domestic garbage disposal rate gap is 26.31%, as shown in Figure 2. This shows that there is no good living environment in rural areas. In terms of education, the gap between rural and urban areas is not large in the following areas: the number of school buildings per student, the number of books per student, and the number of full-time teachers per 1000 students. However, in terms of the number of computers per student and the number of network multimedia classrooms per 100 students, cities are significantly better than rural areas. In terms of medical and health care, there is a large gap in the capacity of medical and health services between rural and urban areas. Cities have more than twice the number of health technicians, practicing (assistant) physicians, and registered nurses, and the number of beds in medical and health institutions per 1000 people, as shown in Figure 3. The gap in the quality of medical and health services is even greater. Both medical and health resources and high-quality services are concentrated in urban areas.

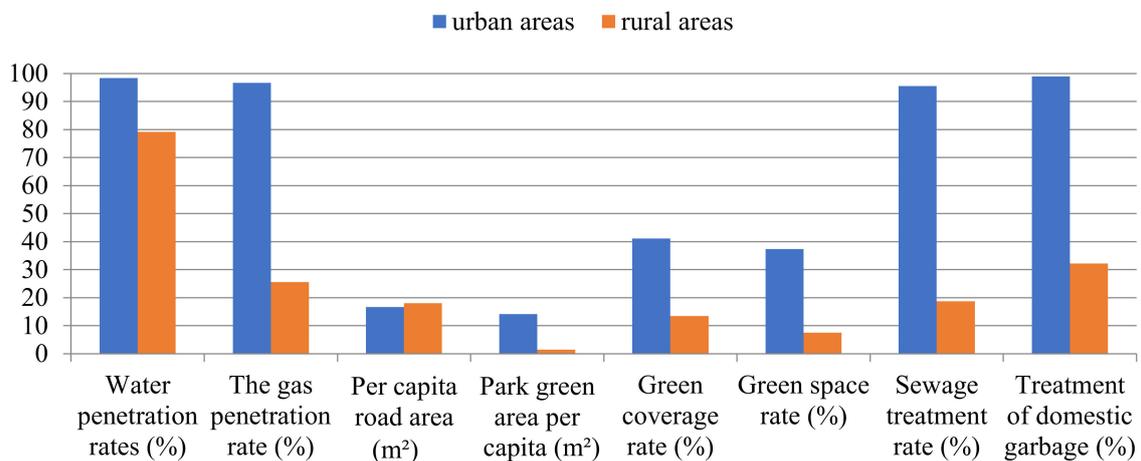


Figure 2. The basic living facilities of urban and rural areas in China. Source: “Urban and Rural Construction Statistical Yearbook in China (2018)”.

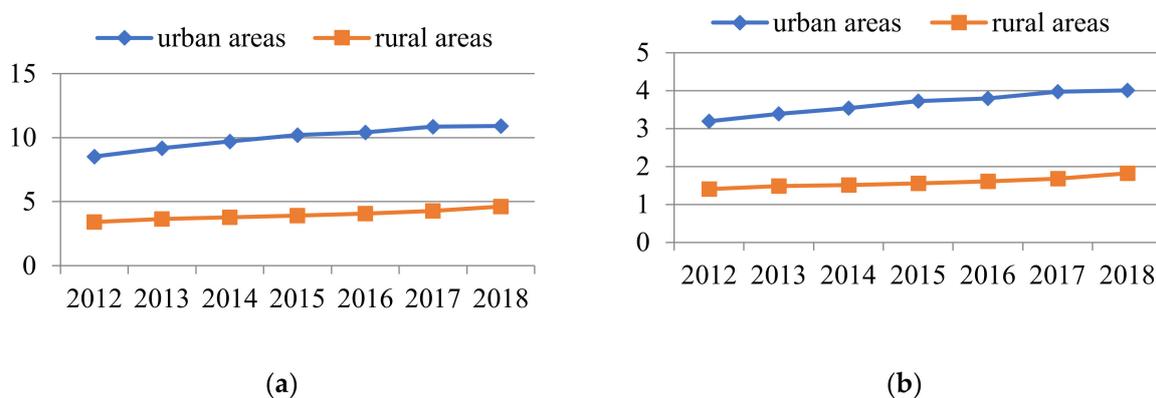


Figure 2. Cont.

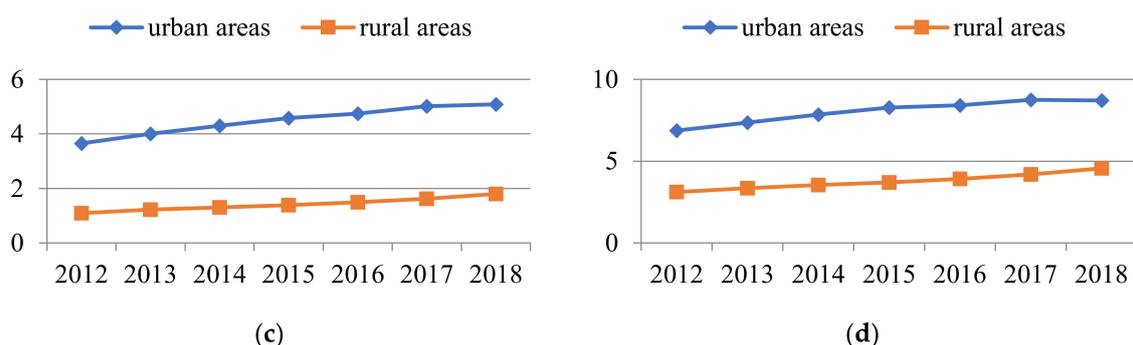


Figure 3. The gap in the capacity of medical and health services between rural and urban areas in China from 2012 to 2018. (a) Number of health technicians per thousand people; (b) Number of practicing (assistant) physicians per thousand people; (c) Number of registered nurses per thousand people; (d) Number of beds (pieces) in medical and health institutions per thousand people. Source: “Health and Family Planning Statistical Yearbook in China” and “Health Statistics Yearbook in China” over the years.

Thirdly, there is a clear digital divide between urban and rural areas in China. The 45th “Statistical Report on Internet Development in China” shows that, as of March 2020, the internet penetration rate in rural areas is 46.2%, while that in urban areas is 76.5%, as shown in Figure 4. As shown in Figure 5, the number of internet users in rural areas of China is 255 million, accounting for 28.2% of the total internet users. The number of internet users in urban areas is 654 million, accounting for 71.8%. In addition, the non-network users are mainly rural residents, accounting for 59.8% of the country’s non-network users in China [9]. The urban–rural digital divide poses a large challenge to the sustainable development of rural areas. Rural areas have fewer computer and network connections than urban areas, and the number of digital information tools such as mobile phones, color televisions, digital televisions, and computers is significantly less than that in cities. Many rural residents cannot benefit from the convenience brought by digital technology. For example, after the pandemic outbreak of COVID-19 in 2020, online teaching has been conducted in most parts of China. However, the broadband, video equipment and network coverage needed for these online classes are relatively underdeveloped in some remote rural areas. Children even run to the hillside to receive internet signals in some rural areas [10]. Due to the lag of rural informatization, the learning needs of children in rural areas cannot be fully met.

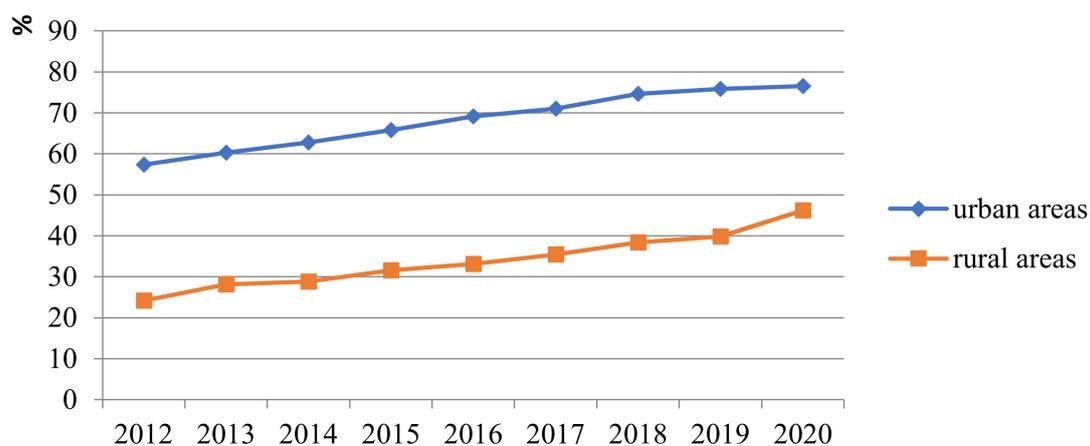


Figure 4. The internet penetration rate in urban and rural areas in China from 2012 to 2020.

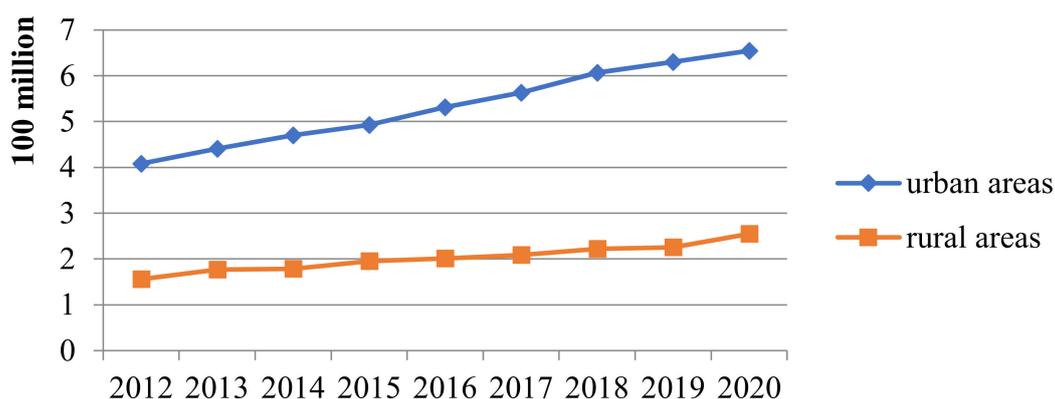


Figure 5. The number of Internet users in urban and rural areas in China from 2012 to 2020.

3. The Strategic Planning for Smart Villages in China

3.1. What Is a Smart Village?

The smart village concept can be defined as a rural development model that fully utilizes the solutions provided by ICT to promote the sustainable development of a village on the basis of clarifying the characteristics and needs of rural development. In “smart city” research, “smart” represents a solution brought by ICT to solve urban problems and promote urban innovation. When we apply the word “smart” to rural areas, it should be noted that rural areas are more regional and heterogeneous than cities, and the main functions of villages are quite different under different time and space conditions. Therefore, the key problems restricting villages’ development are not consistent [11]. The focus of smart villages should be based on the advantages/problems/challenges of the different types of villages and provide targeted solutions for them. As some scholars stated in their research, smart village research should be viewed more from the perspective of problem solving. Problem solving seeks to diagnose the problems in rural areas, and it offers a way of bypassing it by referencing ICT [12].

In the definition of a smart village, there are two other points that need to be emphasized: (i) Becoming a “smart village” is not an inevitable choice for villages, but it may be the most promising choice. Information technology is not the only choice for rural communities, and even in some cases, it is not the most important choice, but it is very important for urban and rural communities [4]. For future rural communities, the building and creation of “smart villages” has become the most promising choice under the situation of rapid urbanization and an increasingly severe urban–rural digital divide. This occurs because smart villages are a good opportunity to choose to connect with the current development of smart cities and seize the opportunities brought by the times to solve villages’ own problems with the solutions brought by ICT; (ii) Becoming smart villages is not the ultimate vision of rural areas, but rather it is a model, method and path adopted by villages to realize their own vision. The vision of a village is to realize the sustainable development of the village, which is related to providing villagers with better living conditions, sustainable economic growth, and an improved ecological environment. A “smart village” represents a village that has chosen such a development path to realize its own sustainable development, that is, to make full use of the solutions provided by ICT to solve the problems faced by the rural area and realize the optimized development of the village.

3.2. A Theoretical Framework of the Smart Village System

The theoretical framework of the smart village system is a systematic description of the smart village. It shows how to achieve sustainable development in rural areas through the construction of smart villages. We will combine general system theory and its analysis methods to analyze the elemental composition of smart villages, as well as the structural levels formed by the different elements

in the rural system. Finally, we will describe the smart village system formed by the interrelation and interaction of different elements according to the specific structural level as a whole.

3.2.1. Three Levels of Smart Village Systems Based on the Perspective of Complex Systems

General system theory was first proposed by L. von Bertalanffy, and it was introduced and developed by Kenneth E. Boulding in 1956 [13]. General system theory describes a level of theoretical model building that lies somewhere between the highly generalized constructions of pure mathematics and the specific theories of specialized disciplines. Through the arrangement of theoretical systems and constructs in a hierarchy of complexity, general system theory corresponds to the complexity of the “individuals” of the various empirical fields, and it shows a possible arrangement of “levels” of theoretical discourse. Boulding proposed a hierarchy of systems with 9 types from a low level to a high level, where layers 1–3 belong to the physical system, layers 4–6 belong to the biological system, layers 7–8 belong to the human and social system, and the ninth layer, which is more complex than the previous eight layers, is “unknowable things”, such as the “God concept”. In order to better understand “how this world is”, Chekland divides the systems created by humans in the evolution of natural systems into three categories: artificial physical systems, human activity systems, and artificial abstract systems [14]. Artificial physical systems are a collection of physical systems designed by humans to serve a certain purpose. The human activity system is a collection of human activities arranged consciously for a certain purpose or task. The man-made abstract system is a collection of ordered and conscious products created by mankind to represent the human spirit. According to the system classification proposed by Boulding, the complexity of artificial physical systems, human activity systems and artificial abstract systems ranges from low to high.

A village is a giant complex system composed of various elements, therefore in order to better analyze and study the smart village system, this paper divides the giant open complex system of the smart village into three levels with low to high complexity: artificial physical systems, human activity systems, and artificial abstract systems. Then, we abstract them into three levels: the physical layer, the activity layer, and the strategic layer [15,16]. The physical layer is located in the lower layer of the smart village system. It includes the material elements on which ICT depends, as well as the existence and physical forms of the material elements under the influence of the application of ICT. The physical layer is the material basis for a village to transform into a smart village. The activity layer is located in the middle layer of the smart village system. It reflects the new forms of people’s activities in production and life in the village under the influence of the application of ICT. The strategic layer is located at the highest level of the smart village system. It is the highest embodiment of “smart” presented by the rural system. Its “smart” nature is mainly embodied in its ability to guide and intervene in the transformation of rural areas into smart villages with scientific development strategies and plans.

3.2.2. Division of the Five Subsystems of a Smart Village Based on the Element–Structure–Function Perspective

From the element–structure–function perspective, the rural system is generally divided into three subsystems: the resource and environment subsystem, the economy subsystem, and the society subsystem [17]. Due to the particularity of a smart village, the strategic subsystem and the information subsystem are also two essential subsystems in the smart village system.

Firstly, the strategic subsystem is an essential element for the emergence of “smart” in village systems, and it is also an indispensable part of the sustainable development of smart villages. In the study of smart cities, some authors have stated that a holistic and comprehensive framework, which could conceptualize different components of a smart city and explain the strategic steps to follow, is needed. An integrated strategy is necessary to transform a city into a smart city [18]. Additionally, some authors believe that smart city research has a very strong normative bias, which promotes a vision of what could be done and how to use available ICT to make citizens’ lives easier without

necessarily reflecting on what needs to be done to effectively implement those suggestions. This calls for the inclusion of policy making and strategy planning in the conceptual framework of smart cities debate and for establishing a functional connection around the objective of sustainability [19]. Based on the above considerations, we propose a strategic subsystem that helps to plan and establish a smart village. Its connotations and functions are consistent with the strategic level.

Secondly, the information subsystem is also essential in the smart village system. The core difference between smart villages and non-smart villages lies in whether the solutions provided by ICT can be fully utilized to serve the sustainable development of the villages. The application of ICT requires the construction of information infrastructure and intelligent application systems and public information platforms to realize the coordination and integration of various intelligent application systems. Regarding the components of rural systems that perform these functions, this paper refines and summarizes them as “information subsystems”.

From the above analysis, it can be seen that the smart village system is composed of five subsystems that perform different functions, namely, the strategic subsystem, the social subsystem, the economic subsystem, the resource and environmental subsystem, and the information subsystem. The strategic subsystem is a collection of related planning, such as the strategic vision, goals, tasks, and implementation measures of smart village planning and building. It is mainly reflected in the strategic planning for the building of smart villages. The social subsystem is a collection of digital and intelligent operations presented by various activities in the fields of village governance and villagers' lives under the influence of ICT. It is mainly embodied in smart service applications in rural areas such as e-government, smart security, smart medical care, smart finance, smart elderly services, and smart education. The economic subsystem is a collection of digital and intelligent operations presented by various rural production activities under the influence of ICT. It is mainly reflected in smart agriculture, rural e-commerce, smart rural tourism, etc. The resource and environment subsystem is a collection of natural resources such as land, water, plants, etc., that support the operation and development of smart villages, as well as the ecological environment formed by their interaction. The information subsystem mainly includes information technology, information infrastructure, and public information platforms. Information technology includes perception technology, communication technology, network technology, application technology, information security, etc. The information infrastructure includes the Internet of Things (IoT), optical fiber broadband networks, wireless communication networks and other information infrastructure. Public information platforms include government clouds, business clouds, agricultural clouds, etc., and various intelligent application systems running on them. The five subsystems are interconnected and interact with each other, and together they constitute a large complex system of smart villages.

3.2.3. The Theoretical Framework of a Smart Village System Based on a Systematic Comprehensive Microanalysis Perspective

The comprehensive microanalysis method of the system is a scientific method used to analyze the subsystems and the relationships between the subsystems in a complex system. It describes a complete multibody system with a clear combination of macroscopic individuals and many clearly positioned microscopic individuals [20]. To better portray the smart village system, this paper describes the microstate of the smart village system with the strategic subsystem, the social subsystem, the economic subsystem, the resource and environment subsystem, and the information subsystem. Then, we describe the structural hierarchy of the smart village system with the low to high complexity of the physical layer, the activity layer, and the strategic layer. As shown in Figure 6, this paper constructs the overall system model of the smart village, namely, the theoretical framework of smart village systems.

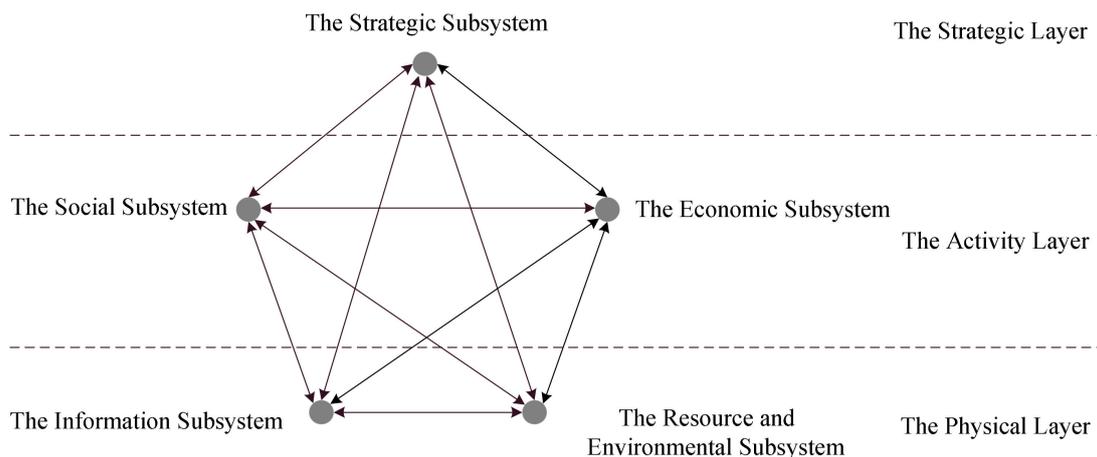


Figure 6. The theoretical framework of smart village systems.

3.3. The Strategic Planning of China's Smart Villages Based on the Perspective of the Smart Village System

The challenges faced by rural sustainable development have attracted great attention from the Chinese government. The Chinese government has proposed the implementation of a rural revitalization strategy and regards the building of smart villages as an important method and approach to achieve rural revitalization and sustainable development. The “Outline of the Smart village Development Strategy” [3] issued by the State Council of China in May 2019 is a programmatic document for China to comprehensively promote the construction of smart villages.

Combined with the theoretical framework of smart village systems proposed in this paper, we have sorted and displayed the smart rural development strategic plan proposed by the Chinese government in the “Outline of the Smart Village Development Strategy”, as shown in Table 1. Table 1 shows that the ultimate vision of China's smart rural development is to achieve sustainable rural development, which specifically expresses “strong agriculture, rich farmers, and beautiful rural areas”. In order to realize this vision, the Chinese government has formulated three-stage goals and formulated tasks and implementation measures. The strategic subsystem outlines the future development direction of the social subsystem, economic subsystem, resource and environmental subsystem, and information subsystem. In addition, it formulates the relevant goals, tasks, and implementation measures to ensure their development in the established direction. Moreover, we can see that in the resource and environment subsystem of the physical layer, with the help of the information technology and public information platform provided in the information subsystem, all kinds of substances and resources have changed their existence from the isolated and scattered state under the non-information state to the state of mutual intelligent connection. This transformation is of great significance in smart villages. Firstly, it can help the rural ecosystem in the resource and environment subsystem to achieve sustainable development with the solutions provided by ICT, and secondly, it can provide material support for the effective operations of various smart economic and social activities in the activity layer. In the strategic plan of the Chinese government, the smart economic and social activities presented in the activity layer of the smart village system mainly include rural e-government and smart public services in the social subsystem and smart agriculture, rural e-commerce, and rural smart tourism in the economic subsystem. This series of smart economic and social activities at the activity level will help the strategic level to achieve the vision of “strong agriculture, rich farmers, and beautiful rural areas”.

Table 1. The strategic planning of China’s smart villages.

Dimension	Planning Content
The Strategic Subsystem	<ul style="list-style-type: none"> • The vision: let agriculture become a vigorous industry, let farming become an attractive profession, and let the countryside become a beautiful home for living and working. • The goals: by 2020, preliminary progress will be made in the construction of smart villages. By 2025, important progress will be made in the construction of smart villages. By 2035, great progress will be made in the construction of smart villages. • The tasks: accelerate the construction of the rural information infrastructure, coordinate the development of urban and rural informatization, build smart and green villages, develop the rural smart economy, promote smart governance in rural areas, and strengthen the supply of smart services. • The implementation measures: strengthen the organization and leadership of government departments, introduce related supporting policies, conduct pilot demonstrations of smart villages, strengthen the support of various talents in the construction of smart villages, and create a good atmosphere.
The Social Subsystem	<ul style="list-style-type: none"> • Rural smart government related measures include: (i) realizing the online disclosure of rural party, village and financial affairs; (ii) relying on the national data sharing and exchange platform system to promote the sharing, opening, and effective integration of agricultural government information resources in various departments; and (iii) relying on the national integrated online government service platform to accelerate the promotion of e-government service reforms such as “run at most once” and “no-face approval” in rural areas. • Rural smart education related measures include: (i) realizing full broadband network coverage in rural small-scale schools and township boarding schools; and (ii) realizing the connection of urban high-quality educational resources with rural primary and secondary schools. • Rural smart medical care related measures include: (i) supporting township- and village-level medical institutions to improve their informatization level; and (ii) realizing the direct settlement of basic medical insurance and the online transfer and continuation of social insurance relations for urban and rural residents for medical treatment in different places.
The Economic Subsystem	<ul style="list-style-type: none"> • Smart agriculture related measures include: (i) laying the foundation for the development of smart agriculture in all aspects, such as improving the “one picture” of remote sensing monitoring of natural resources and the comprehensive supervision platform, building space-based facilities such as those for remote sensing satellites for agriculture and rural areas, and promoting the construction of agricultural and rural big data centers and the entire industrial chain of important agricultural products; and (ii) promoting the in-depth integration and application of ICT within the planting industry, seed industry, animal husbandry, fishery, and agricultural product processing industry. • Rural e-commerce related measures include: (i) implementing the “Internet +” agricultural product export project from the village to the city; (ii) building a batch of smart logistics distribution centers; and (iii) cultivating rural e-commerce product brands. • Smart rural tourism related measures include: (i) developing new business formats such as creative agriculture, adoption agriculture, sightseeing agriculture, and urban agriculture; and (ii) promoting the development of new industries such as recreation, health and creative homestays.
The Resource and Environmental Subsystem	<ul style="list-style-type: none"> • Promote smart and green agricultural production methods, such as establishing an electronic traceability supervision system for agricultural inputs to promote the reduction in the use of fertilizers and pesticides and using the Internet of Things (IoT) technology to monitor land moisture in real time and promote water conservation in farmland. • Protect the rural ecological environment with ICT. The related measures include: (i) establishing a national rural ecosystem monitoring platform; (ii) strengthening the monitoring and protection of the farmland soil ecological environment; and (iii) using satellite remote sensing technology, drones, and high-definition remote video monitoring systems to implement key monitoring of vulnerable and sensitive areas of rural ecosystems. • Build a comprehensive monitoring platform for the rural human settlements environment to realize the monitoring and protection of the quality of drinking water sources in rural areas, as well as the full-time monitoring of rural pollutants and pollution sources.

Table 1. Cont.

Dimension	Planning Content
The Information Subsystem	<ul style="list-style-type: none"> To improve the level of rural network facilities, related measures include: (i) strengthening the joint construction and sharing of infrastructure and accelerating the development of rural broadband communication networks, the mobile internet, digital television networks and the next-generation internet; (ii) supporting the development of broadband networks in rural areas; and (iii) promoting the basics and upgrading of broadcasting and television facilities in rural areas. Improve the supply of information terminals and services, mainly by encouraging the development of information terminals, technical products, and mobile internet application (app) software packages that are adapted to the characteristics of “agriculture, rural areas and farmers”. Accelerate the digital transformation of rural infrastructure, that is, develop smart water conservancy, smart transportation, smart grids, smart agriculture, and smart logistics in rural areas.

4. Smart Village Practices in China

Before the Chinese government issued the “Outline of The Smart Village Development Strategy” in 2019, due to the impact of smart city practices, some smart village practices had already emerged in rural areas in China. Related typical practices are as follows, and their geographical distribution in China is shown in Figure 7.



Figure 7. Distribution of typical smart rural cases in China.

- The pilot “Smart Cloud Village” IoT project in Anhui Province has greatly facilitated smart navigation in rural areas [21]. This project installs interconnected information collection terminals in the village committees and installs cloud IoT landmarks at the entrances, exits, and key intersections of the villages. The built-in navigation chips in cloud IoT landmarks can send geographic data to the navigation system. The project established a powerful IoT information

- collection station with an interconnected information collection terminal, the famous cloud Internet of Things technology, and a 3G multimedia camera. After the information is collected, it is sent to the main control station (public information platform) via the internet. Then, after cloud computing completes the screening and processing of the information, the master console packages the processed information and feeds it back to the corresponding site, thereby serving the intelligent application fields of rural transportation and security.
2. The smart agriculture implemented in Xibodian village, Pinggu district, Beijing has realized the intelligent management of agricultural production and the safe traceability of agricultural products [22]. The 42 greenhouses in the village are equipped with a greenhouse IoT intelligent monitoring system, which uses sensors to collect information such as air temperature, air humidity, soil temperature, soil humidity, light, carbon dioxide, growth pictures, and weather outside the greenhouse. At present, 42 greenhouses have realized the real-time collection, analysis, data monitoring and early warning of production environment data; eight greenhouses have realized video monitoring; and two high-end greenhouses have realized the remote automatic control of irrigation and the remote automatic control of rolling shutters, which have achieved the intelligent management of agricultural production. Moreover, through the installation of a product traceability system, the daily agricultural operations of growing crops in the greenhouse can be browsed through the QR codes printed by the traceability system, which improves the safety of agricultural products.
 3. Rural e-commerce in Shandong and Guangxi provinces helped to effectively solve the problem of poor sales of rural agricultural products [23]. Through cooperation with the domestic e-commerce platforms Alibaba and JD.com, villages in Yantai city, Shandong Province realized the online ordering and offline receipt of famous fruits such as Yantai apples, Laiyang pears, and Fushan cherries, which solved the problem of agricultural product sales. Guangxi Xincheng has also realized the online sales of more than 80 special agricultural products such as passion fruit, blueberries, native chickens, and fragrant pigs through the establishment of the “Smart Village Baihu” system and internet platform, which has lifted more than 30,000 poor people out of poverty.
 4. The shared vegetable garden in the rural areas of Haikou city, Hainan Province has created a new model of smart rural tourism in China [24]. The shared vegetable garden sells agricultural products across the country through the internet. Consumers can experience farming work in their own vegetable fields in the shared vegetable garden during their leisure time, and local farmers provide farming management services in daily life. This method provides farmers with more employment opportunities and promotes farmers’ income, as well as enhances the experience of tourists and vegetable buyers and provides new channels for the development of rural tourism.
 5. The Smart Village Doctor Health Poverty Alleviation Project in Fuzhou, Jiangxi Province enables villagers to access expert services from major hospitals at their doorsteps [25]. This project has established an intelligent medical service system with three-network integration, data sharing, remote medical treatment, and graded diagnosis and treatment among medical institutions at the village, township, county, and city levels. The village health service center records the villagers’ blood pressure, blood lipids, blood sugar, electrocardiograms, and other inspection results in the villagers’ health files and sends relevant data to the service platform. The doctor can contact the village clinic in time based on the data and initially determine the patient’s treatment plan. Village clinics can provide effective treatment to patients according to treatment plans, and remote consultations can also be conducted through mobile video.

In China, the implementation and promotion of smart village strategies have good foundations. Before formulating and implementing smart village strategies, the Chinese government advanced some work in five smart village subsystems; rural areas also have different practice levels in these areas. The overall situation of the relevant smart village practices in China is shown in Table 2.

Table 2. The overall development status of China’s smart villages practices.

Dimension	Practice Content
The Strategic Subsystem	<ul style="list-style-type: none"> • “National Rural Revitalization Strategic Plan (2018–2022)” • “Outline of the Smart Village Development Strategy” • “Digital Agriculture and Rural Development Plan (2019–2025)”
The Social Subsystem	<ul style="list-style-type: none"> • Rural smart government: The Ministry of Agriculture and Rural Affairs of China has integrated and optimized 67 business sub-items, completed 45 full-process optimizations and transformations, and added administrative confirmation and online public service matter sub-items to more than 30 departments of 11 units. China’s National Data Sharing and Exchange Platform has opened more than 1200 data service interfaces in agricultural and rural areas, providing 719 million online data queries and verifications, supporting 51.2 billion data exchanges across departments and regions. • Rural smart education: the internet access rate of primary and secondary schools (including teaching sites) nationwide in rural areas increased from 79.2% at the end of 2016 to 98.7% in August 2020. • Rural smart medical care: China has opened 269 internet hospitals, and 19 provinces have built a unified planned provincial telemedicine service platform. Thirteen thousand Chinese medicine clinics in various regions have connected to the Chinese medicine clinics’ health information platform to ensure that rural areas can effectively access high-quality medical service resources.
The Economic Subsystem	<ul style="list-style-type: none"> • Smart agriculture: corresponding information platforms and intelligent application systems have been established in various fields of agricultural products such as plantations, livestock and poultry breeding, and fisheries. The current national pesticide quality traceability system has collected 901 pesticide production licenses and 190,000 business licenses and has generated approximately 3.8 billion traceability codes. A basic database that includes both processing quality and the special quality of bulk agricultural products has been established. The digital level of agricultural production has reached 18.6%. • Rural e-commerce: as of the end of 2018, more than 9.8 million rural e-commerce companies were in China. The coverage rate of e-commerce service sites in administrative villages reached 64%. The country and township coverage of express delivery outlets reached 96.36%. National rural online retail sales were CNY 1.37 trillion, a year-on-year increase of 30.4%. • Smart rural tourism: as of 2019, 71.5% of rural tourism operators in China have online payment and reservation systems, and the wireless network coverage of rural tourist spots reached 84.0%.
The Resource and Environmental Subsystem	<ul style="list-style-type: none"> • Intelligent rural ecological environment protection: through remote sensing surveys of local data on river and lake governance, approximately 5800 key issues of suspected “random occupation, random mining, disorderly piles, and disorderly construction” were screened out. More than 3000 reported problems were collected through the river and lake inspection app, which effectively supports river and lake management and supervision work.
The Information Subsystem	<ul style="list-style-type: none"> • Informatization in rural areas: as of the end of 2018, 96% of administrative villages had fiber-optic connections, and 95% had 4G network coverage. There were 99.7% telephone penetration rates and 98.1% cable TV signal penetration rates.

Source: “China Smart Village Development Report (2019)”.

However, the smart village practice in China also has some problems, and the most prominent problem is the lack of overall planning and design. The construction of smart villages in China is in the bottom-up stage of independent exploration by various regions. The current practice is based on local governments, enterprises, and institutions rather than villages. Various smart application functions developed and established in different places are still in their respective application state, and systemic coordination is yet to be conducted [26]. Therefore, to promote the construction of smart villages, comprehensive, unified smart village planning and design is urgently needed. The “Outline of the Smart Village Development Strategy”, which is mentioned above, will play an important leading role in the overall planning and design of smart village practices in China. At the same time, in order to better promote and implement the smart village strategy, China is currently conducting pilot work on smart villages. In July 2020, China’s Central Cyberspace Administration and seven other departments jointly issued the “Notice on the Implementation of the National Smart Village Pilot” to deploy the national smart village pilot work, and announced 117 counties (cities, districts) as the national pilot area for smart villages in September 2020. The regional distribution of the 117 pilot counties (cities, districts) in China is shown in Figure 8. In the next step, the Chinese central government will summarize the replicated and popularized practices and experiences generated in the pilot areas, exchange experience in typical cases, and promote them nationwide.



Figure 8. Distribution map of smart village pilot areas in China.

In addition, there is another outstanding problem in the practices of smart villages in China, which is the problem of regional imbalance and strong rural heterogeneity. The bases for rural informatization in different regions in China are quite different. Due to the different levels of economic development, the eastern region in China has a relatively good informatization foundation, while the central and western regions are relatively poor [26]. Moreover, due to the strong regionality and heterogeneity of villages, the functions and developmental characteristics and key problems of different villages are inconsistent [12]. Therefore, different smart villages should focus on different areas. For example, some villages may have relatively developed agriculture and are suitable for smart agriculture; some

villages have rich tourism materials and are suitable for smart rural tourism; some villages have a good business foundation and are suitable for rural e-commerce; and some villages both have better information infrastructure and an urgent need for high-quality public services, which means that they can develop smart public services such as smart healthcare and smart education. The building of smart villages is not the comprehensive construction of smart solutions mentioned in the “Smart Village Development Strategy” in every village, but each village chooses to develop one or several smart solutions based on its own problems, characteristics, advantages and disadvantages.

Figure 9 shows the proposed basic structure for smart villages based on a smart village system theoretical framework and the “Outline of the Smart Village Development Strategy” analyzed in this paper. The construction of a smart village is not to develop all the contents listed in Figure 9 in a village. The correct approach is first to determine the type of smart village the community needs to become based on its characteristics, advantages and disadvantages. At the strategic level of Figure 9, we list several typical smart village types, including “smart agricultural villages”, “smart public service villages”, “e-commerce villages”, “smart tourism villages”, and “comprehensive development type smart villages”. For example, if a village is more developed in agriculture, it may want to develop into a smart agricultural village. Then, at the activity level, it should focus on developing “smart agriculture” in the economic subsystem and agricultural product-related parts in rural e-commerce and rural smart logistics. The information subsystem of the physical layer focuses on building an agricultural cloud platform. The physical layer’s resource and environmental subsystems focuses on building smart water conservancy systems, electronic traceability monitoring systems for agricultural inputs, and smart farmland water-saving systems. Of course, some of the information infrastructure and information terminals of the information subsystem in the physical layer are mandatory options, regardless of what type of smart village is built. Therefore, for the construction of smart villages in different villages, special top-level designs for different villages should be carried out following the unified national standards to ensure that smart village construction can truly help a village solve its problems and realize sustainable development.

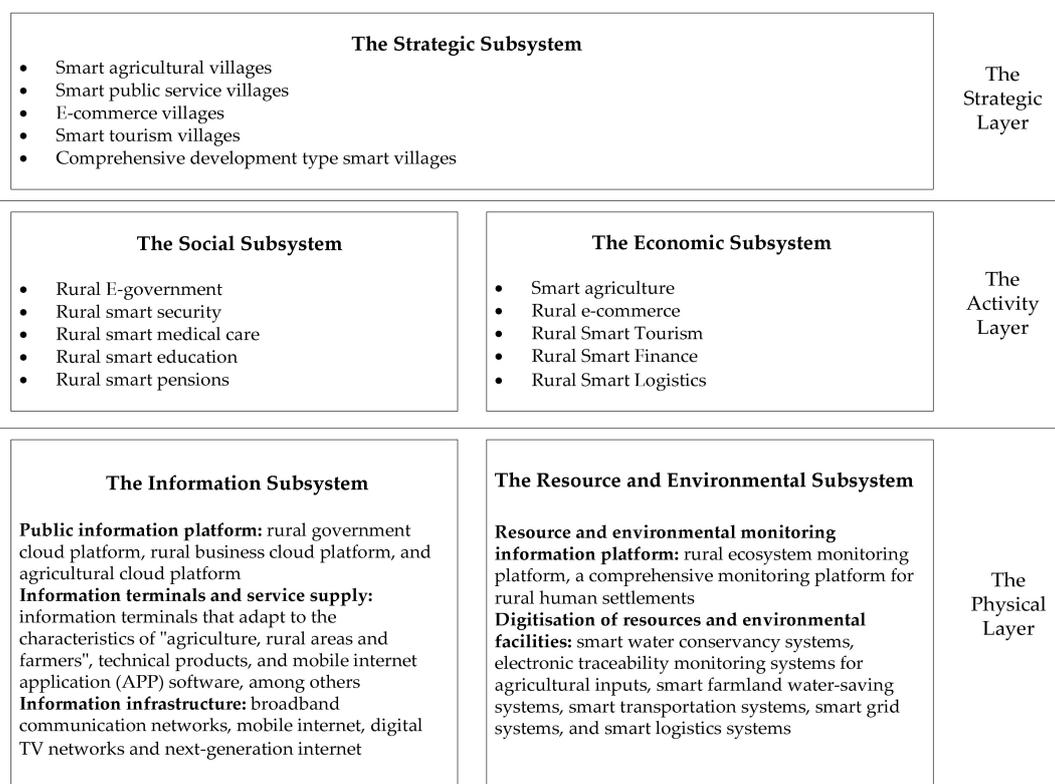


Figure 9. The basic structure of a smart village.

5. Discussion

In a rural area that is lagging, is becoming a smart village the correct choice for the rural area's sustainability? For the current situation in China, the answer is yes. The main reasons are as follows. Firstly, ICT has played a vital role in promoting the revitalization of China's rural areas. In 2018, the Chinese government proposed the implementation of a rural revitalization strategy and carried out large-scale poverty alleviation actions in rural areas. In the next few years, the lesser-developed portions of China's rural areas will be greatly improved. During this process, the government has also carried out the practice of using the internet for poverty alleviation. The internet has played a very important role in helping poor areas escape poverty. Survey data show that 81.2% of internet users believe that the internet has played an important role in bringing together the power of internet users to help poor farmers. Additionally, 77.2% of internet users believe that rural e-commerce has played an important role in helping poor farmers increase agricultural product sales. A total of 75.9% of internet users believe that the internet can make it easier for poor farmers to obtain information about work, social security, and medical care. A total of 74.0% of internet users believe that distance education provides high-quality learning resources for children in poor rural areas [27]. Secondly, widespread access to the internet by rural residents will become China's future development trend. There are 260 million non-netizens in rural areas in China, accounting for 56.2% of all non-netizens and 18.56% of the national population. The data show that non-netizens in rural areas do not use the internet mainly due to a lack of skills, education level restrictions and insufficient equipment, accounting for 48.9%, 18.2% and 14.8% of internet non-use, respectively. The Chinese government is currently using the internet for poverty alleviation in rural areas [28]. The government's action includes five major projects: network coverage, rural e-commerce, intelligent network support, information service, and public network welfare. As the Chinese government continues to carry out poverty alleviation activities in rural areas, especially those concerning the use of the internet, an increasing number of rural residents will be able to access the internet in the future to incorporate themselves into the wave of digitalization. Thirdly, although there are large differences between different villages, smart village construction and development follow local conditions and classifications instead of adopting a unified building model. The rural areas in China are quite different from each other, and their characteristics are also different. The Chinese government believes that for different regions and types of villages, it is necessary to fully respect the rural area's characteristics and the law of informatization development [29]. The government believes that different types of smart villages should be designed separately. The construction of information infrastructure and the design and innovation of smart rural application functions are carried out following local conditions. This ensures that villages of different types and characteristics can have their own smart solutions and development models.

Can the smart village strategy in China be successfully and effectively realized? To realize smart village strategic planning, the Chinese government has carefully designed the smart village construction model. China's Ministry of Agriculture and Rural Affairs pointed out that the construction of smart villages in China involves the participation of multiple disciplines, from technological innovation to capital investment. The government invested in and led the construction of major engineering facilities in some foundational and key smart village areas. Firstly, the government will invest in the construction of the National Agricultural and Rural Big Data Centre, which can realize the sharing of data resources in agricultural, rural management and services across the country. The National Agricultural and Rural Big Data Centre includes the national agricultural and rural cloud platform, agricultural and rural big data platform, and agricultural and rural government information system. It improves the government's ability to manage agricultural and rural areas and scientific decision-making through national data resource sharing and intelligent early warning analysis. Secondly, the government will also invest in the construction of agricultural and rural observation network infrastructure and application systems that can realize sky and ground data integration. The new remote sensing satellites, ground application facilities, and agricultural and rural aviation monitoring networks can form a unified national agricultural and rural ground internet data survey system. This will help achieve

real-time dynamic observations of agricultural production and rural environments in the entire field, process, and coverage systems. Finally, the government is responsible for establishing big data across the entire industry chain of important agricultural products, thereby building a smart agricultural and rural comprehensive service platform to provide complete management of agricultural and rural areas. Smart village construction in China is also inseparable from the extensive participation of other organizations. In addition to increasing the government's investment in smart villages, the government will also adopt methods such as government purchases of services, government–social capital cooperation, and loan interest discounts to attract the participation of social capital and guide industrial, commercial and financial capital to invest in the construction of smart villages. In the government's plan, the government will cooperate with scientific research institutions, universities, and enterprises to cultivate a group of leading talents, engineers and high-level management teams in digital agriculture and rural technology. The government also cooperates with scientific research institutions, universities, enterprises and other entities to conduct business training on smart villages. It allows talent in the field of smart villages to relocate to the countryside. This allows them to popularize the knowledge of smart agriculture and smart villages. It also improves the application and management level of digital technology of rural officials, rural business entities and farmers. Concerning productive agricultural services related to ICT, the Chinese government pointed out that it should guide various social entities to develop and provide such services and provide farmers with more convenient public and business services. These productive agricultural services include market information, agricultural material supplies, waste resource utilization, agricultural machinery operations, primary processing of agricultural products, and “private customization” of agricultural meteorology.

The construction of smart villages in China was initially a bottom-up autonomous exploration process under the influence of smart cities. After the Chinese government proposed implementation of the smart village strategy, it became a top-down policy promotion process. Since 2019, the Chinese government has issued the “Outline of the Smart Village Development Strategy”, and “Development Plan for Digital Agriculture and Rural Areas (2019–2025)” in promoting the development of smart villages. The relevant measures introduced involve conducting smart village pilots in 117 areas across the country. This kind of top-down policy promotion is critical for the current sustainable development of rural areas in China. On the one hand, it can provide a unified overall plan for constructing smart villages in China and effectively solve the problems that different smart systems formed in their independent explorations, which are difficult to integrate. On the other hand, government policies and financial investments attract social capital and resources to smart village construction and use the market and society's power to build smart villages jointly. The Chinese government's role in promoting smart village construction has been to promote the smart village system's strategic subsystem proposed in the previous text to enhance smart village's development through a unified overall plan and related supporting policies. In March 2020, the Chinese Communist government proposed the construction of new infrastructure, including 5G base stations, ultra high voltage (UHV), high-speed intercity railways and urban rail transit, charging piles for new energy vehicles, big data centers, artificial intelligence, and industrial internet. The Chinese government pointed out in the “Notice on the Implementation of the National Smart Village Pilot” issued in July 2020 that it will accelerate the development of rural fiber-optic broadband, mobile internet, digital TV network, and next-generation internet, as well as improve the level of 4G network coverage. At the same time, it was proposed to explore the construction and application of new infrastructures such as 5G, artificial intelligence, and the Internet of Things in rural areas and agriculture. It can be seen that the Chinese government uses strategies and policies to promote the construction of smart villages in lesser-developed rural areas. On the basis of respecting the actual conditions of the countryside and agriculture, it focuses on promoting the digital development of the countryside and agriculture to avoid the further widening of the digital divide between urban and rural areas so those vast rural areas will not be left behind in the wave of informatization.

The current smart village construction model promoted by the Chinese government's top-down policy is inseparable from China's national system. This system is mainly reflected in the centralization of power and the public economy's dominance, which can provide institutional guarantees for China's smart village strategy's realization. The centralization of power in China determines that local governments' power comes from the central government's authority. Local governments (such as provinces and cities) strictly obey the central government's orders. This ensures that local provinces and municipalities maintain a high degree of consistency with the central government at all levels so that the central government's strategy can be highly valued by the locals and can be more thoroughly implemented in the localities. The same applies to the rural revitalization strategy and smart rural strategy proposed by the central government. These strategies are currently the focus of the work of various local governments in China. The mainstay of China's public ownership economy is reflected in the dominant position of public assets in total social assets. The state-owned economy controls the lifeline of the national economy and plays a leading role in economic development. An important manifestation of China's state-owned economy is China's state-owned enterprises. State-owned enterprises are owned or controlled by the state over their capital, which also determines that state-owned enterprises' behavior reflects the will and interests of the government. For example, in the construction of smart villages, three large state-owned enterprises, namely, China Telecom, China Mobile and China Unicom, are mainly responsible for the construction and operation of the new generation of ICT infrastructure and its smart application systems. Such state-owned enterprises are important carriers for the implementation of national policies. China has also established a special type of state-owned enterprise, which is an agricultural policy bank. The only agricultural policy bank in China is the China Agricultural Development Bank. It is responsible for raising funds for agricultural and rural development following national policies, undertaking agricultural financial services, and acting as an agent to allocate funds to support agricultural and rural areas. The Agricultural Development Bank provides financing services for China's rural revitalization and smart village construction following national policies. State-owned enterprises are also dominant in China's power, gas, water supply and drainage, transportation, environmental protection, and sanitation fields. The nature of state-owned enterprises determines that their business will also tilt towards rural revitalization and smart village areas. Therefore, China's top-down smart rural construction model has certain reference significance for countries that implement centralized power and countries where the state-owned economy is dominant in the national economy.

6. Conclusions

Achieving the sustainable development of rural areas is not only a major challenge for the development of rural areas but also the vision and goal for the future development of rural areas, especially for a country such as China, where nearly half of the population lives in rural areas. The planning and practice of China's smart villages provide a basic path for rural areas to achieve sustainable development. A smart village is a rural development model that makes full use of the solutions provided by ICT to promote the sustainable development of rural areas on the basis of clarifying the characteristics and needs of rural development. There are five subsystems of the smart village system, namely, the strategic subsystem, the social subsystem, the economic subsystem, the resource and environmental subsystem, and the information subsystem. The strategic subsystem plans and designs the vision, goals, tasks, and implementation measures of smart villages to ensure that the construction of smart villages can help rural areas achieve sustainable development. Supported by the information technology solutions provided by the information subsystem, the social subsystem, the economic subsystem, and the resource and environmental subsystems help rural areas achieve sustainable social, economic and environmental development through the use of related smart applications. The Chinese government has formulated relevant strategic plans for transforming rural areas into smart villages. The relevant planning has provided the direction for rural areas to eliminate the existing difficulties and achieve sustainable development in the future.

Although there are some typical cases of smart village practices and the construction and development of smart villages have a good foundation in China, there are still some problems in the current smart village practice, such as the lack of overall planning and design and the lack of planning and design for different types of smart villages. The “Outline of the Smart Village Development Strategy” issued by the Chinese government in 2019 will correct for the lack of overall planning for smart village practice in China. Taking into account the large differences in rural areas in different regions of China and the strong heterogeneity between different types of villages, the top-level design of different types of smart villages based on the types, characteristics, advantages and disadvantages of different villages should be strengthened in the future practice of smart villages. From the current situation in China, the construction and development of smart villages in disadvantaged rural areas is the right choice for sustainable rural development. This judgment is based on the important role of ICT in China’s rural revitalization action, the recognition of Chinese rural residents with ICT and the reality of wider access in the future, and the classified construction plan in the construction of smart villages. The Chinese government plays a leading role in the construction of smart villages in China. It carries out the strategic design, policy formulation, capital investment and construction of major engineering facilities for smart villages. At the same time, various subjects including scientific research institutions, universities, and enterprises have been widely involved in the process from technological innovation to capital investment. The top-down smart village construction model currently adopted by China is determined by China’s political and economic system. This economic and political system is mainly reflected in the centralization of power and the public economy’s dominance. It institutionally guarantees that the rural revitalization and smart village strategies proposed by the Chinese government can be implemented in local government and local areas. The Chinese government’s role in promoting smart village construction has been to promote the smart village system’s strategic subsystem proposed in the previous text to enhance smart village’s development through a unified overall plan and related supporting policies. The smart village system’s strategic subsystem guides, regulates, and controls the digital transformation of rural economic and social activities and infrastructure, thereby enabling China’s rural areas to move towards in the direction of sustainable development. The theoretical framework of smart village systems constructed in this paper will provide theoretical guidance for the top-level design of different types of smart villages, which is also a direction that future research can explore.

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