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Realizing a Rural Sustainable Development through a Digital Village Construction: Experiences from China

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Abstract: The rapid application of digital technology in rural areas has been carried out worldwide, but academic research on the theme of digital villages is still in its infancy. The academia is still unclear about the construction content, theoretical framework and realization path of the digital village construction. Against this background, this paper studies how villages can transform into digital villages and achieve a sustainable development. Firstly, this paper builds a digital village technology architecture system from four levels: infrastructure system, village brain, application support system and application service system. The system points out the specific construction content from the technical point of view, and provides scientific guidance for construction activities. Secondly, with the help of digital empowerment theory, the theoretical framework of the digital village construction to promote a sustainable rural development, is constructed from five fields: industry, ecology, culture, service and governance. Finally, the theoretical framework is verified through five Chinese cases, and two characteristics of a digital village construction are summarized to provide reference and guidance for digital village practice activities. The digital village construction should use data, digital technology and digital platform as the base, attract multiple subjects to participate and form symbiotic relationships, and achieve a rural sustainable development.

Keywords: digital village; rural sustainable development; digital empowerment; digital technology

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1. Introduction

The rapid growth of urbanization and industrialization has brought new problems to the rural economy, ecological environment, culture and services. A population exodus, an aging population, poor infrastructure, health problems and education problems have become common problems in rural China [1–4], these problems have contributed to the rural decline. Therefore, rural areas need a series of reforms to change the decaying situation. The digital economy is growing rapidly around the world, and digital technologies, represented by artificial intelligence, blockchains, cloud computing and big data are rapidly penetrating various industries. Especially after the outbreak of the COVID-19 pandemic, the role of digital technology in facilitating social and economic development has been highlighted. In recent years, digital technology has gradually expanded from urban areas to rural areas, which has attracted the attention of many countries. The European Union has developed the Smart Villages initiative, its realization has launched the Digital India Programme [5], and South Korea has formulated the Information Network Village Project [6], which aims to foster the application of digital technology in rural areas as a way to improve the quality of rural life. Therefore, building a digital village has become an effective way to solve the problem of rural development [7].

A digital village is the process of using information technology and digital technology to make targeted transformations, based on the needs and characteristics of the village, and ultimately to achieve a change in the development model of the village. China has

proposed the digital village strategy in 2019, which aims to narrow the gap between urban and rural areas, accelerate the penetration of the digital economy into rural areas, and achieve sustainable development in rural areas. Under the guidance of the digital village strategy, various regions have gradually launched the digital village construction, and 117 digital village pilot areas were identified in 2020. In 2020, the scale of China's digital economy reached USD 5.9 trillion, accounting for 38.6% of GDP. Nevertheless, the digital economy is unevenly developed among the different industries, with digital economy penetration rates of 8.9%, 21.0% and 40.7% in agriculture, industry and services [8]. This shows that China's agricultural digitalization level is relatively low, but it also means that agricultural digitalization has broad prospects for development.

Relying on digital technology, the digital village has changed the traditional rural economic development model and injected great vitality into rural economic development. E-commerce, relying on digital technology, can break the geographical barriers, allowing consumers in less developed rural areas to obtain goods at lower prices, and freeing producers in rural areas from relying on intermediaries to sell their products to a broader market [9]. This model of rural economic development relying on e-commerce has lifted many villages out of poverty. In addition, the practical activities of digital villages in agricultural production have changed the traditional agricultural production methods, significantly contributing to the improvement of rural green productivity and promoting the transformation of rural economic development to green development [10].

The sustainable goals proposed by the United Nations focus on improving rural hunger, poverty, health, environment and education [11]. Sustainable development is to promote the development of economically backward areas without damaging natural resources [12]. Following the integration of the sustainable development goals proposed by the United Nations and China's specific practices, this paper proposes that a rural sustainable development should achieve the goals in five areas: industrial development, ecological livability, cultural prosperity, service improvement and efficient governance. Rural sustainable development has become a research hotspot. Nevertheless, there is still a lack of research on the realization path of a rural sustainable development in the context of the digital economy.

Presently, the application of digital technology in rural areas has attracted the attention of the practical community, but it has not been fully discussed in academic research [13], which makes theoretical research unable to guide practical activities well. Most existing theoretical studies focus on analyzing digital village policies and specific projects in the United States and Europe, which can provide references for China's digital village research. However, due to the significant differences in population, production methods, infrastructure and social environment, among Chinese, European and American villages, digital villages' construction goals and paths in different regions are heterogeneous. Therefore, there is a lack of in-depth studies on the Chinese situation.

The digital village construction is one of the essential ways to achieve a rural sustainable development, but the theoretical logic and realization path of the above process are not clear enough. The following studies were conducted in this paper to fill the existing research gaps. First, this paper proposes the technical construction content of the digital village and constructs the digital village technology architecture system. Next, based on the theory of digital empowerment, this paper will discuss the theoretical logic of the digital village construction, to achieve a rural sustainable development. Finally, through the study of Chinese cases, this paper proposes the realization path of the digital village construction to accelerate the rural sustainable development. Through the research of this paper, we hope to enrich the theoretical research on digital villages and rural sustainable development, and provide references for related practical activities.

To address these topics, this paper proceeds as follows. Section 2 organizes the literature on digital villages, rural sustainable development and digital empowerment. Section 3 constructs the digital village technology architecture system from a holistic perspective. Section 4 analyzes the theoretical logic of digital village construction to achieve a rural sustainable

development. Section 5 summarizes the realization path of the digital village construction to facilitate a rural sustainable development through the analysis of five Chinese cases. Section 6 is the summary of this paper. Section 7 summarizes the shortcomings of this paper and proposes future research directions.

2. Literature Review

2.1. Digital Village

The research on smart villages and smart cities stems from the concept of "Smart Earth" proposed by IBM in 2008. The research on smart cities has received much attention from academia, but smart villages are still a rising topic in academia.

This paper first focuses on the study of smart cities to provide research ideas for the study of the smart village. Due to the vagueness of the concepts of the smart city and the digital city, they are regarded as the same concept and are often used interchangeably [14]. Through a bibliometric analysis, Mora et al., (2019) believe that smart cities and digital cities share some common characteristics, such as focusing on urban ICT infrastructure and services [15]. Nevertheless, smart cities are the framework in which technology, policy and community affect urban liveability, sustainability, governance, productivity, wellbeing and accessibility [16]. Therefore, smart cities involve more extensive aspects than digital cities, which are part of smart cities.

Smart villages are the result of the expansion of the concept of smart development from cities to rural areas, and there are both links and differences between smart villages and smart cities. The deep integration of information technology and digital technology with the economic, ecological, social and cultural fields is the common element of both. Nevertheless, compared with cities, rural areas have weak infrastructure and are subject to more substantial resource constraints, farmers are generally less educated, and rural aging and population loss are very serious [17,18]. In this context, the construction focus of smart villages is different from that of smart cities, and the construction difficulty of smart villages will increase. Therefore, the smart village does not simply apply the technologies involved in the smart city construction to the rural construction [19].

It is difficult to have a uniform definition of a smart village because of the differences in the environment and the problems faced by each village [5]. The most widely cited definition is proposed by the EU Smart Village Initiative, launched by the European Commission. Smart villages combine the advantages of the village itself with digital, telecommunication technology, innovation and a better use of knowledge to benefit residents and businesses through network services [20]. The Chinese government proposes that the digital village is an endogenous rural development process, accompanied by the application of networking, informatization and digitization in rural areas and the improvement of farmers' modern information skills [21]. It can be seen that the digital countryside proposed by China is essentially the same as the smart countryside proposed by the EU, except that Chinese practice and research often choose the term "digital village" due to policy orientation. Therefore, this paper adopts the expression form of the digital village in the follow-up.

Up to now, the digital village has attracted worldwide attention, and some countries and regions have begun to carry out digital village construction activities. India launched the Digital India Programme in July 2015, to transform India from a traditional society to a digitally empowered and knowledge-based society. As an important part of the entire project, the Digital Village initiative aims to increase the rural Internet penetration by building fiber-optic networks [5]. To address the large urban-rural digital divide and rural exodus, South Korea launched the Information Network Village Project in 2001. The project aims to improve farmers' incomes by training farmers' skills, based on infrastructure development, and the project mainly involves network access, digital training, telemedicine, and digital agriculture [6]. The EU proposed the Smart Villages campaign in 2017, which aims to revitalize rural areas by accelerating the rural development by digitalization and improving farmers' quality of life. The campaign involves 16 plans, including sustainable development of the residents' livelihoods, rural industries and public services. Under the framework of

the Smart Villages campaign, Italy, France, Poland and other countries have launched different digital village construction plans, according to their own conditions [22–24]. Moreover, the EU launched a two-and-a-half-year Smart Rural 21 project, in 2019, to select 21 villages for financial and technical support, and eventually promote the smart rural construction experience of 21 villages within the EU. Stojanova et al., (2021) analyzed the digital village construction policies of six countries in the EU, and found that digital village construction aims to solve the problem of the rural population reduction and population aging, climate change, economic development, infrastructure and services, digital transformation and narrowing the gap between urban and rural areas. However, there are differences in the degree of policy attention in different aspects [25].

From the content of the above digital village construction projects in each country, it can be concluded that the focus of the digital village construction differs from country to country. Due to the poor infrastructure in India, it focuses on the construction and improvement of digital technology facilities. The digital technology facilities in European countries are relatively complete, and their project construction scope is more comprehensive, mainly through the use of new technologies and the improvement of public services to improve the rural development environment. Because of the differences between the environment in China and other countries, and the significant differences among the regions within China, the construction of digital villages in China is more complex, but there is a lack of theoretical research papers for the Chinese context. Although Zhang and Zhang have proposed a framework for the Chinese digital village construction, based on complex system theory [26], but does not conduct an in-depth analysis of the Chinese digital village practice cases. At the same time, the most current studies focus on the developmental origin and concept definition of digital villages, the significance of digital village construction, and the policy interpretation of the digital village strategies in various countries, lacking in-depth exploration of the content and construction logic of the digital village construction.

2.2. Rural Sustainable Development

Industrial civilization has caused the decline of rural areas around the world [27], and how to boost the rural sustainable development has become a common concern worldwide. The academic research on rural sustainable development mainly focuses on the two aspects of the participants and the realization path of the rural sustainable development.

The connotation of sustainable rural development is abundant, and it requires the cooperation of multiple subjects, such as the government, villagers, and enterprises to achieve the goal of a sustainable rural development. At different stages of sustainable rural development, the dominant subject will change. In the early stage, the government is often in the leading position and issues a series of policies to facilitate the implementation of the strategy. In the subsequent stage, with the support of the relevant policies, enterprises promote the implementation of the relevant rural sustainable development projects. In the later stage, villagers will actively participate in various rural sustainable development projects under various incentives [28].

In addition to the traditional government, enterprises and villagers, rural key people and universities also play an important role in the process of rural sustainable development. In addressing rural decline, top-down policies may not accurately identify the problems of local villagers and meet their real needs [27]. Nevertheless, there is a group of key people who are not necessarily officially appointed, but are familiar with village affairs and passionate about sustainable village development activities. Rural key people often have rich social capital, and they can link different groups inside and outside the village, making the village adapt to the changing external environment and ensuring the sustainability of rural development [29]. Universities have three primary responsibilities: cultivating students, conducting academic research and serving society. Serving society has become the direction of global higher education transformation [30]. Social responsibility projects, led by universities, should be oriented to the real needs of the villages and combine curriculum teaching with village counseling within the framework of government support. While

cultivating the abilities of students and villagers, the project applies scientific research results to rural practice, and the project itself provides a resource-sharing platform for various related subjects [31].

Sustainable rural development involves a wide range of contents, and scholars currently analyze the paths to achieve sustainable rural development from the perspectives of entrepreneurial activities, financial support, rural tourism, e-commerce and infrastructure development. Entrepreneurship is a critical way to flourish rural industries, and entrepreneurial activities stimulate the endogenous rural development by promoting upgrading industrial structures [32]. At the moment, more than 7.8 million migrant workers in China have returned to their hometowns to start businesses under the guidance of government policies [33]. Ma et al. have studied the entrepreneurial behavior of new generation rural migrant workers returning home, and found that their psychological capital and social capital positively affect entrepreneurial performance [34]. As a complement to traditional means of financing, microfinance and financial cooperatives both play an essential role in alleviating credit constraints and facilitating personal development. Through a meta-analysis of the literature on microfinance, Chliova et al. have found that microfinance increases the income of low-income people, but the positive impact on the health and education of low-income people is very weak [35]. Furthermore, compared with microfinance, financial cooperatives have a stronger role in promoting technology adoption in agricultural production and are more conducive to promoting sustainable growth in agricultural production [36]. Rural tourism development can change the local industrial structure and employment structure, improve the villagers' living environment and increase their income [28]. However, only the establishment of a rural sustainable tourism model can achieve these goals. Gao and Wu put forward that rural tourism can support sustainable rural development only if it simultaneously meets the needs of the material, social and spiritual levels [37]. The success of rural e-commerce is not the simple application of modern technology in rural areas, but the deep integration of e-commerce with rural production methods, business organization forms and social culture [38]. E-commerce promotes rural transformation from five aspects: culture and social changes, diversification of livelihoods, delocalization of livelihoods, the de-linking of livelihoods from land and the institutionalization of rural life [39]. Transportation infrastructure is one of the decisive factors affecting rural economic development [40], but a good transportation infrastructure does not necessarily enhance sustainable rural development. Zhou et al. have found that rural road construction can foster agricultural development in Eastern and Central China, but it will lead to the loss of population and capital in the western region [41]. Although some villagers go out to work to increase their income in the short term, it is not conducive to the sustainable development of the western village.

To sum up, rural sustainable development is a complex concept, with diversified participants and realization paths. Although building from a specific aspect alone will boost rural development, such development is uneven and unsustainable. Only when rural economic, political, cultural, ecological, health and other fields develop together, can a rural sustainable development be truly realized. Therefore, it is necessary to construct the realization framework of the rural sustainable development from an overall perspective to guide relevant practical activities.

2.3. Digital Empowerment

Empowerment is first the subject of psychological attention and subsequently has also received attention from multiple disciplines, such as management, sociology and organizational science. Empowerment refers to how individuals or organizations replace feelings of powerlessness by controlling objective environments and external conditions [42]. Most current studies classify empowerment into three dimensions: psychological empowerment, structure empowerment and resource empowerment. Psychological empowerment focuses on how to improve social psychology, intrinsic motivation and personal motivation [43]. Structure empowerment emphasizes empowering individuals or teams by establishing

empowerment mechanisms [44]. Resource empowerment is the process of increasing the ability of powerless individuals to access, control and manage resources [45].

Digital empowerment is the extension and development of empowerment theory in the digital economy era. The academic community has not yet reached a consensus on the definition of digital empowerment. In 2016, the World Bank pointed out that digital empowerment refers to the wide development benefits generated by the rapid application of digital technologies on a global scale [46]. Lenka et al. put forward that digital empowerment is to obtain empowerment value by improving enterprises' analytic capabilities, intelligence capabilities and connection capabilities [47]. By studying the digital empowerment of e-commerce platforms, Ying et al. have proposed that digital empowerment should focus on the impact of digital technology on the ability acquisition of empowered objects [48]. This paper holds that the essence of digital empowerment is digital technology empowerment. Digital empowerment is to strengthen the behavior subject's ability to deal with problems through the application of digital technology, to help the subject to improve their life and further development, so that it can change from an "incompetent" state to a "capable" state.

Digital technology is one of the critical components of digital empowerment. Digital technology has four characteristics: communication, connection, computation and application. Communication refers to digital technology with the function of marking and connecting [49,50]. Connection focuses on the interaction between digital technology and the external environment [49,51]. Computation indicates that digital technology has the function of large-scale modification and iteration [52,53]. Application emphasizes the application potential brought by the fusion of digital technology and other resources [54,55].

Most studies on digital empowerment focus on the ability for the improvement of vulnerable groups, addressing the issues of women's rights [56,57], patient care [58,59] and student education [60]. From the perspective of enterprises, digital empowerment has the advantages of optimizing resource allocation, reducing innovation costs and improving the labor force level. The main topics of academic research are entrepreneurship management [61], value co-creation [62], business model innovation [63], and green strategy options [64].

A small amount of research on digital empowerment has started to focus on community and regional development. Leong et al. have conducted a case study on Taobao villages in China and found that building a digital innovation platform in e-commerce can lower the entry threshold to the industry and provide villagers with a variety of jobs, freeing villages from local resources constraints, to some extent. Furthermore, to promote the role transformation between different subjects, to reconfigure the supply chain structure, and finally realize the ability to empower marginal communities to develop [65]. Through research on rural Malaysia, Tim et al. put forward that social media accelerates villagers' participation in environmental sustainability projects through three approaches: information democratization, network information association and emergent organizing [66]. Leong et al. have conducted a case study of the financial industry in Indonesia and found that financial companies use digital technology to foster the inclusive development of micro-enterprises and local communities, through emulating services, matching resources and providing equal opportunities [67].

The content of digital village construction overlaps with the rural sustainable development goals, and digital empowerment is a tool to connect the digital village and rural sustainable development. In the context of the digital economy, there is a lack of analysis of the theoretical logic and realization path of the digital village construction to facilitate a rural sustainable development.

3. The Digital Village Technology Architecture System

The digital village is the deep integration of digital technology and the village, and it is an inevitable choice for the village to adapt to the development of the digital economy era. The digital village construction involves a wide range of fields, and the current mature construction mode is to pilot in a specific field first, and then spread to other fields.

However, there are differences in digital technologies in different fields, and if there is a lack of unified construction planning, it is easy to duplicate the construction phenomenon and reduce the positive impact brought by the digital village construction. At present, digital village construction has been carried out in some areas of China, but the results are quite different, and the lack of planned repetitive construction is one of the main reasons for the difference. Therefore, it is necessary to clarify the technical architecture system for construction before implementing digital village projects. All construction contents should be carried out under the guidance of the technical architecture system, which is conducive to unified planning and reduced economic costs caused by redundant construction.

As shown in Figure 1, the digital village technology architecture system constructed in this paper is divided into four levels: infrastructure system, village brain, application support system and application service system. A complete digital village construction needs to include these four levels. The differences in construction in different fields are mainly concentrated in the level of the application service system, while the specific construction content of the other three levels needs to be matched, according to the needs of application development.

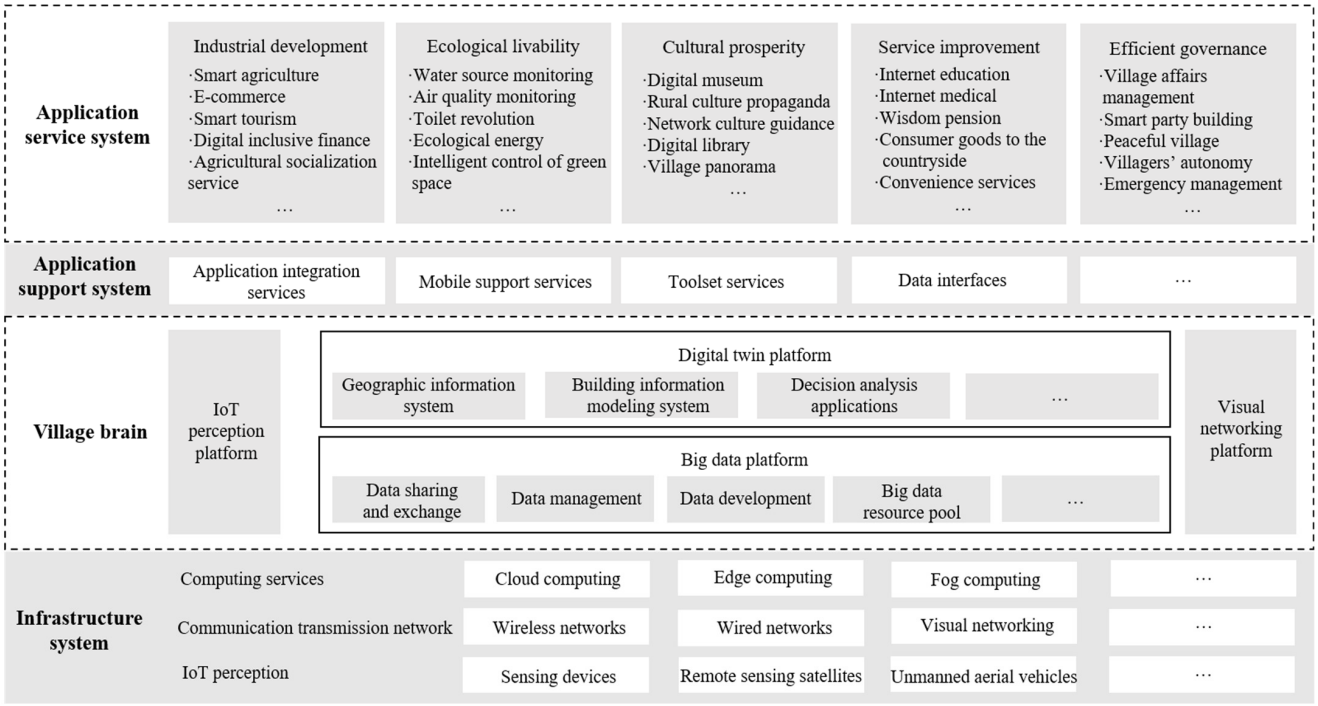

Figure 1. The digital village technology architecture system.

3.1. Infrastructure System

The infrastructure system consists of three parts: IoT perception, communication transmission network and computing services. IoT perception is the front-end of the digital village construction, which realizes data collection, intelligent identification and three-dimensional perception through sensing devices, remote sensing satellites, unmanned aerial vehicles (UAVs), intelligent terminals, video monitoring and weather stations. The communication transmission network is to upload the collected data to the data center efficiently and safely, mainly including wired networks, wireless networks and visual networking. Villages need to set up different types of networks, according to their actual conditions. Computing service is to provide computing power support for the development of various applications through the real-time processing of data. During the construction process, it is necessary to select computing services that match the hardware equipment, according to the server's computing power and the memory's storage capacity. The

computing services mainly include cloud computing, edge computing, fog computing and haze computing.

3.2. Village Brain

Village Brain builds the digital platforms by adopting digital technologies, such as big data, blockchains and artificial intelligence, to support the digital transformation of rural decision-making and the automation of business processes.

1. The IoT perception platform mainly manages the data collected by the IoT in a unified manner, and uses visualization technology to display the data intuitively, promoting the formation of rural big data and providing a basic perception data guarantee for the subsequent application development.
2. Through intelligent analysis technologies, such as face recognition and license plate recognition, the visual networking platform can extract valuable information from massive videos, realize intelligent analysis and judgment, and lay the foundation for subsequent application, management and model innovation. In this process, the video network platform should pay attention to formulating video monitoring standards to support the sharing of various video monitoring resources effectively.
3. The big data platform mainly uses tools, such as data sharing and exchange, data management, data development and big data resource pools to break down industry data barriers, realize the integration and sharing of various heterogeneous data and promote the transformation of data resources into data assets.
4. The digital twin platform uses tools, such as the geographic information system (GIS), building information modeling (BIM) system and decision analysis applications, to realize the integrated display of basic geographic information, perception information and industry application scenarios through 3D modeling. Specifically, the digital twin platform uses digital technology to render the scene to restore the real physical world as much as possible. Moreover, simulation and evolution in digital space can provide prediction guidance for decision-making in the real physical space, reducing the economic cost and negative impact of attempts in real space.

3.3. Application Support System

The application support system connects the two important structures of the rural brain and the application service system through the application of integration services, mobile support services, toolset services and data interfaces. The upper application development can enjoy the efficient and friendly development and runtime environment in the application support system, realizing the rapid switch between cooperation and independent operation and providing support for personalized application development.

3.4. Application Service System

Combined with the digital village's construction content and the rural sustainable development goal, the application service system can be divided into five aspects: industrial development, ecological livability, cultural prosperity, service improvement and efficient governance.

1. Industrial development is the combination of big data, IoT, artificial intelligence and other technologies, with agricultural production and operation activities, through intelligent decision-making and intelligent early warning to improve agricultural production efficiency and product quality, and finally to improve the effective supply of agricultural products and services. The construction content mainly includes smart agriculture, rural e-commerce, smart tourism, digital inclusive finance, and agricultural socialization services.
2. Ecological livability is using digital technology to improve the ecological environment and provide a basis for improving the rural living environment. The construction content mainly involves water source monitoring, air quality monitoring, toilet revolution, ecological energy and the intelligent control of green spaces.

3. Cultural prosperity is using digital technology to introduce external culture into the rural area, while accelerating the inheritance, innovation and dissemination of rural culture. The construction content mainly contains digital museums, rural cultural propaganda, rural network cultural guidance, digital libraries and village panoramas.
4. Service improvement is to use digital technology to facilitate the digital transformation of rural services, improve existing service levels and create new service models. The construction content mainly includes internet education, internet medical care, wisdom pension, consumer goods to the countryside and convenience services.
5. Efficient governance is the use of digital means to deal with all aspects of rural production and life affairs, and to improve the scientific nature of rural governance. The construction content mainly involves village affairs management, smart party building, peaceful village, villagers' autonomy and emergency management.

4. The Theoretical Logic of the Digital Village Construction to Achieve Rural Sustainable Development

The digital village construction is to accelerate the realization of a rural sustainable development through digital empowerment. Specifically, digital village construction can achieve industrial development, ecological livability, cultural prosperity, service improvement and efficient governance in rural areas. Based on the existing literature and theoretical analysis, this paper constructs a theoretical framework for the digital village construction to achieve a rural sustainable development, as shown in Figure 2.

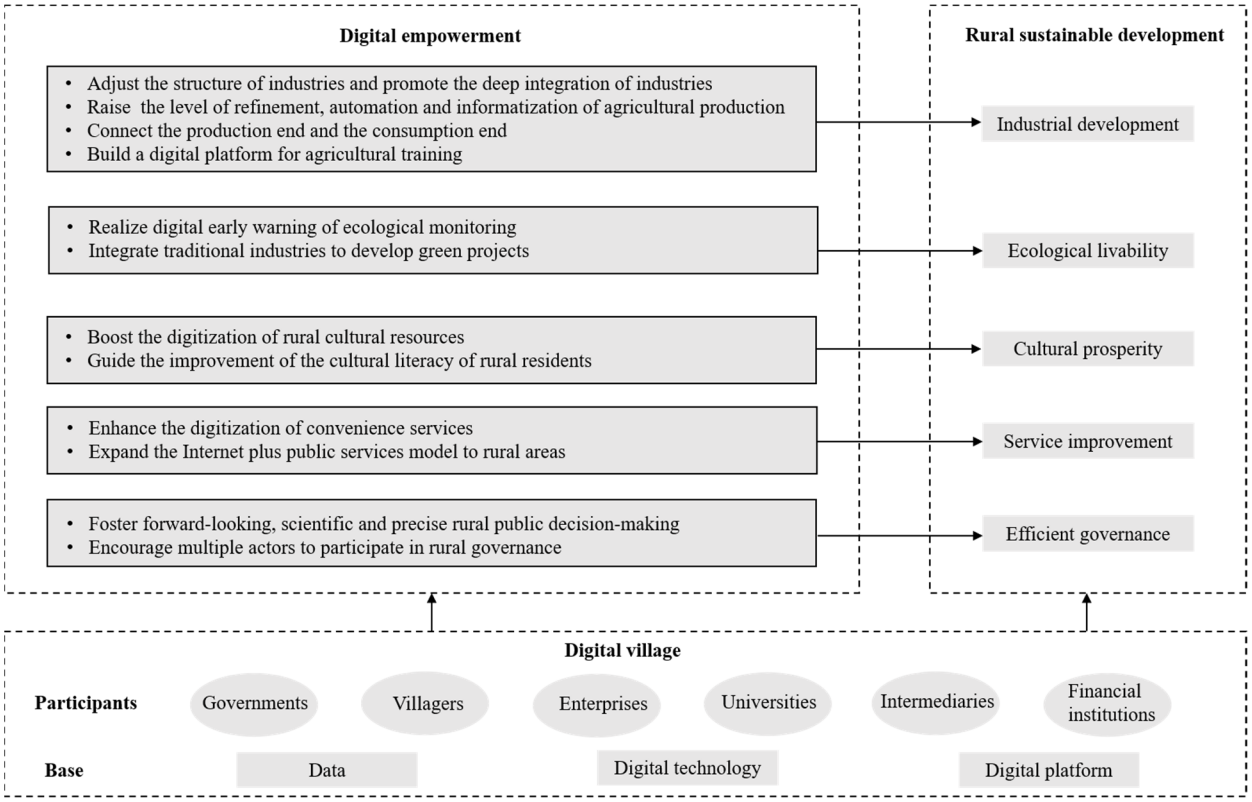

Figure 2. The theoretical framework for the digital village construction to promote a rural sustainable development.

4.1. Digital Village Construction and Industrial Development

Modern agriculture is mainly composed of three major parts: industrial system, production system and management system. The industrial system is the structural framework of modern agriculture, the production system is the power support of modern agriculture and the management system is the guarantee for the operation of modern agriculture. The

production system reflects the requirements of productivity, and the management system reflects the requirements of the production relations, both of which jointly support the development of the industrial system. The digital village construction promotes industrial development through the digital empowerment of the three major agriculture systems.

In the industrial system, digital empowerment can enhance the benefit of the agricultural industry chain by adjusting the industrial structure and promoting industrial integration. At present, the primary industry in rural areas mainly provides raw materials, and the production chain and sales chain are not sound; the secondary industry is mainly based on rough processing and simple processing, and the deep processing capacity is insufficient; the integration between the tertiary industry and other industries is inadequate, and there is a lack of in-depth excavation of unique rural culture. By using big data and artificial intelligence to conduct in-depth analyses of agricultural market data, it is beneficial for business entities to identify the real needs of consumers and develop the agricultural product processing industry in a targeted manner. This is conducive to promoting the joint development of primary processing and finishing, and forming a new pattern of integrated development of agricultural production, processing and circulation. Furthermore, enterprises use digital technology to deeply explore the production, leisure and cultural functions of agriculture, and develop new industries, such as tourism agriculture, shared agriculture, customized agriculture and creative agriculture, which is conducive to both economic and ecological benefits.

In the production system, the use of digital technology to raise the level of refinement, automation and informatization of agricultural production, is to achieve cost reduction and increase efficiency. Currently, China's agricultural science and technology have made significant progress. The national agricultural science and technology progress contribution rate exceeds 60%, and the total mechanization rate of crop cultivation and harvesting has reached 71% [68]. Agricultural mechanization is the use of mechanical equipment to replace the simple mechanical labor of humans, and cannot replace human decision-making. The use of digital technology to analyze the acquired data can replace the manual decision-making to a certain extent. If digital technology is combined with mechanical equipment, it can drive the transformation of agricultural production in the direction of intelligence. Through the deep integration of satellite positioning systems, remote sensing technology and geographic information systems with traditional agricultural production, farmers can be assisted in precise spraying, rational fertilization, intelligent irrigation, the early warning of diseases and insects, early warning of fire and animal tracking [69]. Using digital technology to transform the agricultural production process will help liberate agricultural productivity, reduce agricultural production costs, enhance the quality of agricultural products, and improve the ability of agricultural production to resist risks.

Digital empowerment shapes the agricultural management system in the following two ways. Firstly, it builds a digital platform to connect the production and consumption end, and improve the enthusiasm and income of farmers in production and operation. In traditional agricultural operations, information asymmetry often leads to an imbalance between supply and demand, and excessive intermediate channels lead to the insufficient bargaining power of farmers. All of these may lead to the phenomenon of cheap grain hurting farmers, finally hitting farmers' enthusiasm for production and operation. Traditional agricultural operators can use digital technology for e-commerce transformation, realize direct connection between producers and consumers on the e-commerce platform and reduce the multi-layer distribution. This can not only improve the farmers' information acquisition ability, risk resistance ability and self-selling ability, but also improve the farmers' bargaining powers and abilities to distribute income in the agricultural industry chain [70]. Secondly, the use of digital technology to build an agricultural training platform improves the quality of agricultural operators. Due to the attraction of industrialization and urbanization, a large number of rural young and middle-aged laborers flow to cities, resulting in a shortage of the rural labor force. Currently, most agricultural operators are older and are women, who lack business skills, which makes it difficult for them to gain advantages

in market competition. Through in-depth cooperation, the government, enterprises and agricultural universities jointly establish a remote training system for agricultural management talents on the digital agricultural training platform. By combining online and offline methods to teach agricultural business subjects about agricultural production and operation, agricultural practitioners can improve their business management skills.

4.2. Digital Village Construction and Ecological Livability

Due to the poor infrastructure in traditional rural areas, it is difficult to deal with the waste generated by production and life, completely. At the same time, in order to pursue economic benefits, some high-polluting enterprises concentrated in rural areas do not pay attention to the environmental protection measures, which has caused great damage to the ecological environment in rural areas.

Using the advantages of digital technology can improve the rural ecological environment in the following three ways. First of all, to facilitate the transformation of agricultural production methods from extensive to digital, green and low-carbon by using digital technology. In the traditional agricultural production process, farmers rely on their personal experience to spray pesticides and fertilizers, and there is often an overuse phenomenon. Excessive use easily causes problems, such as the excessive heavy metals in the land, eutrophication of water, pollution of the groundwater and pollution of the environment, reducing the environmental carrying capacity of the countryside. However, IoT can realize the refined delivery of pesticides and fertilizers [71,72], reducing the damage to the ecological environment in agricultural production. In the second place, digital ecological monitoring reduces pollution levels and environmental governance costs through early warnings. Traditional rural ecological governance is mainly ex-post governance. The cost of governance after a pollution incident is relatively high, and the damaged ecological environment is often difficult to restore to its original state. However, using the digital monitoring platform to analyze the multi-dimensional data returned by the sensor, the ecological pollution early warning and automatic alarm can be carried out through the changing trend of the relevant values, which improves the forward-looking and digital level of the rural ecological environment governance. Last but not the least, the integration of digital technology and traditional industries facilitates the optimization of the rural ecological environment. Due to urban economic development planning and insufficient supervision in rural areas, some high-polluting enterprises are often concentrated in rural areas, and their substandard emissions cause tremendous pressure on the rural ecological environment. Nevertheless, increasing the support of the digital inclusive finance for green projects promotes the flow of production factors to the low-pollution and low-emission production sectors, thereby squeezing the development space of high-pollution industries [73]. At the same time, it will also force related industries to adopt green technologies for production and reduce pollution emissions to the outside world. Moreover, the rise of smart tourism in rural areas will force rural areas to reduce pollution and beautify the environment.

4.3. Digital Village Construction and Cultural Prosperity

Rural culture is an inherent driving force for rural sustainable development. However, in the process of urbanization, the exodus of the rural population has led to the decline of some rural cultural activities with a sense of history and belonging, and the inheritance of traditional cultural skills is facing tremendous obstacles. The decline of rural culture hinders the realization of a rural sustainable development.

Using digital technology can promote the inheritance and development of rural culture in the following two ways. First of all, to boost the digital transformation of rural cultural resources. For example, with the decline of local opera, the carrier materials, such as costumes and theaters, have also declined. Nevertheless, digital technology can copy real things into virtual space, avoiding the disappearance of traditional culture [74]. Furthermore, based on the characteristics of the reproducibility of data and high penetration of digital technology, digital cultural resources can spread traditional culture on a large

scale, which is conducive to developing traditional rural culture. Secondly, to guide the improvement of the cultural literacy of rural residents by using digital technology. One of the essential carriers of cultural resources is the villagers, whose cultural literacy level affects the level of cultural development. The villagers' access to external things on the digital platform can improve their information acquisition ability, which is conducive to broadening their horizons and enriching their material and spiritual life. At the same time, villagers can also spread rural culture through digital platforms.

4.4. Digital Village Construction and Service Improvement

For the moment, rural public services have problems, such as low service efficiency, low service quality and insufficient service items. In addition, although the construction of equalizing public services between urban and rural areas in China has been highly valued by the government, there is still a large gap between the urban and rural public service levels. The digitalization of rural services can effectively solve the pain points of rural services.

Using digital technology can improve rural services in the following two ways. Initially, to enhance the digital transformation of convenience services by using digital technology. Due to unclear responsibilities of government agencies and the insufficient quality of villagers, it is often difficult for villagers to successfully handle business at one time. Relying on the advantages of information integration and data sharing, the application of digital technology can break down information barriers and organizational barriers, to realize innovative service content, and transform service forms and the collaborative organizational structure. This can effectively solve the problems of information asymmetry and the decentralization of rural public services, and improve the accuracy, timeliness and convenience of public services. In another, to accelerate internet plus the public services to rural areas by using digital technology. The traditional form of the public service supply is exclusive and competitive, while digital technology can transmit some urban public services to the countryside with lower marginal costs [50], which not only improves the utilization efficiency of public resources, but also significantly eases the gap between the urban and rural public services. For example, distance education can break spatial constraints and interconnect rural schools with urban schools, enabling rural students in remote areas to enjoy high-quality urban educational resources and facilitating the balanced development of urban and rural education [75,76].

4.5. Digital Village Construction and Efficient Governance

Although the practice of rural governance in China has achieved remarkable progress in recent years, there is still a mismatch between the effectiveness of rural governance and the need for social development. The complexity of rural governance content and the complexity of the task in the new era make it difficult for the traditional governance model to meet the needs of the public, which requires the use of digital technology to build a new rural governance model. Rural digital governance empowers the handling of public affairs in the fields of rural economy, politics, culture, society and ecology, through digital empowerment.

Digital technology can be used to transform traditional rural governance models from the following two aspects. Firstly, to use digital technology to foster the forward-looking, scientific and precise transformation of rural public decision-making. At present, rural public decision-making is mainly based on the subjective judgment of decision-makers, and the decision-making effect is closely related to the quality of decision-makers. Moreover, the governance is mostly after the event, and the ability to predict and deal with it is insufficient. As the primary link of governance, low-quality decision-making will greatly increase the pressure on the subsequent governance. In the context of relying on the combination of big data and artificial intelligence, through the analysis of multi-dimensional rural data, the correlation between complex information and the laws behind phenomena can be quickly discovered, and the development direction of events can be accurately predicted [77], making rural governance forward-looking, scientific and precise. Secondly, to use digital technology to encourage multiple actors to participate in rural governance. One of the

purposes of rural governance is to serve rural residents better, and rural governance is closely related to every rural resident. Nevertheless, due to the information asymmetry and the lack of channels for villagers to express their wishes and participate in governance, the enthusiasm of ordinary villagers to participate in rural governance is insufficient. On the digital governance platform, villagers can not only timely obtain relevant policies and village-level government information released on the platform, but also reflect their own demands through the platform. Relevant departments can accurately understand villagers' demands through the platform and deal with them in a targeted manner, accelerating the formation of a rural governance system oriented by villagers' demands and effectively improving the match between the governance demands and supply. Digital technology takes advantage of information sharing to narrow the information gap between the government and villagers by opening up the communication channels, and provide an open and transparent monitoring mechanism to stimulate individual participation in rural governance, ultimately promoting the transformation of the rural governance model from the unitary vertical management model to the multi-governance model.

5. Case Study

5.1. Case Selection and Data Collection

Firstly, in order to ensure that the case areas have good results in the digital village construction, we select case areas from the digital village pilot areas announced by the Chinese governments at all levels. Second, as the digital village construction is a very complex systematic project with a long construction period, and China's digital village construction is still in its infancy, it is difficult to find the same case with good construction results in different fields. Therefore, this paper adopts the multi-case study method and selects a corresponding digital village case for each of the five fields of rural sustainable development. At the same time, this paper pays attention to the wide range of economic development, topography, transportation and population in the case areas, to make the cases more representative so that the research results can provide reference experiences for more regions to build digital villages. Based on the above case selection principles, this paper selects the digital village construction in Feng County, Wuning County, Taishun County, Xifeng County and Deqing County as the case study objects. This paper has collected more than 260,000 words of original data from papers, news reports, official corporate websites, government reports and other channels, laying a good research foundation for case analysis. The geographical location of each case is shown in Figure 3, and each region is marked with a black dot in the map. Table 1 shows the brief contents of the case study.

5.2. Digital Agriculture Case in Feng County

Feng County is the main agricultural production area in Jiangsu Province, among which apples, burdocks, and fungus are the highest quality agricultural products. However, due to the extensive production methods, low quality of agricultural products, single sales channels, and poor brand effect, the traditional production and operation mode of Feng County is difficult to adapt to the requirements of modern agriculture. In this context, Feng County began to boost the transformation and upgrading of agriculture through digital empowerment.

Feng County boosts its traditional agriculture's digital upgrading and transformation, by activating data elements. Data is one of the most important factors of production in the digital economy era. The local government is deeply aware of the importance of data and began to break down administrative barriers in 2013 to foster the realization of data collection and sharing. Feng County established a public data center in 2017. Currently, the public data center has collected 340 million pieces of five types of data, including agricultural resource data, agricultural production data, agricultural business entity data, agricultural-related key data, and single-variety big data, and has realized the communication and sharing among the systems. This has laid a solid data foundation for the transformation and upgrading of the agricultural production and operation.

In terms of the agricultural industry, Feng County facilitates industrial upgrading and transformation by using digital technology to facilitate industrial restructuring and integration. Feng County has a long history of burdock planting, with a perennial planting scale of over 8000 acres. The sales of burdock products are mainly fresh burdock, and the sales price is not high. The rest of the products are mainly sold in burdock tea, but due to the small audience, the sales volume is not high. Although local companies have been developing new products of burdock, the market has not responded well. In order to solve this problem, Kanghuibainian (a local company) and the Alibaba Group reached an agreement in September 2020 to carry out in-depth cooperation in new product creation, production and marketing docking and online marketing. Following the mining and the analyzing of Taobao data with its robust digital capabilities, the Alibaba Group suggested that Kanghuibainian focus its new product development on snacks and meal replacements, and gave specific taste suggestions. Following the research and development, Kanghuibainian launched burdock egg rolls and burdock meal replacement products, and the online sales of these two products maintained a monthly growth rate of 30%. With the increase in the sales of burdock products, Feng County also established a burdock industrial park to support the construction and development of a burdock product technology research and development center, a burdock standardized planting base, a deep processing base of agricultural products and a cold chain logistics base, with the help of digital technology. At the moment, in the sales of burdock products in Feng County, 30% are fresh burdock products, and the remaining 70% are deep-processing burdock products. With the advantage of digital empowerment, the burdock industry in Feng County has achieved industrial restructuring and deep industrial integration.

Figure 3. Geographical distribution of cases.

Table 1. Brief content of cases.

Case Study	Feng County	Wuning County	Taishun County	Xifeng County	Deqing County
Affiliation	Industrial development	Ecological livability	Cultural prosperity	Service improvement	Efficient governance
Topography	Plain	Mountainous region	Mountainous region	Mountainous region	Plain, hills, Mountainous region
Transportation	★★★★★	★★★	★★	★★	★★★★
Population	930,000 people	320,000 people	270,000 people	220,000 people	550,000 people
2021 GDP	USD 7.9 billion	USD 2.5 billion	USD 1.9 billion	USD 2.4 billion	USD 8.8 billion
Case background	Feng County is the main agricultural production area in Jiangsu Province, but the sales price of agricultural products is not high and there is a lack of well-known brands.	Due to the insufficient number of supervisors and the limited supervision in Wuning County, the ecological environment in some remote villages is poor.	Taishun County is abundant in intangible cultural heritage, but its inheritance and development have encountered bottlenecks.	The distribution of medical resources in Xifeng County is uneven, the primary medical conditions are poor. Villagers in remote areas cannot enjoy high-quality medical services.	Traditional governance methods have a time lag, resulting in a complicated and ineffective governance.
Concrete measure	• Establish a public data center. • Local enterprises and Alibaba Group promote the burdock industry for industrial restructuring and integration. • Local farms and Jingdong Group build smart farms together. • Establish e-commerce parks and a livestreaming training base.	• The County has united telecom operators to build a habitat environment governance platform. • The County has jointly established China's first ecological product savings bank with Nanchang University.	• The County has carried out a digital transformation of the Taishun baijia banquet. • The County has built a mini program called "Fun Taishun" to provide a customized offline reservation for performances.	• Promote the construction of medical infrastructure. • Accelerate the digital transformation of the traditional medical infrastructure. • Establish a telemedicine system.	• Establish a digital village big data center. • Build "the map of the digital village". • Boost the transformation of rural governance to be forward-looking, scientific and precise. • Use digital technology to optimize the rural governance process.

Table 1. *Cont.*

Case Study	Feng County	Wuning County	Taishun County	Xifeng County	Deqing County
Result	• Collect 340 million pieces of agricultural data. • The growth rate of online sales of burdock products is 30% per month. 70% are deep-processing burdock products. • Labor inputs, fertilizer use, and pesticide use have all decreased on the smart farm, and farm income has increased by 70%. • The e-commerce turnover of Feng County in 2020 was USD 1.79 billion. Through online sales, the county has cultivated several famous brands of agricultural products.	• Wuning County had achieved a 99% harmless treatment rate of garbage under the premise of reducing the number of ecological management personnel by 60%. • The ecological product savings bank business has expanded from one pilot village to 12 villages, covering more than 5000 farmers. It has issued USD 2.2 million of ecological product mortgage loans, collected and cashed more than USD 298,400 of material products.	• In 2020, Taishun baijia banquet attracted 200,000 tourists to travel to Sankui Town. • The County has held more than 500 intangible cultural heritage performances and experience activities in seven months through online orders, attracting more than 100,000 visitors.	• Xifeng County has established electronic health records for more than 200,000 people. • It only takes 10 min on average to issue a diagnosis report through the telemedicine system, and tens of thousands of patients have enjoyed the excellent service.	• Collect 900 million pieces of basic data. • Through the supervision of the village governance platform, the accuracy rate of garbage classification has increased by more than 50%. • During the six months of operation of the rural governance platform, more than 100,000 cases have been handled, with an 86% reduction in processing time and a 95% disposal rate. • Within two years, villagers have reflected more than 200,000 problems through online platforms, with the disposal rate reaching 97.2%.

Note: The number of ★ indicates the degree of transportation convenience. The greater the number of ★, the more convenient the transportation in the area.

In terms of agricultural production, Feng County uses digital technology to promote the transformation of production from relying on experience farming to refined production, standardized production and intelligent decision-making. In the Apple Smart Farm jointly built by Feng County and Jingdong Group, the digital collection equipment, such as the ground Internet of Things data collection equipment, image and video collection equipment, intelligent insect collection equipment and meteorological monitoring equipment, have been laid out. The agricultural big data platform collects agricultural production data in real-time through these digital collection devices, and at the same time uses digital technologies, such as big data and artificial intelligence, to analyze the data. Based on the data analysis results, the platform provides guidance for agricultural production activities, such as whether to fertilize, irrigate and spray pesticides. By adopting digital precision planting, the farm not only improves the quality of agricultural products and the standardization of production, but also improves the risk resistance of agricultural production. For example, apple planting is hardly affected in the case of unfavorable weather. In the context of the deep integration of digital technology and apple planting, the human input of smart farms has dropped by 45%, the use of chemical fertilizers has dropped by 20%, the use of pesticides has dropped by 30%, the retail premium of apples has increased by 100%, and the farm revenue has increased by 70%.

In terms of agricultural operations, e-commerce uses digital technology to get through the production end and the consumption end, reducing the complex intermediate links and promoting the exchange of information between the two ends. First, the government vigorously promotes the construction of an e-commerce system. Feng County established an e-commerce development working group, issued a large number of relevant documents to accelerate the development of e-commerce, and set up a special support fund of USD 3 million for e-commerce development. In addition, the county has successively built three county-level industrial parks and four town-level industrial parks, attracting more than 150 enterprises to settle in the parks, with an annual transaction volume of up to USD 6 billion. Secondly, with the support of the Alibaba Group, Feng County established a Taobao operation center, based on the featured industries to provide a full-link support for e-commerce practitioners. With the help of the Alibaba Group, Feng County can form an industrial agglomeration, obtain traffic support and reduce supply chain costs. At present, Feng County has built one Taobao town and three Taobao villages. Finally, Feng County attaches great importance to the cultivation of e-commerce talents. Feng County has built a 4000-square-meter e-commerce livestreaming training base and has introduced Alibaba experts to train streamers to improve their livestreaming skills. Furthermore, Feng County also regularly connects with Taobao's official livestreaming activities, and relies on a good cooperation foundation to obtain Taobao's official traffic support to help online sales. For the moment, Feng County has trained more than 12,000 e-commerce practitioners and more than 1500 streamers. By vigorously promoting the construction of the e-commerce system, the e-commerce transaction volume of Feng County in 2020 was USD 1.79 billion, and there are more than 1320 e-commerce enterprises in the county with more than 40,000 employees. The county has built 15 town-level e-commerce service stations and 675 village-level e-commerce service outlets, reducing the cost of express delivery in rural areas by 20%. Through online sales, the county has cultivated four Chinese geographically indicated agricultural products and one regional public brand.

5.3. Digital Ecology Case in Wuning County

Wuning County is mainly composed of mountains and hills with abundant rainfall, and these conditions are suitable for tree growth. The forest coverage rate of Wuning County is as high as 75.5%, and the overall ecological situation is good. Nevertheless, due to the insufficient number of supervisors and the limited supervision in Wuning County, some remote villages have environmental damage, such as garbage dumping and water pollution. In this context, the county has built a habitat environment governance platform

on the big data cloud platform of the agriculture department of Jiangxi Province to improve the rural living environment of Wuning County.

First, Wuning County uses digital technology to promote the transformation of the rural living environment governance to intelligence and precision. The County united telecom operator uses artificial intelligence, big data, cloud computing, IoT and other digital technologies to build a habitat environment governance platform. The platform includes seven sections: overview of Wuning, research and analysis, sewage treatment, garbage treatment, village appearance, toilet revolution, long-term management and protection. Through intelligent monitoring, unmanned aerial vehicle inspection and GPS positioning sanitation vehicles, the platform realizes the functions of the big data early warning, point-to-point monitoring and long-term management services, forming real-time monitoring and delicacy management of the rural living environment, throughout the day and the whole region. For example, the county has installed IoT devices and surveillance cameras on dustbins. If the dustbins overflow, an automatic alarm will occur at the platform's back end, and the information will be sent to the garbage transporter, who will clean up the garbage in time. This mode not only realizes the timely removal of garbage and prevents the accumulation of garbage from polluting the environment, but also greatly reduces the work intensity of the transporter. Through the empowerment of the digital platform, Wuning County has achieved a 99% harmless treatment rate of garbage under the premise of reducing the number of ecological management personnel by 60%. In addition, villagers can also upload environmental pollution problems to the platform through voice, video and photos. The platform staff will register and accept the problem within 24 h, handle them within 72 h, and give feedback within five days. At present, the completion rate of reported incidents on the platform is as high as 99.8%. The active participation and supervision of the villagers in the ecological environment work have improved the rural living environment in Wuning County.

Second, Wuning County deeply integrates digital technology and the financial industry to enhance the virtuous cycle development of the rural ecological environment and rural economy. The county and Nanchang University jointly established China's first ecological product savings bank, which formed a list of ecological products, based on remote sensing data and ecological resource confirmation data. The internal platform of the bank uses geographic information systems and big data technology to conduct information management, market transactions, resource supervision and benefit evaluation of various ecological products. The essence of the ecological product savings bank is a natural resource management and operation platform. Through circulation, mortgage, shareholding and storage, the bank transforms the fragmented ecological resources into centralized asset packages, and finally realizes the conversion among resources, assets and capital. By using commercial means to attract farmers to participate in the planting and managing of ecological products, the bank has gradually formed a virtuous interaction cycle between the economy and ecology. Within half a year of its establishment, the ecological product savings bank has expanded its business from a pilot village to 12 villages, covering more than 5000 farmers. It has issued USD 2.2 million of ecological product mortgage loans, collected and cashed more than USD 298,400 of material products, and achieved good ecological and economic benefits.

5.4. Digital Rural Culture Case in Taishun County

In ancient times, the inconvenient transportation in mountainous areas led to less damage by external wars, so Taishun County has preserved a large number of ancient cultures, buildings and cultural relics. At the same time, Taishun County has 296 intangible cultural sites due to its profound historical and cultural heritage. However, as the awareness of traditional culture inheritance, among the younger generation, is gradually weakened, traditional culture inheritance and development have encountered bottlenecks. In response to this problem, the county uses digital technology to form a closely integrated model of "culture plus tourism", realizing a two-way interactive mechanism between cultural

inheritance and tourism development, and effectively solving the problem that traditional culture is difficult to inherit.

First, Taishun County carries out the digital transformation of rural cultural resources. Originated in Sankui Town, the Taishun baijia banquet has more than 800 years of history. It is an intangible cultural heritage integrating sacrificial culture, food culture, festival culture and blessing culture, with a profound historical background and strong local characteristics. The baijia banquet cultural experience park takes the evolution of the historical plots as the main line of visit. With the help of holographic images and digital 3D technology, combined with real scenes, tourists are placed in ancient scenes to understand the historical allusions and evolution of the baijia banquet. This immersive and interactive experience is more likely to arouse tourists' interest in an in-depth understanding of the intangible cultural heritage in the plot, which is conducive to the dissemination of intangible cultural heritage. In 2020, the baijia banquet has attracted 200,000 tourists to travel to Sankui Town.

Second, Taishun County uses digital technology to promote rural culture. Scenic spots in the county often have intangible cultural heritage performances, but the time and location of the performances are fixed, which causes inconvenience for tourists to watch the performances. The county has set up a mini program called "Fun Taishun", through which tourists can choose 16 intangible cultural heritage performance items, including a puppet show, bamboo carving, glutinous rice sculpture and horse-shaped lantern dance, to make a customized offline reservation for the performance. This mode greatly meets the diversified and personalized needs of tourists. Taishun County has held more than 500 intangible cultural heritage performances and experience activities in seven months through online orders, attracting more than 100,000 visitors. The "Fun Taishun" mini program includes scenic spot booking, hotel accommodation, food recommendations, and an intangible cultural heritage takeaway. All tourism-related needs in Taishun County can be met on this platform. The county boosts the publicity and performance of the intangible cultural heritage through tourism, which further enhances the inheritance and development of the intangible cultural heritage, and the rich and colorful intangible cultural heritage also increases the tourism attraction in Taishun County.

5.5. Digital Medical Case in Xifeng County

Xifeng county is located in hilly areas, within the ravines and valleys, natural conditions and traffic conditions are poor. The medical services in Xifeng County have problems, such as poor basic medical conditions, a low level of medical cooperation, and insufficient sharing of medical information, which restrict remote villagers from enjoying high-quality medical services. In order to solve this problem, the county uses digital technology to transform the medical system comprehensively and accelerates the high-quality medical resources to sink into the countryside.

Xifeng County actively fosters medical infrastructure construction to lay the foundation for the realization of digital medical services. The county vigorously promotes the network construction of town-level health centers and village-level clinics, and has built an information network covering the county's health and medical institutions. Moreover, the county ensures that each health center has five departments, including a remote consultation room, imaging room, electrocardiogram room, inspection room and digital vaccination clinic. It is also equipped with nine types of equipment, including digital radiography, color ultrasound, electrolyte analyzer, automatic biochemical analyzer and general practice system, to meet the basic medical needs of villagers.

Xifeng County provides efficient medical services to patients through the digital transformation of the traditional medical infrastructure. First of all, the county set up a health and medical cloud platform to develop 16 business system functions in six aspects: basic service management, residents' health service, medical core business, medical business collaboration, medical business supervision and big data analysis. Secondly, the county has established a population health information platform on which information, such as patient medical records and inspection images, are stored. When patients seek medical treatment,

they can authorize the medical institutions to access their electronic health records through a QR code, which greatly improves the work efficiency of doctors and encourages them to focus more on the diagnosis and treatment of patients. Xifeng County has established electronic health records for more than 200,000 people, covering 92.3% of the county's resident population. Finally, Xifeng County has established a unified reservation and registration platform for county-level public hospitals, and has promoted county-level public hospitals to carry out construction activities, such as a queuing call system and self-printing of test results, which effectively solved the problems of difficult registration and crowded queues for patients and improved the quality of the medical environment.

Xifeng County enhances the rational allocation of medical resources between urban and rural areas through telemedicine, and facilitates the sinking of high-quality medical resources into rural areas so that villagers can enjoy convenient and high-quality medical services. Due to the poor facilities and poor medical skills of the grass-roots medical institutions in the past, some villagers are reluctant to seek treatment in primary medical institutions, even when they suffer from minor diseases, but choose to go to the county public hospital for diagnosis and treatment. This phenomenon not only brings inconvenience to the patients themselves, but also squeezes high-quality medical resources. In response to this problem, based on the telemedicine platform of Guizhou Province, Xifeng County's telemedicine system connects three public hospitals with all primary health centers. At present, the medical model of the first diagnosis at the grass-roots level and two-way referral has been formed, which not only brings convenient and effective medical services to patients, but also leaves high-quality medical resources to those who need them most. Xifeng County has vigorously boosted the construction of grass-roots health centers, which has greatly improved the medical environment at the grass-roots level. Currently, the medical equipment in the grass-roots health centers can meet patients' inspection needs. When encountering difficult-to-diagnose examination images, the grass-roots doctors can upload the examination results to the county-level regional diagnostic center through the telemedicine system. The experts of the diagnosis center will make a timely diagnosis and issue a diagnostic report to help doctors make accurate diagnoses and targeted treatment for the patients. It only takes 10 min on average to issue a diagnosis report through the telemedicine system, and tens of thousands of patients have enjoyed the excellent service. In the follow-up treatment process, patients can communicate remotely with doctors in county-level hospitals through primary health centers, making it more convenient for patients to seek medical treatment and reducing the cost of medical treatment.

5.6. Digital Village Governance Case in Deqing County

Deqing County is located in the Yangtze River Delta region with good geographical advantages. In 2012, the county built a geographic information industrial park, attracting more than 300 enterprises to settle in the park and forming a geographic information industrial cluster. In 2018, the county held the first United Nations World Geographic Information Conference, which significantly promoted the application of geographic information technologies, such as drone aerial photography and high-precision positioning. Deqing County has formed a rural governance model, based on "the map of the digital village" because of its strong advantages in combining geographic information technology with digital technology.

Deqing County attaches great importance to the role of data in the digital village and has established a digital village big data center. The center releases unified data standards for rural agriculture, which are conducive to the construction of rural data bases and the improvement of the data resource system, providing data support for the development of various applications. Through various data collection channels, such as government data import, IoT device perception, and on-site data collection, the center has collected 282 types from 58 departments and about 900 million pieces of basic data.

Relying on big data and geographic information technology, Deqing County has built "the map of the digital village" to visualize rural governance. Taking spatial data,

such as electronic maps, 3D real-world maps and remote sensing images as the base, the county has established a digital twin village by superimposing data from departments, such as agriculture, water conservancy, transportation, cultural tourism and civil affairs. By comparing the images from different time points, the location and cause of the problem can be quickly identified.

Deqing County uses digital technology to boost the transformation of the rural governance from an experience-driven ex-post governance to a forward-looking, scientific and precise governance. Wusi Village in Deqing County is located in the scenic Mogan Mountains. Tourists will gather in Wusi Village in large numbers during holidays, which can easily cause congestion and conflicts. Through the use of big data collision analysis and electronic fence technology, the village analyzes information, such as the number of tourists, stay time and the trend of people flow, to realize the early warnings of overcrowding. Once the early warning occurs, the village can deploy staff to guide the location in advance to prevent a large number of tourists from gathering at a certain point, and avoid the bad experience caused by the passive management after the event, under the traditional governance model. In addition, relying on the rural governance platform constructed by "the map of the digital village", the accuracy of the rural governance can be improved by effectively combining online and offline data. " The map of the digital village" can monitor the garbage classification of each villager. Once the garbage classification is unqualified, the village governance platform will automatically send the information to the mobile phone of the sanitation manager, who will go to the household for garbage classification guidance and education. Through the supervision of the village governance platform, the accuracy rate of garbage classification has increased by more than 50%.

Deqing County uses digital technology to optimize the rural governance process, to improve the enthusiasm of multiple subjects, to participate in rural governance, and promote the formation of a two-way interactive rural governance model. Traditional rural governance models can be divided into top-down and bottom-up models. In the top-down model, government departments regularly inspect villages and solve problems after discovering them, which has high costs and an untimely governance. However, with the help of UAV remote sensing technology to automatically collect data, and through the function of data analysis and event flow processing of the rural governance platform, the platform will automatically distribute the problems to the grid staff. The grid staff will handle the tasks offline after the platform claims and uploads the processing results. Finally, the whole process will be completed through online auditing, forming a closed-loop chain of discovery, solution, evaluation and consolidation. Most parts of the process can be automated, which can not only discover and deal with problems in time, but also significantly reduce the cost and workload of the governance. During the six months of operation of the rural governance platform, more than 100,000 cases of illegal construction and environmental damage were found in the county, which reduced the handling time by 86% and resulted in a 95% disposal rate.

In the bottom-up model, villagers reflect problems to government departments, which then verify and deal with problems. However, due to various reasons, such as the inefficiency of government departments and the opaque handling process, villagers often find it difficult to bear the high economic and time costs, and some villagers often choose not to reflect relevant problems. The county uses digital technology to build the "My Deqing" mini program to achieve a two-way communication between the government and villagers. As a platform for communication, villagers can discuss and propose solutions to problems they care about in production and life on the mini program, which is conducive to realizing villager autonomy. Furthermore, villagers can reflect problems on the mini program. Based on the event flow system, the platform classifies and transmits problems to the relevant government departments for processing, and finally forms a closed-loop full-process processing mechanism of reflection, response, processing, feedback and evaluation, to realize the interaction between the front-end villagers and back-end government. The entire process is open and transparent online, which greatly arouses villagers' enthusiasm

to participate in rural governance. Within two years, villagers reflect more than 200,000 cases of neighborhood disputes and contract management through online platforms, with the disposal rate reaching 97.2%.

5.7. Case Summary

In this chapter, this paper analyzes the practical activities of the digital village construction in Feng County, Wuning County, Taishun County, Xifeng County and Deqing County. It summarizes two characteristics existing in the digital village construction process.

First, the construction of the digital villages should focus on the vital role of data and digital technology. Data is one of the most important factors of production in the digital economy era and is also the main object of the digital technology operation. All five cases have built different types of data centers or digital platforms, and conducted the in-depth mining and analysis of the collected data, to support the application development in different fields. In this process, it is essential to focus on formulating data standards and planning for building digital platforms. Rural data contains heterogeneous data from multiple fields, and different data types will increase the difficulty of data collection, storage and analysis. Therefore, local governments should formulate corresponding data standards for different data types. Furthermore, although the cost of applying digital technology and purchasing digital equipment is decreasing, it is still a huge cost for rural areas, and a single village can not afford the high construction cost of digital villages. In five cases, a county or district often establishes a common digital platform, while different villages only need to access the platform through a digital interface and develop applications on the platform, according to their own development needs. This requires the county government to have a long-term plan in the construction of the digital platform, and the government should balance the pursuit of advanced technology and meet the real demand, to meet the performance requirements of different types of application development on the digital platform.

Second, the construction of the digital village requires the joint participation of multiple subjects, such as the government, enterprises, farmers, universities and financial institutions. Only through the interaction between different subjects can the rural sustainable development be achieved. The government is an essential promoter of the digital village construction, often attracting the active participation of other subjects through formulating relevant policies. Farmers are the main participants and beneficiaries of the implementation of the digital village, and only by giving full play to the farmers' subjective initiatives, can the goal of a sustainable rural development be achieved. The digital village is a costly project, which cannot be run for a long time only relying on government funds. It is necessary to stimulate the vitality of enterprises and let them act as the glue between the system and the market to connect different subjects. The deep involvement of enterprises not only brings market capital into the project construction, but also uses their own market experience to combine various production factors in an optimal way, making up for the shortcomings of ordinary farmers in modern management.

6. Conclusions

As a result of urbanization and industrialization, there are many problems in rural areas, such as a population exodus, population aging and environmental pollution, which seriously hinder the sustainable development of rural areas. From the construction of digital cities, it can be concluded that digital technology can change the regional development mode and accelerate the sustainable development of the regions, which provides a reference for how to foster the sustainable development of rural areas. Currently, the academic community has reached a consensus on promoting the development of rural areas through digital empowerment, but the research on the digital village is still in its initial stage. The academic community has not yet formed a clear understanding of the content of the digital village construction, the theoretical logic of the digital village construction and how to build the digital village. Against this background, this paper studies how to transform rural areas into digital villages and achieve a sustainable development from the perspectives

of the technical system, theoretical logic and case analysis, in order to make up for the shortcomings of the existing research on digital villages and provide reference and guidance for the practice of digital villages.

Firstly, this paper constructs the technology architecture system of digital rural construction, which is divided into four layers: infrastructure system, village brain, application support system and application service system. From the holistic perspective, this paper proposes that the construction of the digital village needs to be planned, and all construction contents need to be within the technology framework system, while the specific construction contents need to be weighed by the villages, according to their own development needs and economic capacity. From the technical point of view, this paper points out the technical building content of the digital village, and provides guidance for the orderly and efficient construction of the digital village. Secondly, this paper uses the theory of digital empowerment to analyze the theoretical logic of realizing a rural sustainable development through the digital village construction, from five perspectives of industry, ecology, culture, service and governance. The theoretical logic research makes up for the lack of clear theoretical logic of the digital village construction in academia. Finally, through the case study of the digital village construction in five regions of China, this paper proposes that the important role of data, digital technology and digital platforms should be emphasized in the process of the digital village construction, and it is necessary to attract the participation of multiple subjects and form a good interactive relationship. Through the case studies, this paper makes up for the lack of existing literature on digital villages in the Chinese context, and provides a reference for digital village practice.

The village is a complex system, which requires the joint development and cooperation of different fields in order to achieve the goal of a rural sustainable development. This paper believes that the digital village construction is to convert real things in rural areas into binary codes, process the data through digital technology and finally give suggestions that can assist actual decision-making to promote a rural sustainable development. Therefore, the digital village construction should take data, digital technology and digital platforms as the basis, and through the formulation of interactive rules, to enhance the formation of the symbiotic relationships among the different subjects, such as the government, villagers, enterprises, financial institutions and universities, in order to achieve the goal of rural sustainable development.

7. Limitations

This paper focuses on the realization of a rural sustainable development through the digital village construction, but does not consider the negative impact of the digital divide and data privacy security in the process of the digital village construction, and also neglects the analysis of the technology adoption strategies, which need to be considered in future research. In addition, because the digital village and rural sustainable development involves a wide range of fields, possibly due to the limitation of the case selection, the research conclusions of this paper may not provide more detailed and targeted references, and future research needs to expand the scope of attention.

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