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Article

Application of Information and Communication Technologies for Public Services Management in Smart Villages

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Abstract

Information and communication technologies (ICTs) are becoming increasingly important for sustainable rural development through the smart village concept. This study aims to model ICT's potential for public services management in European rural areas. It identifies ICT applications across rural service domains, analyzes how these technologies address specific rural challenges, and evaluates their benefits, implementation barriers, and future prospects for sustainable rural development. A qualitative content analysis method was applied using purposive sampling to analyze 79 peer-reviewed articles from EBSCO and Elsevier databases (2000–2024). A deductive approach employed predefined categories to systematically classify ICT applications across rural public service domains, with data coded according to technology scope, problems addressed, and implementation challenges. The analysis identified 15 ICT application domains (agriculture, healthcare, education, governance, energy, transport, etc.) and 42 key technology categories (Internet of Things, artificial intelligence, blockchain, cloud computing, digital platforms, mobile applications, etc.). These technologies address four fundamental rural challenges: limited service accessibility, inefficient resource management, demographic pressures, and social exclusion. This study provides the first comprehensive systematic categorization of ICT applications in smart villages, establishing a theoretical framework connecting technology deployment with sustainable development dimensions. Findings demonstrate that successful ICT implementation requires integrated urban–rural cooperation, community-centered approaches, and balanced attention to economic, social, and environmental sustainability. The research identifies persistent challenges, including inadequate infrastructure, limited digital competencies, and high implementation costs, providing actionable insights for policymakers and practitioners developing ICT-enabled rural development strategies.



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Keywords: smart villages; information and communication technologies (ICTs); sustainable development; public services; digital transformation

1. Introduction

The concept of smart villages, which is seen as the way forward for the future survival of rural communities, is gaining ground in rural development in the European Union and other countries. Smart villages are defined as “communities in rural areas that develop innovative solutions to the challenges of the local context. They build on existing local strengths and opportunities, engaging in the sustainable development of their territories. They adopt a participatory approach to design and implement their strategies to improve economic, social and environmental conditions, in particular by promoting innovation and mobilising

solutions offered by digital technologies” (Bokun & Nazarko, 2023). According to Thapa and Thapa (2022), the smart village is conceptualized as a socio-technical phenomenon in which the strategic application of information and communication technologies (ICTs) is integrated with community-based social practices to facilitate inclusive and sustainable rural development. In the smart village, ICTs are not understood as merely neutral tools or automation but as a fundamental driver that interacts with social processes, community goals, and capacities, together shaping sustainable development actions and outcomes. According to Mańkowska et al. (2023), a smart village is a model of rural development that strategically uses ICTs by integrating them with community practices and local resources. ICTs help to address challenges like limited access to public services and declining economic competitiveness by providing access to digital services, more efficient resource management, and new business opportunities. Flexible access to public services is one of the key features of a smart village. Access to public services in rural areas is often achieved through ICTs.

The Organisation for Economic Co-operation and Development has defined rural public services as those traditional and digital services that require a certain degree of involvement of public authorities in order to ensure their availability and quality in regions that face specific challenges due to their geographical characteristics. Public services can include healthcare, education, transport, communications, energy, social services, and other basic services that are essential for the functioning and well-being of a community. Accessibility is a key component in the definition of public services in rural areas, as geographical isolation, distance, and population density have a major impact on service delivery mechanisms. The OCED review highlights that the provision of public services in rural areas needs to be organized differently from urban areas due to different demographic, geographical, and economic conditions and the need for adaptation to the local context (OCED, 2010). The use of ICTs, such as digital platforms, decision making systems, artificial intelligence, the Internet of Things (IoT), and others, for the management of public services in rural areas offers the potential for a better quality of life for the population (Cvar et al., 2020). These ICS simplify the monitoring of the status of rural public service areas, the collection and processing of data, the saving of resources, the forecasting of future prospects, the anticipation of preventive actions and the rapid resolution of incidents, and the making of rural management decisions based on reliable data. They act as a lever for smart villages to become more resilient, to make better use of their resources, and to improve the attractiveness of rural areas and the quality of life of rural people. Malik et al. (2022) provide similar insights, noting that ICTs in rural areas address complex socio-economic challenges, ensuring inclusive and sustainable development of rural communities. ICT deployment enables improved access to services, increased efficiency of production, development of the local economy, and promotion of community involvement in decision making processes. Despite its positive potential, ICT integration in rural areas faces structural challenges, dominated by inadequate technical infrastructure, limited digital competences, high costs of technology deployment, and a lack of solutions tailored to local needs. According to the authors, addressing these challenges requires an integrated approach involving both the development of physical infrastructure and the improvement of the digital skills of rural populations, as well as the systematic integration of ICT into rural development strategies (Malik et al., 2022). Mańkowska et al. (2023) add that the main challenges in the implementation of the smart rural concept are insufficient funding, weak telecommunication infrastructure, lack of digital skills of the population, and the need to tailor technological solutions to the needs and context of specific locations.

Despite the increasing use of ICTs for rural public services, there is currently still a lack of sufficient research to answer the questions of what ICS are used in rural areas, what

benefits they provide, what challenges they face, what will be the future demand for them, how well they are integrated, and what are the future possibilities for integration to achieve rural prosperity. Many studies conducted by foreign researchers highlight the benefits of using ICT to improve the quality of life of rural populations, management efficiency, and sustainable development. In particular, many researchers emphasize the importance of urban–rural integration and cooperation through the use of ICTs in terms of resources, knowledge, and bridging the gap between urban and rural populations. However, it is still difficult for rural communities to decide which ICT solutions would be effective in enhancing their well-being. [Cvar et al. \(2020\)](#) found that “the quality of life of people in rural areas is strongly improved by the deployment of ICT solutions in different domains, but their deployment needs to take into account the specificities of ecosystems.” Moreover, according to these authors, smart cities are characterized by technology-intensive fragmentation and densification, while smart villages are characterized by a lack of technological capacity. Cooperation between the two ecosystems is therefore essential to ensure quality of life in both ecosystems and to bridge the gap between them. These researchers have found that unlike the smart city, the smart village is characterized by a lack of technological and infrastructural resources and that smart cities and villages need to collaborate with each other, share resources, and adopt and implement joint technological solutions ([Cvar et al., 2020](#)). [Veeranna et al. \(2022\)](#) emphasize that “information technology can significantly improve the quality of life of rural populations by optimising areas such as smart agriculture, smart weather and irrigation management, smart animal husbandry, smart healthcare, smart energy monitoring and smart education.” [Kalinka et al. \(2020\)](#) stress that smart villages operate on the basis of the neo-endogenous model, which emphasizes the increased role of local communities in planning processes and the importance of taking into account the economic, social, environmental, cultural, and service delivery indicators that reflect the dimensions of sustainable development in the decision making process of ICT implementation. According to these authors, a balance between nature conservation, meeting people’s needs, and economic growth, complemented by technological solutions, is an essential prerequisite for building a sustainable and intelligent rural community, especially in areas facing specific challenges. This insight sheds light on the challenge of reconciling ICT deployment aspects with the requirements of sustainable rural development. Sustainable rural development is a comprehensive, integrated process aimed at improving the quality of life and economic well-being of people living in rural areas in a balanced way while preserving environmental resources for future generations. This process encompasses three main dimensions, economic (increasing productivity and creating jobs), social (ensuring social equity, affordable education, health, and infrastructure), and ecological (protecting biodiversity, essential ecosystems, and ecological processes), all of which together contribute to building sustainable, resilient, and prosperous rural areas ([OCED, 2010](#)). Sustainable development of rural areas is “A process that seeks a balance between the ecological/environmental, social and economic dimensions of areas. It implies improving living and working conditions in rural areas, while respecting the social, cultural and environmental values of the areas” ([Suárez Roldan et al., 2023](#)). These authors also stress the importance of endogenous development principles for rural development, which prioritize local control in development processes, the use of the resources available in the territory, and the maintenance of local profits. Aspects like the integration of technology into agricultural production processes, the infrastructural dimension, which includes communications and communication systems, and access to networks and communications in rural areas all have an impact on the sustainable development of rural areas. [Lai et al. \(2024\)](#) specify that the development of smart rural ICTs involves the implementation of differentiated spatial planning, the formulation of targeted digital policies to attract talent

and develop technological competences, the deployment of integrated digital systems to enhance sectoral synergies, the promotion of data-driven decision making through the development of an agricultural information analytics infrastructure, and the development of an inclusive digital infrastructure that bridges the rural–urban digital divide and adapts to demographic changes, including the demands of the ageing population.

Thus, it can be assumed that in order to create quality living conditions in rural areas, it is necessary to ensure the accessibility of public services, compatibility with sustainable development objectives, integration with urban ICTs, the implementation of a neo-endogenous approach, and the improvement of the population’s digital literacy. This requires knowledge of the current situation of the use of ICT in rural areas, the problems that can be solved through the use of appropriate ICT, and the challenges that can be encountered in their selection, deployment, and use. Based on these insights, the research described in this paper was carried out to model the potential of ICTs for the management of public services in rural areas in the context of the concept of sustainable development. The objectives of the study were as follows: to identify which ICTs are used in which rural public services areas; to identify the specific rural problems to which these ICTs are applied; and to analyze the benefits, challenges, and future prospects of ICT applications in the context of sustainable development.

The results of the survey revealed that a wide range of rural stakeholders are currently using ICTs to address the key challenges facing rural areas, such as limited access to public services, inefficient resource management, and demographic challenges. Successful technology deployment requires urban–rural cooperation and a neo-endogenous model that emphasizes the role of communities, which is currently not being successfully implemented everywhere. ICT solutions need to address all dimensions of sustainable development (economic, social, environmental), but they require an integrated approach that includes not only technology but also infrastructure development and digital skills training. Despite the clear benefits, the ICT development process faces challenges, such as insufficient infrastructure, limited digital skills and high costs, and a weak orientation towards reconciling all dimensions of sustainable development. ICT deployment focuses more on solving rural problems than on exploiting opportunities. It has been identified that successful ICT deployment requires cooperation between different stakeholders, with a particular role for local leaders. The study highlights that there is no one-size-fits-all technological solution—they need to be tailored to the demographic, geographic, and socio-cultural characteristics of specific areas.

This study will make a significant contribution not only to the scientific understanding of the specificities of the application of ICTs in rural public services but also to the enhancement of the potential for well-being in rural areas in the context of the concept of smart development, especially if the results are taken into account by strategic decision makers in the context of sustainable rural development.

2. Materials and Methods

In order to achieve the aim of the study, a qualitative content analysis method was chosen. This method was chosen because it allows for the extraction of categories from a large number of scientific publications that reveal the phenomenon under analysis. The combination of categories and subcategories allows for revealing the nature of the analyzed phenomena, gaining unique knowledge about them, and forming conclusions based on empirical data (Zydzionaite & Sabaliauskas, 2017). The sample was drawn using a non-probability sampling method, purposive sampling, by selecting the scientific publications that best reveal the phenomenon under study. Qualitative content analysis does not aim to provide precise data for a statistical study, so the sample was drawn according to certain

predefined parameters. Cases of ICTs used in smart villages for the management of public services were selected for the study because they had special characteristics and specific, distinctive features that enabled the researcher to gain a deeper understanding of the object of the study. Data for the study were collected until no new cases were found within the defined research period and databases—a saturated research sample. The collection of cases was not aimed at quantity, as, in the case of qualitative content analysis, at least one mention of a component of the phenomenon under study confirms its existence and relevance. The research sequence is presented in Figure 1.



Figure 1. Logic scheme of the methodology.

The research sample was formed by collecting scientific publications from EBSCO and Elsevier databases. These databases were selected due to their full article access, content search capabilities in specific disciplines, and exclusive peer-reviewed academic literature. Both databases offer intuitive search and filtering options, with full institutional access available to the authors. The search terms “Smart village”, “Digitization”, and “Information and communication systems” were used. The period of the searched publications was defined as 2000–2024. This period was chosen because the EU rural development policy measure “Smart Villages” was launched in 2017, but ICT use in rural areas existed before this initiative. Although this issue was not discussed at the political level, there were already examples of ICT use in reality and in the scientific sphere. To analyze the situation before the policy measure’s implementation, the 2000–2024 period was selected for scientific literature analysis, as 2024 represents a clear, round timeframe that allowed for finding all articles published in those years. Only open access scientific publications were searched. The method of data collection was document selection, which involved analyzing the texts of scientific publications.

The EBSCO database provided 27 results for the parameters specified. The Elsevier database provided 123 results. Further screening of scientific publications was carried out by reviewing the abstracts and checking articles with keyword searches of the text for “Smart village”, “Digitization”, and “Information and communication systems”. For the primary analysis of the texts of the scientific publications, generative artificial intelligence (GenAI) Claude Ai was used. It was used to assess whether the selected scientific publications contained sufficient data on the object of study. After assessing the suitability of the abstract of the scientific publication for the purposes of the study and the sufficiency of the repetition of keywords, 20 scientific articles published in the EBSCO database and 59 scientific articles published in the Elsevier database were selected for the study. Other articles were rejected as inappropriate for the context of the study or due to insufficient repetition of keywords and lack of explanations and insights and were used only for review purposes.

The selected research articles were searched for units of meaning—paragraphs or sentences—that reveal the answers to the research questions and enable the formation of categories that reveal the phenomenon under analysis. The research analyzed the published (manifest) content of data. The study used a deductive qualitative content analysis methodology, as the structure of the data analysis was based on the data of previous research, i.e., it builds on the basis of existing knowledge in order to test the data of previous research and the validity of the developed theories in the new context. In the course of the analysis of the data, the data were analyzed from generalities and generalizations to individual details, highlighting the distinctive characteristics of the phenomenon under study. This reveals the diversity of characteristics of a phenomenon in a given setting. To this end, a matrix of categories and subcategories was developed throughout the study, which included the following components: ICT scope, ICST name, ICT definition, problem solved by ICT, challenges and statements supporting the categories and subcategories, and authors.

The researcher analyzed the selected scientific publications and coded the research data according to the predefined categories, i.e., they analyzed the interview texts in an attempt to find out how the research phenomenon is described in the context of the specific study and what are the possibilities of its application in the selected new context. The conclusions of the study were drawn from the understanding of the categories and subcategories identified, as well as the statements describing them, by means of a matrix of categories. Following a deductive approach, the categories and subcategories identified in the study were used to build a model of the relationship between ICT and its applications in rural areas, using the VOSviewer_1.6.20 tool for visualization. The results of the study are presented by categorizing the use of ICTs according to the areas of public services in rural areas, revealing the problems they solve and the opportunities they exploit, identifying the challenges encountered, and formulating recommendations for future ICT deployment initiatives in rural areas.

3. Results

In the context of smart villages, information and communication technologies (ICTs) are addressing a wide range of rural challenges. This section discusses the main ICT applications and challenges and problems encountered based on the results of a qualitative content analysis of scientific articles in the field of smart villages. The areas of ICTs and their applications in the management of public services in smart village areas (smart agriculture, cooperation and communication, commerce, learning and education, health, silver community, home, tourism, transport, energy, environment, governance, finance, waste, water, and work) identified in the study are presented in Figure 2 and discussed in more detail below, with a description of the problems addressed, the benefits provided,

and the challenges faced. The discussion of ICT areas below includes figures showing the most commonly used ICT categories in that area. The descriptions of ICT spheres include subcategories that reveal more precisely which technologies comprise those ICT categories.

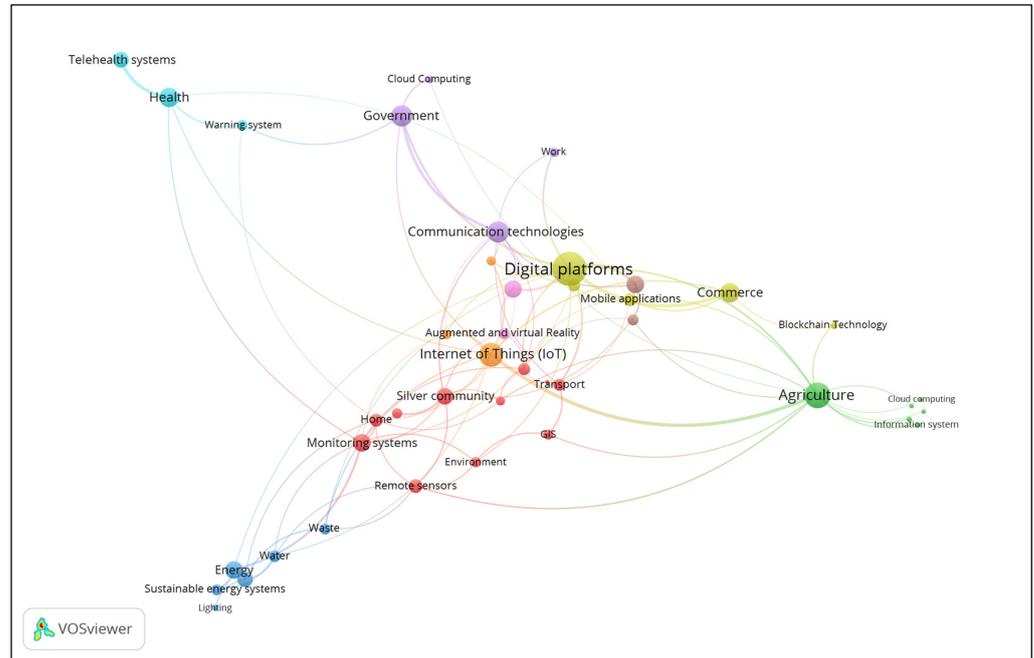


Figure 2. ICT links to smart village public service areas.

3.1. Smart Agriculture

Figure 3 shows a range of advanced ICTs used in agriculture to address the inefficiencies of traditional farming and modernize agricultural practices. The academic literature reveals a number of key ICT categories corresponding to the clusters of ICT technologies that are transforming the field.

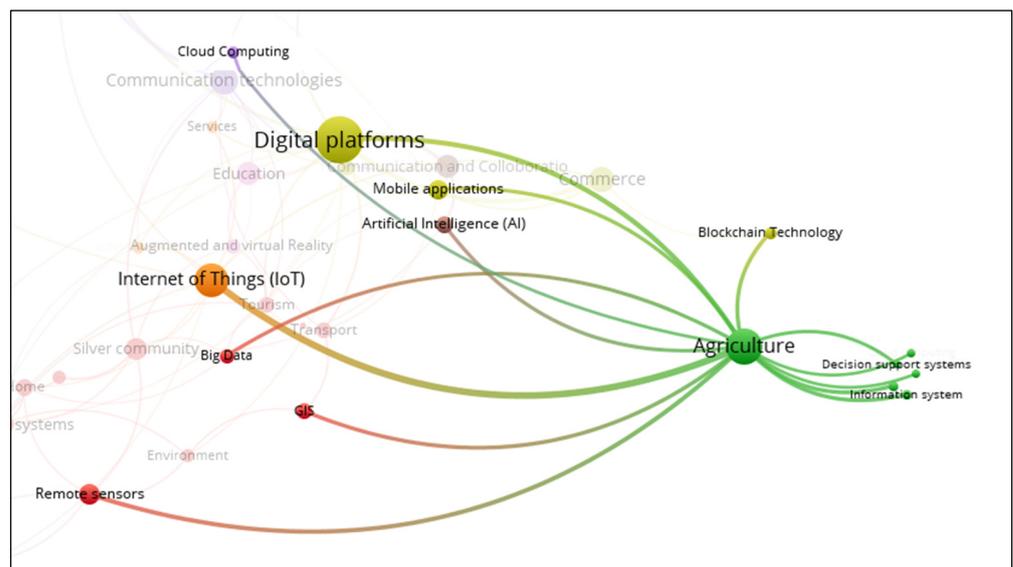


Figure 3. ICT categories in smart agriculture.

Artificial intelligence and big data are helping to more accurately analyze climate changes, water usage, livestock movement, and pasture and forest development (Malik et al., 2022). According to Hlaváček et al. (2023), Somasekhar et al. (2022), Veeranna

et al. (2022), and Ilie et al. (2022), artificial intelligence systems are effectively used for smart irrigation systems, drought sensors, and agricultural and food management chain data analysis.

Blockchain technology, as indicated by Enayati et al. (2024), Ferrari et al. (2022), and González et al. (2023), strengthens the transparency, traceability, and productivity of agricultural supply chains. Fraser (2022) describes blockchain software that helps farmers record, plan, and manage their operations, ensuring better control and data independence.

Cloud computing provides the ability to create networks of remote servers capable of storing, managing, and processing agricultural data (Ilie et al., 2022). Metta et al. (2024) emphasize that cloud technologies are increasingly used for networking, collaboration, business, e-governance, community, and farm management.

Geographic information systems (GIS) allow farmers to plan production based on timely information obtained directly from cultivated land (Veselinović et al., 2021). Janota et al. (2023) explain how GIS maps help comprehensively assess soil potential for biomass cultivation.

Internet of Things (IoT) devices, such as drones, robots, sensors, and smart gates, address inefficient farming and resource use issues. Malik et al. (2022) emphasize that the use of drones and robots, coupled with innovative IoT technologies, helps analyze crops, detect diseases, and manage disaster risks. Senkayas and Aysun (2019) describe various advanced IoT systems, including beekeeping tracking systems, greenhouse monitoring, meteorological stations, and smart gates.

Digital platforms, including agri-fintech and farm management platforms, address the problem of limited access to financial and market interfaces. Singh et al. (2023) and O'Neill Somers and Stapleton (2020) note that these platforms provide financial solutions, agricultural advice, and market interfaces for agricultural value chain participants.

Despite the obvious benefits of ICTs in agriculture, their implementation faces significant challenges. Tetteh Quarshie et al. (2023) reveal that many small farms lack access to digital tools, while Thackara (2019) and Fraser (2022) draw attention to data management and autonomy issues. Soluk et al. (2021) emphasize that successful technology implementation also requires appropriate skills, and Jakobsen et al. (2023) warn that technology alone is not enough to overcome food system sustainability challenges.

ICT integration in agriculture addresses a wide range of problems, including inefficient monitoring of farming conditions, limited capacity to process large amounts of data, lack of transparency and traceability in supply chains, and complex navigation between regulations. Various ICT systems enable farmers to make data-driven decisions, optimize resource use, and increase productivity. However, ICT deployment in agriculture faces significant challenges. Rural areas often lack the digital skills and infrastructure necessary to support such technologies. There is also a high cost barrier to implementation and maintenance, especially for small farms. Data privacy, security issues, and system interoperability problems remain critical aspects. Successful ICT implementation requires an integrated approach that considers the entire rural ecosystem, needs, and opportunities to share data, technologies, and resources, ensuring both economic and environmental sustainability.

3.2. Smart Communication and Collaboration

In the modern digital era, the transformation of rural communication systems is becoming an increasingly significant factor in social and economic development. The implementation of digital communication and communication tools encompasses a wide spectrum of technologies, from artificial intelligence and the mobile applications to digital platforms and other communication technologies, like electronic information boards. They are shown in Figure 4. These technologies address fundamental rural challenges, including

social isolation, limited access to information, insufficient communications infrastructure, and demographic changes.

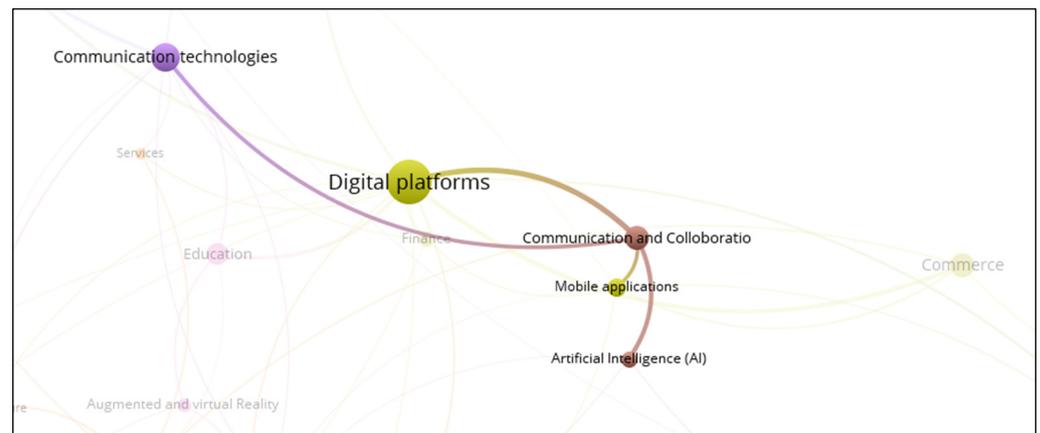


Figure 4. ICT categories in smart communication and collaboration.

As [Stein et al. \(2022\)](#) emphasize, digital neighborhoods can strengthen social support and promote civic participation, while [Atkočiuniene and Vazoniene \(2019\)](#) highlight the importance of digital and telecommunications technologies in creating networks of traditional and new interests in rural territories. Successful smart communication and cooperation in smart villages require digital platforms such as decision support systems, online discussion group platforms, and open data forums. Also, mobile applications and access to web portals and social networks.

Despite obvious benefits, the implementation of communication technologies in rural areas faces complex challenges. The digital divide, illustrated by limited access to telecommunications and the internet, remains a key issue, as confirmed by research by [Varghese \(2016\)](#). Additionally, technological limitations, such as insufficiently developed broadcasting system infrastructure, mentioned by [Cho and Park \(2023\)](#), and the lack of digital skills identified by [Torabi et al. \(2023\)](#), impede successful technology adoption. [Manapa Sampetoding and Er \(2024\)](#) note that implementing the smart village concept requires integrating artificial intelligence with big data technologies to combat population decline, while [Hlaváček et al. \(2023\)](#) emphasize the importance of communication technologies, like electronic public notice boards and municipal television in improving information accessibility.

Successful implementation of digital communication systems in rural areas requires a comprehensive combination of infrastructure development and human capital development strategies that ensure technologies are accessible, adaptable, and beneficial to all demographic groups in rural communities—from youth who, according to [Fennell et al.'s \(2018\)](#) research, use mobile phones with mobile applications and the internet to expand social networks, to older residents for whom information accessibility may be particularly relevant in addressing everyday communication challenges.

3.3. Smart Commerce

ICT is transforming trade and commercial opportunities in rural areas, creating a smart commerce environment that helps overcome traditional geographic, informational, and market barriers. The integration of digital platforms, from e-commerce platforms to mobile solutions, gives rural businesses the opportunity to reach a broader consumer base more effectively. ICTs applied in the commercial sector in the context of smart villages are presented in [Figure 5](#).

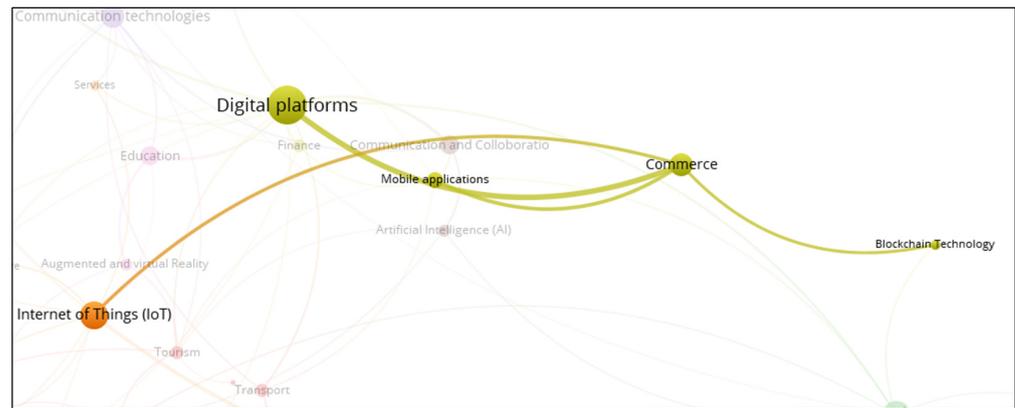


Figure 5. ICT categories in smart commerce.

Stein et al. (2022) indicate that digitalization strengthens local supply offerings and new business models, while Despotović et al. (2020) confirm that the modern development of rural areas in Montenegro relies on modern business communication tools, including online marketing. The spectrum of smart commerce technological solutions includes digital platforms for e-commerce and marketplaces, online marketing, social network business tools, also blockchain systems, mobile applications, and the Internet of Things (IoT). Bielska et al. (2021) state that personal farmer digital platforms provide an opportunity to reach customers directly, eliminating intermediaries in the retail chain. Meanwhile, Gaudel et al. (n.d.) emphasize that the internet gives entrepreneurs the opportunity to take advantage of business opportunities and effectively demonstrate business existence through information exchange.

Smart commerce solutions (digital platforms, internet of things, mobile applications, blockchain technologies) help address several key rural business issues. First, they help overcome limited local market accessibility, which is confirmed by Tiwasing et al.'s (2022) research showing that 80% of rural business owners in the United Kingdom seek to use e-commerce for international trade in goods and services. Second, these solutions improve the efficiency of direct food supply chains, as demonstrated by the Open Food Network (OFN) platform described by Singh et al. (2023). Third, they reduce information asymmetry between producers and consumers, as illustrated by automated planning platforms mentioned by Metta et al. (2024), which help farms better coordinate activities with customers.

Despite the clear benefits of smart commerce, its implementation in rural areas faces complex challenges. Infrastructure limitations, including limited internet connectivity faced by rural areas, restrict entrepreneurs' ability to fully leverage the opportunities offered by digital commerce. The lack of digital skills, especially among traditional rural business owners, as shown by Soluk et al.'s (2021) research on Indian rural microenterprises, makes it difficult to adopt new technologies. Additionally, as noted by Hofmann-Souki et al. (2024), the creation of regional platforms often consumes most of the resources available in such projects, leaving little room for technology maintenance and development.

Successful implementation of smart commerce solutions in rural areas requires a comprehensive approach that encompasses not only technological aspects but also infrastructure development, digital skills development, and integrated business models that meet the unique needs of rural communities and leverage their strengths in the global digital marketplace.

3.4. Smart Education

In rural areas, access to education and its quality remain two of the biggest challenges, which are being addressed through various ICT implementations shown in Figure 6.

The scientific literature reveals several main technology groups transforming traditional learning practices.

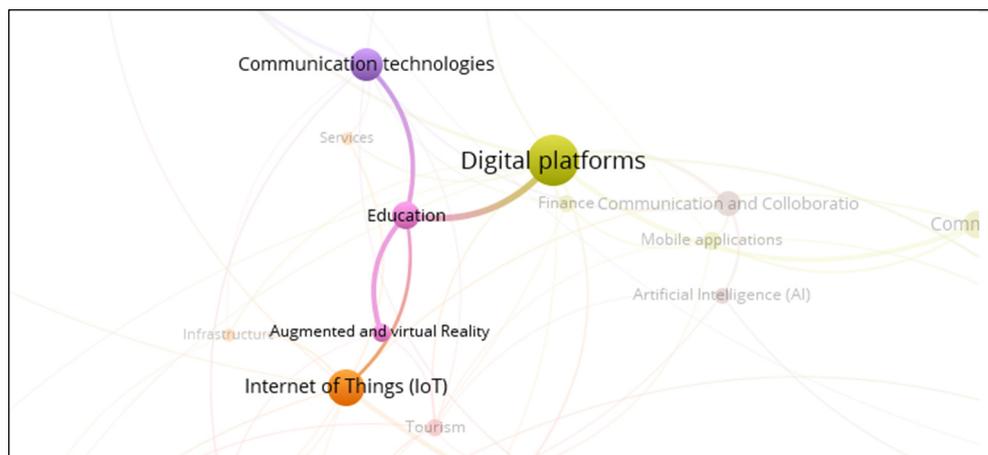


Figure 6. ICT categories in smart education.

Digital education platforms, discussed in the work of [Despotović et al. \(2020\)](#), [Ilie et al. \(2022\)](#), and [Gorelova et al. \(2024\)](#), address the problem of limited access to educational resources. [Ferrari et al. \(2022\)](#) and [Emerllahu and Bogataj \(2024\)](#) emphasize that distance learning systems help students for whom physical accessibility to educational institutions is limited. It is important that learning for rural residents is not only accessible remotely but also inclusive. For this purpose, augmented and virtual reality (AR/VR) technologies can be used, as indicated by [Malik et al. \(2022\)](#), to allow students to experience simulated learning environments and gain knowledge. [Lučan et al. \(2024\)](#) describe online simulation games applied for inclusive learning purposes.

Learning from remote rural areas requires not only digital platforms but also digital skills for learners. Digital skills development platforms, which reduce the digital divide, are analyzed by [Sasu et al. \(2024\)](#), [Tiwasing et al. \(2022\)](#), and [Andrei et al. \(2023\)](#). Research by [Fennell et al. \(2018\)](#) and [Zhang et al. \(2023\)](#) confirms that digital literacy can be achieved through greater participation in digital learning activities. [Varghese \(2016\)](#) and [Vidmar et al. \(2022\)](#) describe online knowledge systems as important elements for ensuring access to educational resources.

Despite the benefits, ICT implementation faces significant challenges. [Bokun and Nazarko \(2023\)](#) emphasize the importance of reliable internet, [Sept \(2020\)](#) and [Stein et al. \(2022\)](#) mention the accessibility of digital tools, while [Marioara and Armanca \(2020\)](#) describe the “Smart School” project as a solution for educational development in rural settings. [Głębocki \(2023\)](#) and [Bogataj et al. \(2022\)](#) emphasize the need to improve IT literacy in the context of rural development, not just within formal education frameworks. Infrastructure shortages, the digital divide, and limited physical access to technologies remain the main challenges that must be addressed comprehensively.

3.5. Smart Health

In rural areas, healthcare accessibility remains one of the biggest problems, which is being addressed through various ICT solutions presented in [Figure 7](#). The scientific literature reveals several main technology groups transforming healthcare practices in rural communities.

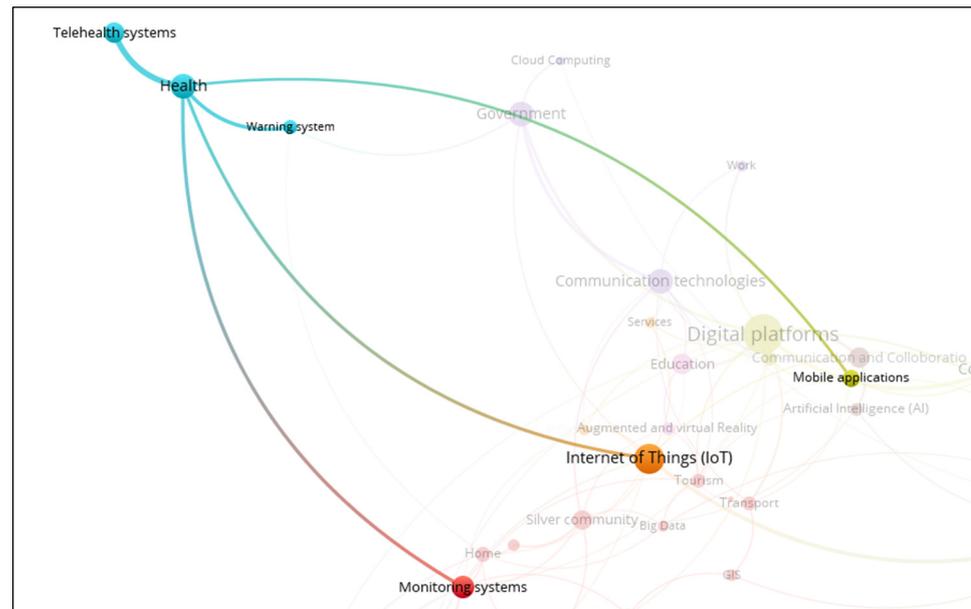


Figure 7. ICT categories in smart health.

Telemedicine systems constitute the largest ICT group designed to address limited accessibility to healthcare services. [Stein et al. \(2022\)](#), [Sasu et al. \(2024\)](#), [Despotović et al. \(2020\)](#), [Ilie et al. \(2022\)](#), and [Varghese \(2016\)](#) emphasize that remote healthcare monitoring systems can fill gaps in the healthcare system and compensate for the lack of personal care in remote rural areas. [Bokun and Nazarko \(2023\)](#), [Emerllahu and Bogataj \(2024\)](#), and [Lučan et al. \(2024\)](#) emphasize the importance of reliable internet for access to digital healthcare services in rural areas. [Zhang et al. \(2023\)](#) and [Rajer and Bogataj \(2022\)](#) confirm that the integration of e-health and telemedicine into healthcare is crucial for addressing care gaps in remote rural areas.

Monitoring systems, including remote monitoring systems, video surveillance systems, and smart homes, address security and health monitoring issues. [Sasu et al. \(2024\)](#) mention the acquisition and/or expansion of video surveillance systems, while [Vidmar et al. \(2022\)](#) and [Drobež et al. \(2021\)](#) emphasize the importance of wireless sensor networks for monitoring the health and activities of older people. [Tan et al. \(2021\)](#) indicate that 83% of elderly people would like smart emergency contact systems to be implemented in a smart retirement village, including wearable electronic devices with fall alerts and basic medical information.

Warning systems, such as integrated emergency systems and mobile emergency applications, address slow responses to emergency situations. [Hlaváček et al. \(2023\)](#) mention radio communication with an integrated emergency system and a mobile application for calling for help. [Cowie et al. \(2020\)](#) describe an IoT emergency response system designed for sharing medical information between first responders and paramedics, saving critically important time.

Internet of Things (IoT) devices and mobile applications also play an important role in providing healthcare services in rural areas. [Manapa Sampetoding and Er \(2024\)](#) indicate that health and social services combine IoT as infrastructure with digital platforms. [Lučan et al. \(2024\)](#) describe the smartphone application designed for rural health volunteers making healthcare decisions for elderly people.

Despite the obvious benefits, ICT implementation faces significant challenges, including the digital divide, limited access to technology, and inadequate infrastructure. [Nedeljko et al. \(2023\)](#) emphasize that digital technologies for health and care service provision are not systematically integrated into regional health and social infrastructure, and there is

significant inequality in access to ICT among older adults. Research by [Liu et al. \(2024\)](#) and [Pontones-Rosa et al. \(2021\)](#) show that the adoption of new technologies may be limited by computer availability at home, especially among older and lower-income residents.

3.6. Smart Silver Community

The well-being and independent living of elderly people in rural areas are becoming increasingly relevant challenges, which are being addressed through various ICT solutions listed in Figure 8. The scientific literature reveals several main technology groups transforming care practices in silver communities.

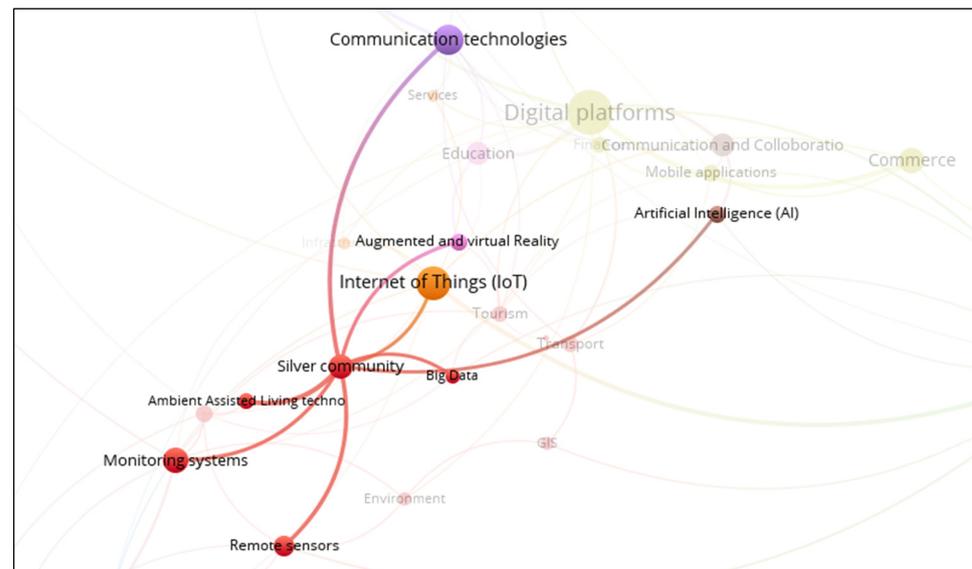


Figure 8. ICT categories in smart silver community.

Ambient Assisted Living (AAL) technologies constitute the largest ICT group designed to help elderly people live independently. [Podgórnjak-Krzykacz et al. \(2020\)](#), [Bogataj et al. \(2022\)](#), and [Vidmar et al. \(2022\)](#) emphasize that AAL technologies, including smart homes, sensors, embedded systems, and robotics, create an ecosystem that helps elderly people with decreasing physical and cognitive capabilities. [Drobež et al. \(2021\)](#) and [Rajer and Bogataj \(2022\)](#) indicate that communication technologies can significantly reduce the risk of falls, social exclusion, and loneliness, thus delaying the need to move to nursing homes.

Remote sensors and monitoring systems effectively address security and health monitoring issues. [Podgórnjak-Krzykacz et al. \(2020\)](#) mention GPS devices with a 24/7 monitoring system designed for elderly people with memory disorders. [Bogataj et al. \(2020\)](#), [Rajer and Bogataj \(2022\)](#), [Dokl et al. \(2022\)](#), and [Lučan et al. \(2024\)](#) describe wearable technologies with sensors for health monitoring, portable electrocardiographs for atrial fibrillation detection, and fall posture monitoring systems.

Artificial intelligence (AI) and big data help predict potential health problems and optimize care services. [Emerllahu and Bogataj \(2024\)](#) emphasize that social innovations in smart villages are based on the application of smart living environments with integrated artificial intelligence. [Drobež et al. \(2021\)](#) indicate that big data analysis can help identify trends and optimize care provision. [Cho and Park \(2023\)](#) describe an AI-based care service where elderly people can communicate emotionally, receive various information, and use emergency functions.

Internet of Things (IoT) devices and communication technologies, including social networking applications and interactive information kiosks, address the problem of social isolation. [Bogataj et al. \(2020\)](#) and [Nedeljko et al. \(2023\)](#) emphasize that the use of

ICT ensures connection between an individual and their social network, reducing the impact of social and geographical isolation. [Lučan et al. \(2024\)](#) describe a virtual village platform designed to reduce social isolation, as well as a medication reminder bracelet and a mobile application.

Despite the obvious benefits, ICT implementation faces significant challenges. [Lučan et al. \(2024\)](#) reveal that the ability of older Polish residents to adopt ICT solutions faces obstacles, especially among the oldest segments of rural communities. [Nedeljko et al. \(2023\)](#) note that digital technologies for health and care service provision are not systematically integrated into regional infrastructure, and there is significant inequality in access to ICT among older adults. [Jakobsen et al. \(2023\)](#) indicate that although smart home technologies can help detect and predict loneliness and social isolation, addressing these problems requires a comprehensive approach.

3.7. Smart Home

Smart home technologies deployed in rural areas play an important role in addressing the quality of life and independence issues of residents, especially elderly people. They are presented in Figure 9. Elderly people living in rural areas often face difficulties in safely managing their homes, especially as their functional abilities decrease; therefore, various smart technologies are used ([Bogataj et al., 2020](#)).

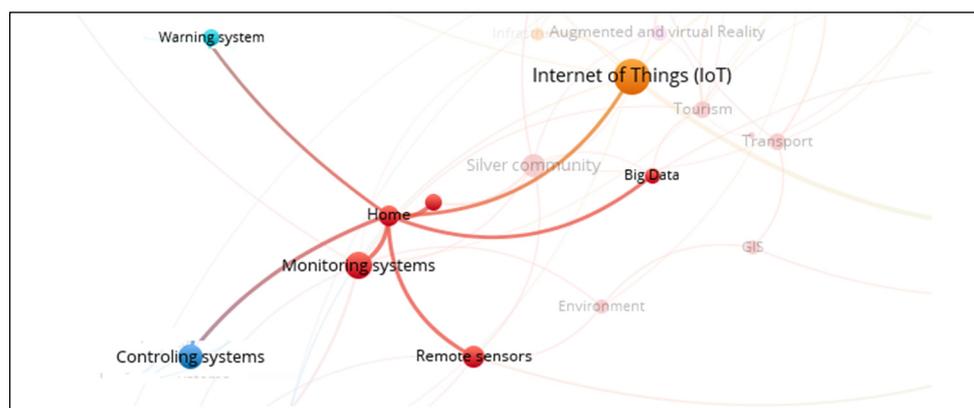


Figure 9. ICT categories in smart homes.

Smart homes use various technologies to collect and process data ([Bokun & Nazarko, 2023](#)), so the provision of long-term care services in rural areas can be facilitated by smart homes ([Vidmar et al., 2022](#)). These technologies allow elderly people to live independently by using automated systems, even in the absence of relatives ([Rajer & Bogataj, 2022](#)). They can facilitate healthy, safe, and responsive environment supported living in rural areas, where elderly people can receive healthcare services ([Gómez-Carmona et al., 2023](#)). Research shows that 97% of adults over 90 years old did not activate help in case of a fall, which confirms the effectiveness of automatic sensors and warning systems ([Rajer & Bogataj, 2022](#)). Ambient technologies and control systems improve living conditions. [Głębocki \(2023\)](#) notes that “smart homes with integrated automatic systems increase energy efficiency and comfort.” IoT sensors and monitoring systems ensure home security. [Bielska et al. \(2021\)](#) indicate that these technologies “allow monitoring of the home environment and rapid response to dangerous situations.” Research by [Nedeljko et al. \(2023\)](#) and [Enayati et al. \(2024\)](#) confirms the effectiveness of these systems. Smart home technologies in rural areas improve the quality of life of elderly people, ensure their safety, and promote independence, despite various technological and infrastructural challenges.

With the rapid development of smart home technologies, there is an increasing need to create effective systems in rural areas, but efficient management and control of the

energy required for such homes in rural environments face many challenges (Huang, 2024). The main challenges include data security and privacy, efficient energy management, technological infrastructure in rural areas, and big data-driven decision making (Bokun & Nazarko, 2023).

3.8. Smart Tourism

ICTs in rural tourism play an essential role in promoting the attractiveness and competitiveness of rural areas, as shown in Figure 10. Therefore, to achieve sustainable development of rural areas, it is advisable to integrate ICT into the tourism sector, as well.

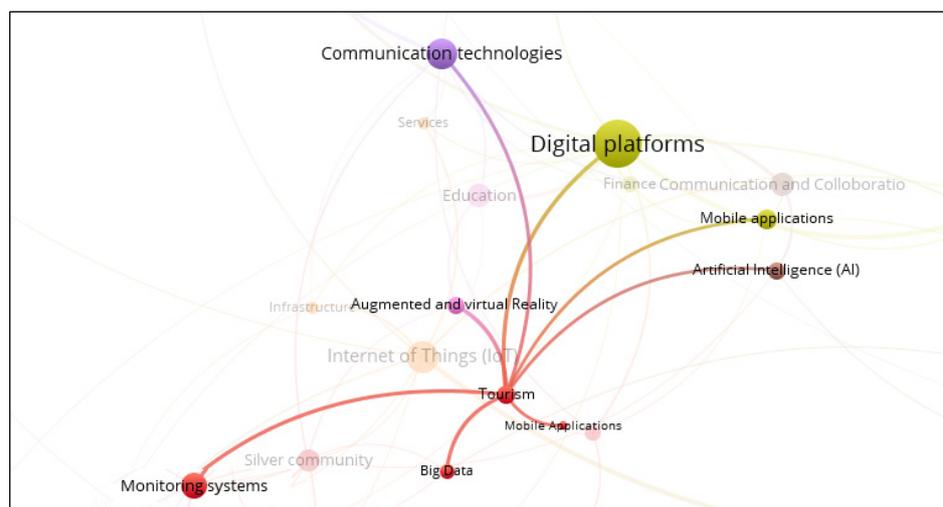


Figure 10. ICT categories in smart tourism.

For rural areas to develop sustainably and for residents to have a good quality life, income, creation of social connections, and care for the environment, infrastructure, and culture are needed. These processes are significantly accelerated by tourism development, especially smart tourism development. Virtual reality solutions are used for virtual village tours, helping to address the problem of limited promotion of rural areas (Atkočiuniene & Vazoniėne, 2019). Augmented and virtual reality technologies enhance visitor experiences. Vidmar et al. (2022) emphasize that augmented reality “can revive historical objects and offer interactive educational experiences.” Smart digital platforms in tourism help improve the economy and promote tourism offerings, especially in border regions (Palma Pinar & Mecha López, 2022). Integrated multi-service platforms cover areas like tourism, public services, mobility, and energy, providing digital services to end users (Gómez-Carmona et al., 2023). Digital platforms, according to Lombardo et al. (2023), “help small rural tourism businesses reach a wider audience.”

Artificial intelligence and mobile applications personalize tourist experiences. Tetteh Quarshie et al. (2023), Thackara (2019), and Janota et al. (2023) emphasize that these technologies “help create visitor-tailored experiences based on their interests and needs.” Mobile applications help address rural tourism development issues by providing information about local attractions (Głębocki, 2023). Digital experience technologies are used to increase accessibility to cultural heritage, creating immersive experiences related to cultural heritage, history, and traditions. Immersive museum technologies are used to present cultural artifacts and history (Lombardo et al., 2023).

The adoption of smart tourism technologies is hampered by two main challenges: the number of people without access to new technologies due to poor social and economic conditions and the number of rural residents who have access but lack sufficient skills. Online reservation systems in rural accommodation facilities are becoming increasingly

important to meet tourist needs (Torabi et al., 2023). Advanced technologies are used in education in rural tourism, including, for example, various games on farms. Recreational activity management systems help to integrally manage the recreational activities of farms (Metta et al., 2024).

Monitoring technologies are used for tourist flow management, and advanced analytical tools are used to optimize tourist routes. Big data analysis tools are used to assess and predict tourism's impact (Flores-Crespo et al., 2022). One of the main challenges is the digital divide between urban and rural areas (Torabi et al., 2023) and limited promotion of tourism infrastructure and communication technologies (Zhang et al., 2023). Efficient data transmission and communication technologies are particularly relevant in rural areas (Flores-Crespo et al., 2022).

3.9. Smart Transport

Transport ICT plays an important role in addressing various rural mobility problems, with ICTs presented in Figure 11. Car sharing applications help solve the problem of limited mobility options in rural areas where public transport is often insufficient. In Germany, for example, rural communities acquired an electric car whose reservation, payment, and administration are managed through a smartphone application (Sept, 2020). Transportation sharing applications allow residents traveling by car to larger cities to publish this information to other residents who do not have vehicles (Głębocki, 2023).

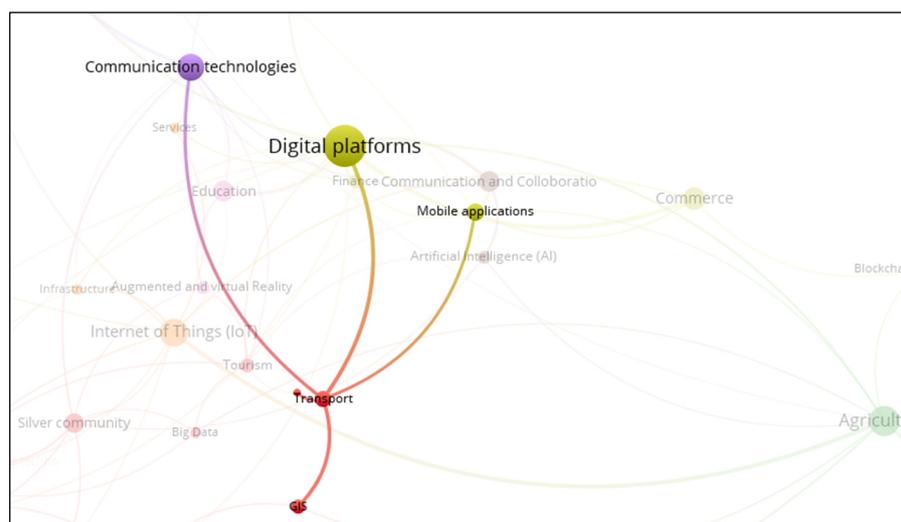


Figure 11. ICT categories in smart transport.

Digital platforms for resident mobility improve connectivity in rural areas where residents face difficulties accessing services due to poor transport (Andrei et al., 2023). Integrated transport systems improve public transport efficiency by applying modern methods of digital communication with passengers, such as ticket purchasing, vehicle location tracking, and information sending (Vaishar & Št'astná, 2019).

Smart transport systems help address mobility issues, especially for elderly people in rural areas (Lučan et al., 2024). Sustainable transport options are often included in projects related to renewable energy and smart energy grids (Bokun & Nazarko, 2023). Geographic information systems and navigation tools help address transportation and mobility issues faced by older adults in rural areas (Vidmar et al., 2022). Digital platforms and GIS optimize transport routes. Digital logistics management systems improve inefficient logistics in rural areas, which are caused by low population density and large distances (Hofmann-Souki et al., 2024). Digital ordering and tracking websites improve rural logistics coordination; for example, when users place an order in a store, store employees deliver goods to a local bus

terminal (Hofmann-Souki et al., 2024). Logistics management software connects farmers with logistics operators (suppliers and recipients) (Metta et al., 2024).

Mobile applications providing traffic information and communications help solve transportation and mobility problems by ensuring access to traffic information in rural areas (Nedeljko et al., 2023). Connected and autonomous vehicles can be of great benefit to elderly and physically disabled people who particularly suffer from limited mobility in rural areas (Cowie et al., 2020). Mobile applications, according to Singh et al. (2023), allow for “ordering transport services on demand.”

The main challenges faced in implementing transport ICT in rural areas are inadequate public transport infrastructure (Vaishar & Št’astná, 2019), limited mobility options for elderly people (Lučan et al., 2024), and inefficient logistics due to low population density and large distances (Hofmann-Souki et al., 2024).

3.10. Smart Energy

ICTs used in the energy sector help solve various problems related to energy production, management, and consumption in rural areas. The ICTs used are presented in Figure 12.

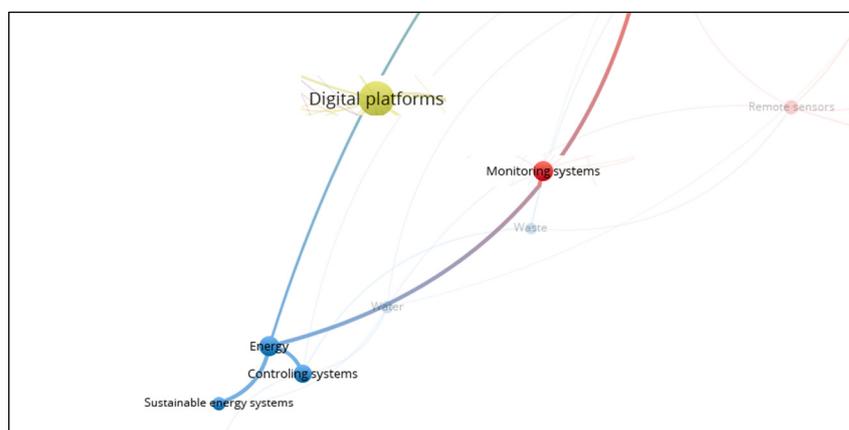


Figure 12. ICT categories in smart energy.

Monitoring systems are used for energy consumption monitoring, addressing the problem of inefficient energy (Malik et al., 2022; Stein et al., 2022). Mobile applications for energy consumption monitoring help overcome limited access to information and services due to geographical distance in rural areas (Stein et al., 2022). Digital platforms with visualization are used for renewable energy resource planning, addressing the problem of inefficient renewable energy resource planning (Głębocki, 2023).

Renewable energy technologies and smart energy grids help address sustainability challenges in rural areas that need sustainable energy solutions (Emerllahu & Bogataj, 2024; Bokun & Nazarko, 2023). Sustainable energy systems help manage energy more efficiently in rural areas (Lučan et al., 2024), while digital technologies for renewable energy sources and energy efficiency help reduce the digital divide between rural and urban areas (Bokun & Nazarko, 2023). Photovoltaic devices help reduce dependence on non-renewable energy sources (Hlaváček et al., 2023), and renewable energy systems allow for the production and sale of solar energy to the electricity grid and heating water and homes from renewable energy sources (Bielska et al., 2021).

Energy controlling systems are used to address the problem of inefficient energy management in rural micro-electric grids, as many rural electrification projects fail due to inefficient energy management and a lack of understanding of energy consumption patterns. Smart micro-electric grid management systems help integrate intermittent renewable

resources by applying management procedures that improve reliability, resilience, and sustainability. Multi-agent energy systems help address the scale and adaptability issues of energy management, as centralized optimization methods have clear disadvantages (Prinsloo et al., 2016).

Smart meters are used for energy monitoring and management, addressing the problem of inefficient energy management in rural areas (Varghese, 2016). Smart energy grids help ensure sustainable electricity without the need to connect to the national grid (Cowie et al., 2020). Energy trading platforms allow for direct energy trading, addressing the need for localized energy trading platforms in remote rural areas (Prinsloo et al., 2016).

The main challenges faced in implementing energy ICTs in rural areas are inefficient energy use (Malik et al., 2022), dependence on non-renewable energy sources (Marioara & Armanca, 2020), the digital divide between rural and urban areas (Bokun & Nazarko, 2023), and limited access to reliable electricity supply (Varghese, 2016).

3.11. Smart Environment

ICT in the environmental sector plays an important role in addressing various problems in rural areas and ensuring the sustainable development of rural areas, as shown in Figure 13.

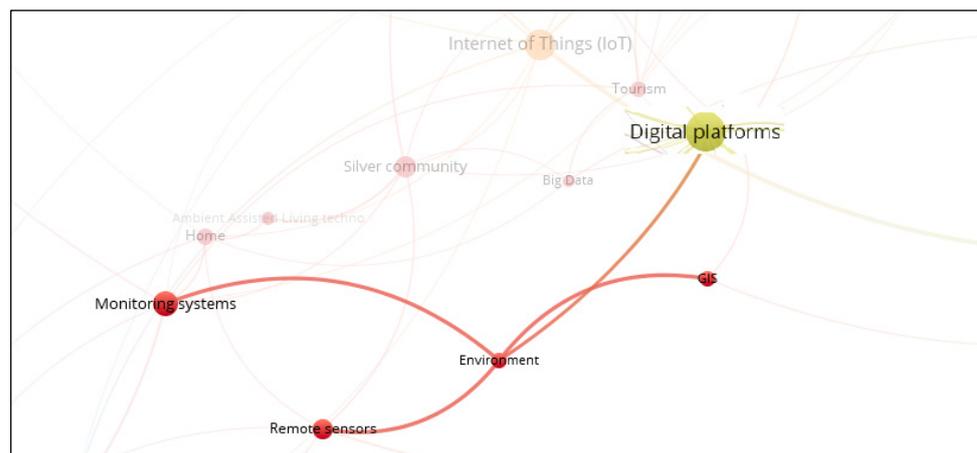


Figure 13. ICT categories in smart environment.

According to Vaishar and Št'astná (2019), geographic information systems (GIS) are widely used for rural planning and management, addressing the problem of inefficient spatial planning and management. They are also used for geographic information management and spatial analysis of territories, as they enable innovative solutions for sustainable development (Gorelova et al., 2024). Environmental monitoring systems, such as smart benches with remote sensors, help collect real-time data on pollution and noise levels (Hlaváček et al., 2023). Environmental monitoring systems are also used to address outdoor environment maintenance challenges and ensure safe and friendly spaces for elderly people in rural areas (Vidmar et al., 2022). Monitoring systems are used for continuous environmental and landscape monitoring and management, and they can be used in many areas or applied at regional or national levels (Navío-Marco et al., 2020). Veselinović et al. (2021) emphasize that “environmental monitoring technologies allow for a better understanding of ecosystem changes and timely identification of problems.”

Multi-sectoral digital platforms help address the problem of lack of functional knowledge economy spaces in rural areas, as rural areas often lack appropriate infrastructure for knowledge creation, sharing, and innovation, resulting in fragile rural economies (Singh et al., 2023). Digital platforms provide information about the state of the environment.

Lombardo et al. (2023) indicate that these platforms “help local communities make informed decisions on environmental issues.” These studies are complemented by the work of Janota et al. (2023). Cloud computing systems are used for environmental data processing and analysis, addressing the need to process large amounts of environmental data (Ferrari et al., 2022).

The main challenges faced in implementing environmental ICT in rural areas are the lack of real-time environmental data (Hlaváček et al., 2023) and urban-centric development paradigms that have resulted in the isolation of rural business ecosystem participants and related interaction spaces, leading to the fragility of the rural knowledge economy and rural decline (Singh et al., 2023).

3.12. Smart Government

ICT in the government sector plays an important role in improving administration and service delivery in rural areas and involving residents in local governance processes, with ICTs presented in Figure 14.

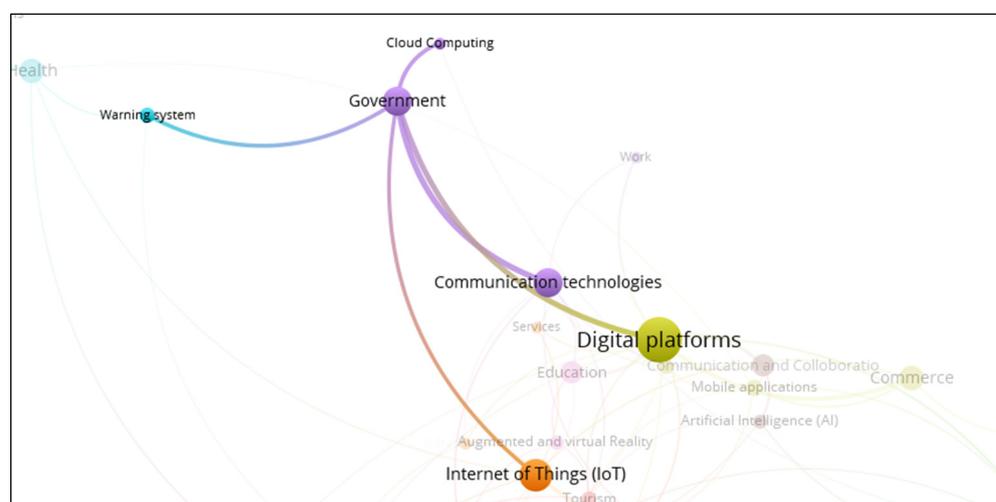


Figure 14. ICT categories in smart government.

Digital platforms, as networked administrative tools used for e-government or e-participation, help overcome geographical distance and ensure access to public services (Stein et al., 2022). Various platforms for government, health, banking, and educational services help rural residents access these services, which would be difficult to access due to geographical distance (Veselinović et al., 2021; Sasu et al., 2024). Digital ecosystems encompass community and specific services, technical platforms, and core infrastructure, helping to address various rural area problems (Sept, 2020). For example, cloud computing is used for data analysis, but its application in remote areas can be complex due to limited network connectivity. Communication systems and protocols are also used in cloud computing to address the problem of limited connectivity options in rural areas (Malik et al., 2022).

Communication technologies help provide administrative services, addressing limited access to administrative services. Smart institutions, such as offices, schools, or cultural centers, use modern solutions for more efficient service delivery (Andrei et al., 2023). The administrative management aspect covers three areas, public services, transparency, and policy, and digital technologies help ensure better quality of life, better public services, and more efficient use of local resources (Szalai et al., 2021). Warning and alert systems ensure faster responses to emergency situations. Głębocki (2023) emphasizes their importance for ensuring public safety.

According to Vaishar and Št'astná (2019), SMS and email notification systems improve communication between municipalities and citizens, replacing traditional municipal radio. Disaster warning systems with internet of things sensors ensure effective warning of residents about natural or human-made disasters. E-government and e-participation platforms address the problem of limited citizen participation in rural governance, enabling two-way communication.

Rahaju et al. (2023) say that electronic government systems help the government communicate with the public, the business world, and other stakeholders. User authentication systems help protect rural financial data and ensure that only authorized users fill them in. Rural finance system modules help efficiently prepare budgets and financial reports.

Digital technologies for e-government allow rural communities to access government services, digital healthcare, remote learning, and e-commerce, which is vital for reducing the gap between rural and urban areas (Emerllahu & Bogataj, 2024); The Internet of Things and sensor networks help monitor and manage rural resources (Bokun & Nazarko, 2023).

The main challenges faced in implementing government ICT include limited access to advanced computing resources, limited connectivity options (Malik et al., 2022), limited access to public services due to geographical distance (Stein et al., 2022), inefficient public services (Andrei et al., 2023), and inefficient communication between municipalities and citizens (Vaishar & Št'astná, 2019).

3.13. Smart Finance

ICT in the financial sector helps address various problems related to financial services' accessibility in rural areas, as presented in Figure 15. Digital platforms are used to ensure access to financial services for rural residents who face difficulties accessing banking and financial services (Despotović et al., 2020). Self-service payment points for local taxes and fees help streamline local tax collection, as traditional tax collection methods can be time-consuming and inefficient (Marioara & Armanca, 2020).

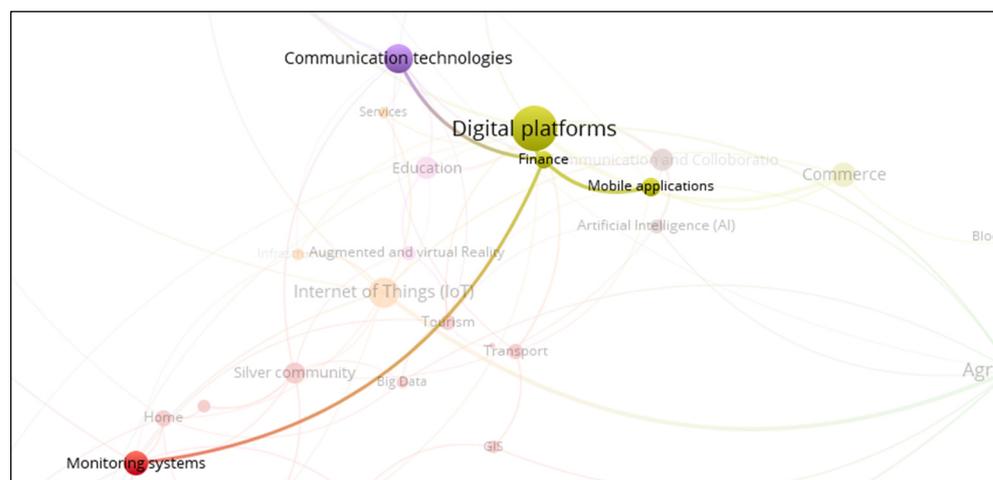


Figure 15. ICT categories in smart finance.

Rural finance monitoring systems help address inefficient and non-transparent rural financial management problems, including difficulties in rural financial planning, budgeting, administration, and reporting. Online integration with the Rural Community Empowerment Service and Regional Inspectorate helps related agencies oversee the financial management performed by rural governments (Rahaju et al., 2023).

Mobile applications with payment solutions are very popular among consumers and producers and considered one of the most effective tools for expanding the scope of financial services while reducing financial transaction costs (Gaudel et al., n.d.). Electronic

wallet applications address limited access to modern financial services, as rural areas lack access to cashless payment systems (Manapa Sampetoding & Er, 2024).

Digital platforms with planning module in the rural finance system is used to address inefficient rural development planning problems, helping to create and manage rural strategic plans. The administration module helps streamline financial administration in villages, addressing issues with payment request letters, disbursement, and accountability management (Rahaju et al., 2023). Digital financial platforms promote financial inclusion, addressing limited access to financial services in rural areas (Zhang et al., 2023).

Various communication systems ensure the use of electronic payroll systems, which improve inefficient financial management by addressing employee payment management challenges (Hlaváček et al., 2023). Also electronic fee collection systems help solve inefficient local revenue collection problems and facilitate local tax management (Hlaváček et al., 2023). Mobile money wallets address financial access and digital payment problems, allowing rural farmers to use mobile phones for payments or receiving money in the comfort of their homes (Tetteh Quarshie et al., 2023). Digital payment tools help address limited access to financial services in rural areas, compensating for the lack of banking and payment infrastructure (Soluk et al., 2021). Digital financial systems improve financial management by ensuring a well-structured financial management system (Ayu Purnamawati et al., 2023).

The implementation of financial ICT in rural areas faces several important challenges. One of the main challenges is the problem of limited access to financial services, as rural residents often have difficulties accessing banking and financial services due to geographical distance and limited banking infrastructure (Despotović et al., 2020). Although digital platforms can help address this problem, their implementation requires appropriate technological infrastructure and internet connectivity, which are not always available in remote rural areas. Another challenge is inefficient and non-transparent rural financial management, including difficulties with financial planning, budgeting, and reporting (Rahaju et al., 2023). Although rural finance systems can be implemented to address these problems, their effective use requires proper staff training and ongoing supervision. An important challenge is also the inefficiency of traditional local tax collection methods, which can be addressed by implementing self-service payment points, but this requires investment and technological solutions (Marioara & Armanca, 2020). Limited access to modern financial services, such as cashless payment systems, also remains a problem in many rural areas (Manapa Sampetoding & Er, 2024), and financial inclusion and access to digital financial systems are not yet ensured in all rural communities (Zhang et al., 2023).

3.14. Smart Waste System

The research results revealed that various ICTs are used in the waste management sector to ensure convenience for residents and sustainable rural area development, which are presented in Figure 16.

Waste management systems address inefficient waste management problems, which many municipalities consider a priority (Balco et al., 2021). Controlling systems for waste sorting help solve inefficient rural waste management problems by improving efficiency, accuracy, and responsiveness. Internet of Things (IoT) devices in waste bins allow for automatic collection of daily data on waste weight, sorting accuracy, points collected by residents for correct waste sorting, and waste disposal time and location (Liu et al., 2024). Waste management digital platforms help local administrations manage public services in an integrated, replicable, coordinated, and intelligent manner (Navío-Marco et al., 2020).

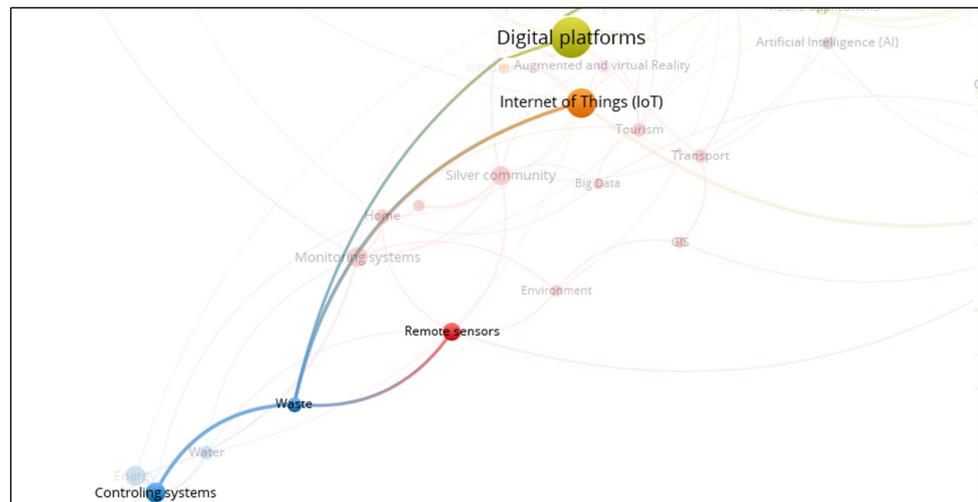


Figure 16. ICT categories in smart waste systems.

Smart waste bins with remote sensors notify waste management services when they need to be emptied, which can significantly reduce costs in rural areas if bins are only visited when they need to be emptied (Cowie et al., 2020).

When implementing waste management ICT in rural areas, several important challenges are encountered. Traditional rural waste sorting management systems often face limitations in efficiency, accuracy, and responsiveness (Liu et al., 2024). Due to dispersed rural populations, the provision of public services, including waste management, becomes expensive (Cowie et al., 2020). The lack of automatic and accurate data collection on waste disposal practices complicates effective management planning (Liu et al., 2024). Waste management systems must be integrated with other public services, which creates additional technological challenges (Navío-Marco et al., 2020). Although waste management is important, municipalities often have to prioritize among various smart solutions, including environment, water, and air quality (Balco et al., 2021).

3.15. Smart Water System

Smart water management technologies in rural areas help solve various problems related to efficient water resource use, which contributes to increasing well-being and sustainable development opportunities in rural areas. ICTs applied to water system management are presented in Figure 17.

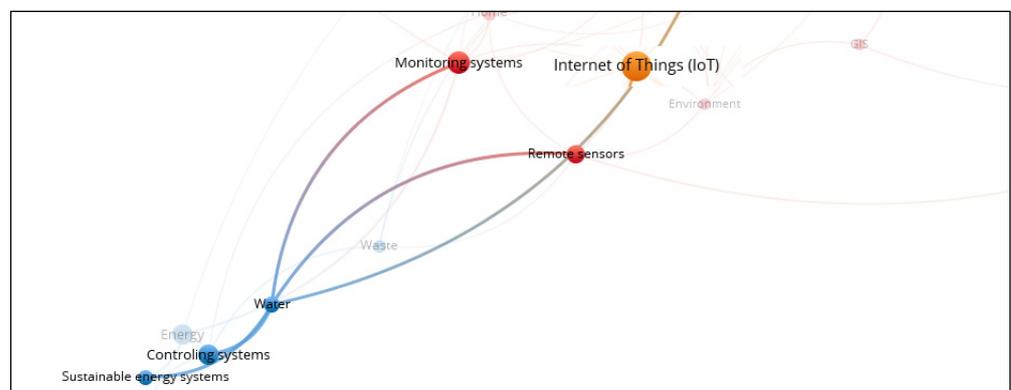


Figure 17. ICT categories in smart water systems.

Controlling systems with smart irrigation automation in agriculture helps solve the problem of inefficient water use, reducing unnecessary water consumption and irrigation

costs (Senkayas & Aysun, 2019). Smart water monitoring systems are considered one of the most important smart village strategies, along with smart energy, healthcare, transportation, and education (Lučan et al., 2024).

Waste container marking systems with remote sensors help address the problem of inefficient waste management by enabling data collection and payment modifications (Hlaváček et al., 2023). Automated water monitoring systems solve water shortage problems by automatically compensating for water shortages in the main reservoir during drought periods. Soil water forecasting tools help farmers better manage water resources and adapt to climate conditions (Fraser, 2022). Internet of things, remote sensors for heat and water meter readings help overcome difficulties in monitoring and managing heat and water consumption (Hlaváček et al., 2023).

However, the implementation of these technologies also faces challenges. Sufficient input from meteorological services is required to help farmers connect soil water forecasting tools with seasonal climate forecasts (Fraser, 2022). Rural areas also face water resource challenges that require effective water management (Lučan et al., 2024). Technology implementation challenges include drought periods when proper water resource management is particularly important and ensuring efficient utility management using remote sensors (Hlaváček et al., 2023).

3.16. Smart Work System

ICTs, presented in Figure 18, play an important role in the work sphere of rural area residents by addressing various employment problems and creating economic and social opportunities in the context of sustainable development.

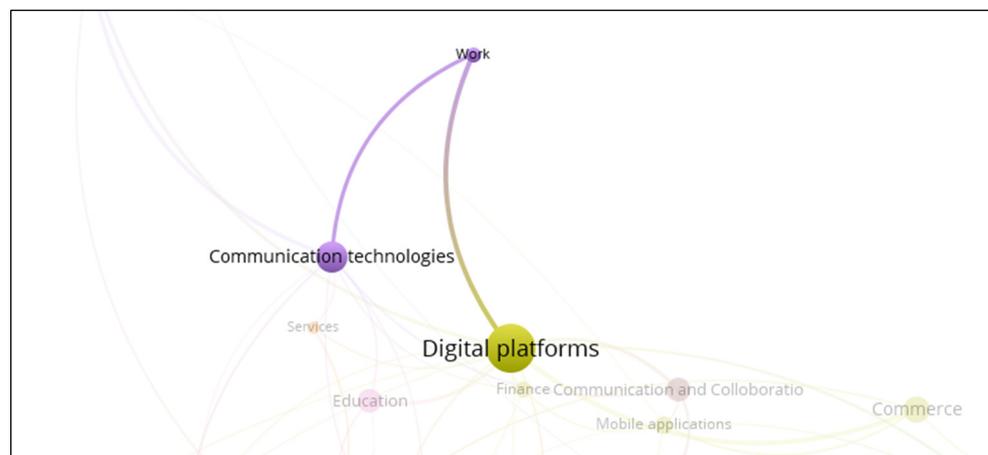


Figure 18. ICT categories in smart work systems.

Remote work technologies help solve rural depopulation and lack of job opportunities, as remote work can be more attractive to rural–urban migrants who can combine living in a rural environment with attractive and well-paid remote work (Głębocki, 2023). Digital transformation provides numerous technical possibilities for remote work (Manapa Sampetoding & Er, 2024).

Digital platforms, such as rural Business Process Outsourcing (BPO) centers, address limited employment opportunities in rural areas, especially for youth, by reducing costs and requiring minimal infrastructure to set up rural BPOs instead of forcing rural workforce to migrate to cities. Communication technologies allow access to job search portals and smart employment systems help rural youth find information about job opportunities, and the internet is much more widely used for job searching and academic purposes (Fennell et al., 2018).

Communication technologies create possibilities of teleworking, which is also important, although only about a quarter of respondents used ICT for remote work (Pontones-Rosa et al., 2021). Smart employment systems and human resource management software help better manage seasonal work; for example, a tool created by a private company helps employers regularly hire and register temporary workers (Metta et al., 2024). Remote work solutions also address the problem of lack of skilled job opportunities in rural areas, as workers who prefer the rural environment as a place to live should not have to give up skilled work in another region (Pontones-Rosa et al., 2021).

The main challenges faced when implementing work ICT in rural areas are the lack of job opportunities forcing young people to leave villages (Głębocki, 2023), limited access to job opportunity information (Fennell et al., 2018), difficulties managing seasonal work (Metta et al., 2024), and lack of skilled job opportunities (Pontones-Rosa et al., 2021).

4. Discussion

The analysis of the application of ICT in the context of smart villages reveals a wide range of technologies and their applications, problems, and challenges and allows us to discuss the trends that have emerged, extending possibilities for their future application.

The results confirm the observations of various authors (Bokun & Nazarko, 2023; Mańkowska et al., 2023; Cvar et al., 2020; Veeranna et al., 2022; Junaidi et al., 2025) that in the implementation of the smart village concept, the use of advanced digital technologies in conjunction with other innovations contributes to solving the challenges of local contexts. The study identified a wide range of technologies (from the Internet of Things to artificial intelligence, digital platforms, and blockchain) that are applied in different areas of public services. These results are also in line with Thapa and Thapa's (2022) insight that the smart village is a socio-technical phenomenon in which ICTs are integrated with community practices. The results of the study support Bokun and Nazarko's (2023) assertion that the smart village concept is indeed a cross-disciplinary phenomenon. The identification of 15 key areas in which ICT systems are applied—smart agriculture, commerce, collaboration and communication, education and learning, healthcare, silver communities, home systems, tourism, transport, energy, the environment, governance, finance, waste systems, water systems, and work solutions—illustrates this interdisciplinarity. Each area has its own specific problems for which the same ICT technologies are used or applied in different ways.

The smart village concepts presented by Junaidi et al. (2025) and others mentioned above are not only focused on solving problems but also characterized by “rural communities that exploit their existing strengths and resources, as well as develop new opportunities.” The results of the study reveal that in practice, many rural areas are still more focused on solving problems than developing opportunities. This is evident in many areas; for example, health technologies are more often focused on “gaps in the health system” than prevention and wealth creation.

Veeranna et al.'s (2022) assertion that “information technology can significantly improve the quality of life of rural populations” has been substantiated in our study and complemented with concrete examples. In particular, it has become apparent that in rural areas, different population groups (farmers, working-age and elderly people, young people) face different challenges that require specialized ICT. For example, these include ambient assistive living and home technologies for the elderly, distance learning platforms for young people, and precision farming systems for farmers. However, the study's analysis of the smart silver community found that “while smart home technologies can help to detect and predict loneliness and social isolation, a holistic approach is needed to address these issues.” This suggests that the optimism of the authors regarding the introduction of technology as a universal solution may be exaggerated.

The structural challenges identified by [Malik et al. \(2022\)](#) and [Mańkowska et al. \(2023\)](#)—inadequate technical infrastructure, limited digital competences, high costs of technology deployment, and a lack of locally tailored solutions—were confirmed in our study. Specific challenges have been identified in each of the areas analyzed, often linked to more general issues of infrastructure, skills, and feasibility. In particular, the digital divide between rural and urban populations emerged as a challenge, manifesting itself in both physical infrastructure and human capital (digital skills and knowledge) dimensions.

The results of the study provide particularly strong support for [Cvar et al. \(2020\)](#) regarding the importance of urban–rural cooperation to bridge the gap between these ecosystems. Our study found that in many areas (especially health, finance, and energy), effective ICT deployment requires an integrated approach that incorporates the technological potential and resources of both urban and rural areas. While the previous studies reviewed and this study found that smart rural areas are characterized by a lack of technological and infrastructural resources, smart cities and rural areas need to collaborate, share resources, and adopt and implement common technological solutions. Such integration, as our study shows, allows villages to benefit from the technological potential of cities and cities from the resources of villages. Rural areas can benefit from urban ICT through integration, sharing of technological solutions, database data, storage facilities, networks, expertise, and technological capabilities in order to improve public services, the economy, and quality of life. Villages can also benefit cities in various ways with their ICT resources, including transfer and integration of digital services (e-health, e-learning, e-administration), access to rural infrastructure for city residents, rural start-ups and apps for urban residents' tourism or food supply needs, training and skills development, use of rural ICT for public transport and logistics to connect urban and rural areas, a common business and innovation ecosystem, and regional cooperation. However, the problems of urban–rural technological integration revealed in the study often point to a one-way relationship, where rural areas become dependent on urban technologies rather than mutual cooperation. This suggests that in practice, the benefits of urban–rural integration are often unevenly distributed, rather than reciprocal, as suggested in the introduction.

The results of the study reveal a divergence from the insights of [Kalinka et al. \(2020\)](#) and [Suárez Roldan et al. \(2023\)](#) on the importance of sustainable development dimensions in ICT deployment decision processes. We observed that effective application of ICT requires a balance between economic, social, environmental, and institutional aspects. The study identifies that not all areas of technology application (in particular, energy, the environment, agriculture, commerce, and finance) show an imbalance in the importance of sustainable development principles. Here, technology tends to focus more on the economic and social dimensions and less on the environmental dimension. For example, in agriculture, energy, commerce, and finance, most of the technologies analyzed are focused on increasing productivity and optimizing operations, rather than conserving resources or preserving biodiversity. This suggests that in practice there is less focus on a holistic model of sustainable development.

Also, the areas and applications of ICTs identified in the study are in line with the neo-endogenous model mentioned by [Kalinka et al. \(2020\)](#), which emphasizes a greater role for local communities in planning processes. The results showed that the most effective ICT solutions are those that are adapted to the specific needs of local communities and integrated into existing social practices. However, the study did not only identify good examples but also revealed the dominance of the top–down model, where technological solutions are implemented in a way that does not meet the needs of local communities. For example, [Fraser \(2022\)](#) and [Thackara \(2019\)](#) point to “data governance and autonomy issues” in the context of agricultural technologies, suggesting that local communities do not

always have sufficient control over the technologies they deploy. These results contradict the recommended model of neo-endogenous development, in which communities should play a central role.

The differences in IoT trends between smart cities and rural areas identified by [Cvar et al. \(2020\)](#) were not only confirmed in our study but also complemented by an important observation: ICTs are becoming a bridge between urban and rural areas. While smart villages are characterized by a lack of technological capacity, as the authors argue, the study revealed that cloud computing and remote servers allow for moving part of the computation to centralized urban centres, thus solving the problem of limited local resources. Collaboration on ICT between urban and rural areas enables rural areas to have more efficient ICT solutions. The observation about the need to share resources and to adopt and implement joint technological solutions was highlighted in our study through examples like telemedicine, distance learning, and smart financial infrastructure. The development of these areas is not possible without close urban–rural cooperation, infrastructure, and knowledge sharing.

A significant finding of the study, which complements previous studies, concerns the importance of ICT integration. While individual technologies can be effective in solving specific problems, the greatest benefits come from integrated systems that allow for data sharing and coordination between different areas. For example, agricultural data can be useful for environmental solutions and transport data for tourism development.

While this study has revealed important insights into the application of ICT in smart villages, a number of limitations must be mentioned. Firstly, the qualitative content analysis is based on published academic literature, which may not reflect all solutions in practice. Second, the study did not assess the actual effectiveness and impact of ICT solutions, only their applicability. Thirdly, the technologies analyzed in the academic literature may differ from those actually implemented in practice, particularly in developing countries and remote regions. Fourthly, technology is evolving rapidly, and some of the solutions identified in this study may be superseded by newer solutions. Fifthly, the study has paid less attention to socio-cultural factors that determine the adoption and adaptation of technologies in different contexts.

Future empirical studies analyzing the effectiveness of ICT adoption in different geographical, economic, and cultural contexts would be useful. The interactions and integration of technologies should also be further explored in order to create holistic smart village ecosystems.

5. Conclusions

1. Smart villages use a wide range of information and communication technologies, including the Internet of Things (IoT), artificial intelligence, blockchain, cloud computing, geographic information systems, mobile applications, and others. These technologies are being applied to a wide range of public services, from agriculture to healthcare, energy, tourism, finance, and waste management.
2. ICTs address the fundamental problems of rural areas: limited access to services due to geographical distance, inefficient management of resources, demographic challenges (aging and depopulation), social exclusion and geographic isolation, and lack of economic opportunities. In each field, technologies are adapted to specific problems; for example, telemedicine systems address limited access to healthcare, while the Internet of Things in agriculture addresses resource inefficiency.
3. The study confirmed the importance of urban–rural cooperation in the development of ICT-enabled solutions. Smart villages, faced with a lack of technological and infrastructural resources, can take advantage of the technological potential of cities,

- and cities can take advantage of rural resources and products. Such integration helps to reduce the digital divide and ensure more balanced technological development.
4. The most successful implementation of ICTs has been achieved through a neo-endogenous model that emphasizes the role of local communities in planning processes. The study shows that technological solutions need to be tailored to the local context, taking into account the specific needs, capacities, and available resources of rural communities.
 5. The introduction of ICTs in the context of smart villages covers all of the dimensions of sustainable development: economic (increasing productivity, creating business opportunities models), social (improving access to services, promoting social inclusion), and environmental (more efficient use of resources, mitigating the effects of climate change). Technology acts as a lever to improve all of these dimensions in a balanced way.
 6. The study has shown that effective ICT deployment requires an integrated approach, encompassing not only technological solutions but also infrastructure development, digital skills training, appropriate cooperation models, and the adaptation of social practices. Technologies are not just neutral tools but factors that interact with social processes, community goals, and capabilities.
 7. Despite the clear potential benefits of ICTs, their deployment faces significant challenges: inadequate infrastructure (especially broadband internet), limited digital skills, high deployment and maintenance costs, the complexity of adapting technologies to specific local contexts, and data security and privacy issues.
 8. Successful deployment of ICT solutions requires collaboration between different stakeholders, from local communities and businesses to public sector institutions and technology developers. The role of local leaders is particularly important in promoting the adoption and adaptation of technologies to community needs.
 9. The study has shown that there is no one-size-fits-all ICT solution for all rural areas—technologies need to be adapted according to demographic, geographical, economic and socio-cultural factors. This is particularly important in addressing the digital divide between different age groups and across regions.

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Abbreviations

The following abbreviations are used in this manuscript:

ICTs Information and communication technologies

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