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THE CONCEPT OF SMART VILLAGES – ITS DEVELOPMENT OPPORTUNITIES, PROSPECTS AND CHALLENGES

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Purpose: This article aims to present the concept of Smart Villages as a modern approach to rural development that integrates information and communication technologies, innovative solutions, and active involvement of local communities. The article analyses the possibilities of developing Smart Villages in the context of Polish realities, considering their potential for sustainable development, improving residents' quality of life, and strengthening the local economy. At the same time, the challenges and limitations that may accompany implementing this concept in practice will be reflected.

Design/methodology/approach: The article uses an approach based on literature analysis, case studies, and available empirical data. A literature review on the Smart Villages concept and its application in various international contexts was conducted in the first stage. Then, examples of implementations of this concept in Poland and other countries were analyzed, identifying key success factors and implementation barriers. In order to better understand local realities, statistical data on rural areas in Poland and the results of previous studies on the level of digitalization and involvement of local communities were used. The entire analysis was supplemented with a reflection on the development prospects of this concept in the context of Polish reality.

Findings: The Smart Villages concept has significant potential for transforming Polish rural areas through integrating modern technologies, developing sustainable initiatives and increasing local community involvement. The implementation of smart solutions contributes to the improvement of digital infrastructure, which allows residents to have better access to education, remote work and health services, such as telemedicine. Initiatives related to renewable energy sources and environmental protection support the sustainable development of local communities while generating savings and improving the quality of life. In agriculture, innovative technologies, such as the Internet of Things or precision farming, increase production efficiency and enable better resource management. The analysis also showed that engaging residents in decision-making processes and implementing smart projects strengthens social capital and contributes to the activation of local communities.

Originality/value: The originality and value of the article result from the comprehensive approach to analyzing the Smart Villages concept in the context of Polish socio-economic reality. In contrast to previous studies, which often focus on large smart city projects, the article focuses on rural areas' unique challenges and opportunities, offering a new perspective on their development. The presented conclusions can be a valuable source of knowledge for policymakers and practitioners implementing smart solutions locally. Additionally, the article

indicates the importance of social participation and innovative technologies in building more sustainable and resilient rural communities, which can contribute to creating coherent regional development strategies.
Keywords: smart villages, smart city.
Category of the paper: Research paper.

1. Introduction

Modern rural areas, especially those aspiring to be called "Smart Villages", have faced challenges of an unprecedented scale and complexity. Global climate change, depopulation of rural areas, dynamic technological development, and the need to ensure residents' safety and high quality of life require innovative solutions in crisis management. Crises such as natural disasters, epidemiological threats, or infrastructure problems reveal the weak points of traditional management systems while creating space for the implementation of advanced technologies and new organizational models. The literature (Wolski, 2018; Kalinowski, 2021; Howard, 2023; Emerllahu, 2024) on the subject increasingly indicates that the key to effective crisis management in Smart Villages is the integration of information and communication technologies (ICT) with traditional management strategies. Such solutions include real-time monitoring systems, using artificial intelligence to predict and model crises, or creating platforms supporting cooperation between various entities. However, despite significant technological progress, many villages still struggle with the lack of a coherent strategy integrating these innovations into everyday functioning (Wolski, 2018; Kalinowski, 2021).

This publication examines modern technologies' role in crisis management in smart villages. It is based on a case study analysis of selected Smart Villages that have successfully implemented advanced crisis management systems.

The first part of the article presents the conceptual foundations of the Smart Villages concept . It discusses the genesis of the creation and assumptions of the Smart Villages concept. The second part of the article includes examples of using smart solutions in villages, including Finnish, Danish and Polish ones. A contemporary approach to crisis management in Smart Villages requires a view beyond the traditional management framework. A holistic approach is necessary, which considers both technological, social, and organizational aspects. This publication combines these elements into a coherent narrative that can serve as a basis for further research and practical implementations. In an era of increasingly frequent and complex crises, developing and implementing smart solutions is becoming a challenge and necessary for building safe and resilient villages of the future.

2. The origins of the concept of the smart village

The origins of the Smart Village concept are rooted in dynamic socio-economic and technological changes that have highlighted the challenges facing rural areas, such as depopulation, limited access to public services, and growing digital exclusion. Figure 1 shows population migration in Poland in 2019. The figure shows the spatial distribution of population migration in Poland at the municipal level, showing a clear differentiation between regions regarding net migration. Blue indicates areas with a positive migration balance, where more people arrive than leave a given municipality. That applies mainly to economically developed regions that are attractive regarding work, education, or quality of life, primarily around large cities such as Warsaw, Krakow, Wrocław, Poznań or Gdańsk. This phenomenon reflects the suburbanization process, in which people move to the suburbs of large cities agglomerations.

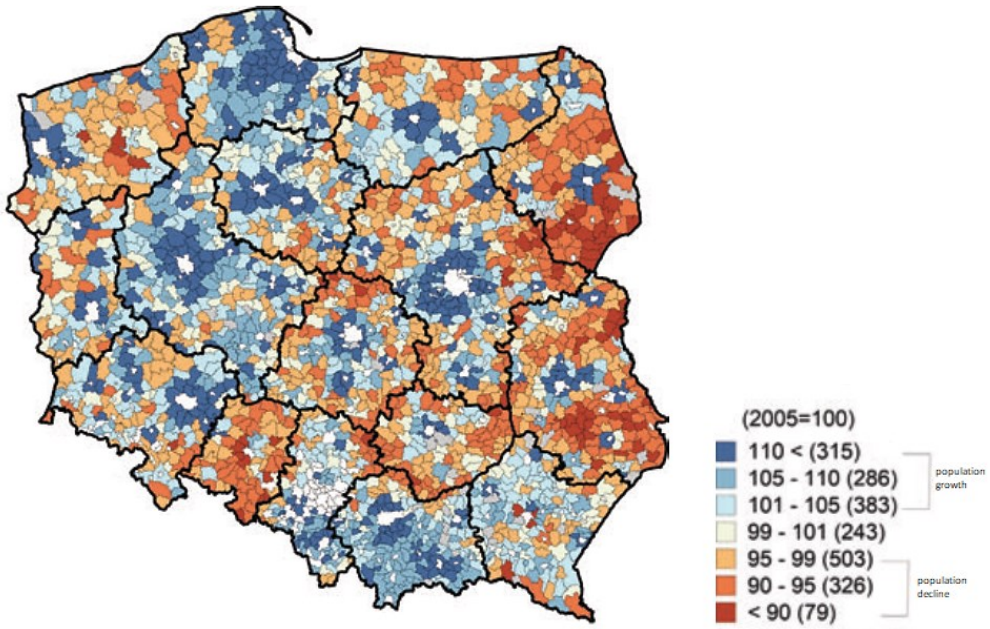

Figure 1. Migration of the Polish population.

Source: Wolski, 2018; Kalinowski, 2021.

In turn, the orange and red colors symbolize areas with a negative migration balance, i.e., places where more people leave than settle. That applies primarily to peripheral regions, rural areas, and those with limited development opportunities, evident in the east and northeast of Poland. Migrations from these areas are often motivated by the search for work or better living conditions in larger urban centers or abroad. The map's general picture shows dynamic urbanization and suburbanization processes, accompanied by the depopulation of less developed rural and peripheral areas, emphasizing spatial disproportions in the country's development. The concept of Smart Villages is an attempt to stop the migration of people from rural areas. This concept arose from the search for solutions enabling the sustainable development of rural regions and integrating their inhabitants within the global economy and

information society. The concept of a smart village was introduced to the public debate, particularly by the European Union. The 2017 EU Action for Smart Villages document defined them as communities using digital technologies and innovations to improve the quality of life, optimize public services, and effectively manage local resources (Wolski, 2018; Kalinowski, 2021). That was a response to challenges such as depopulation and marginalization of rural areas and the need for a more flexible and locally adapted approach to development (Kalinowski, 2021). Earlier studies and models from other regions inspired the European concept of smart villages. In particular, in India in 2010, scientists N. Viswanadham and Sowmya Vedula developed a model of smart villages as ecosystems integrating technological, natural and social resources. This model assumes that innovative management and the use of local potentials can lead to the self-sufficiency of villages and improve the quality of life of their inhabitants (Bokun, 2023; Lakshmanan, 2022). In the European context, the development of the Smart Village concept was related to the evolution of rural policy, which was moving away from a centralized management model towards a bottom-up approach, with greater involvement of local communities. In particular, information and communication technologies (ICT) were emphasized as a tool to eliminate differences between cities and villages. ICT allowed for improved access to education, health care, and public services and for integrating villages with socio-economic networks at the national and international levels (Bokun, 2023; Zavratnik, 2020). This concept was also shaped by global challenges, such as demographic changes, the need for energy transformation, or the implementation of sustainable development goals (SDGs). The implementation of Smart Villages has been recognized as a tool to achieve these goals more effectively, especially in areas such as eliminating poverty, improving access to education and promoting a low-emission economy (Wolski, 2018).

Contemporary Smart Villages are, therefore, a response to the challenges of the modern world by combining modern technologies with local potential, activating communities, and promoting sustainable development. This model is increasingly being adopted in various regions, adapting to specific cultural and geographical conditions (Emerllahu, 2024; Lučan, 2024).

3. The idea of a smart village

The village concept is a modern approach to rural development based on the use of digital technologies, innovations, and the involvement of local communities to improve the quality of life, increase the efficiency of public services, and sustainable resource management. Smart Village is based on integrating digital technologies and innovations with local initiatives to improve residents' quality of life, optimize public services, and effectively use local resources. In this approach, local communities play a key role in defining their needs and

challenges, giving projects a bottom-up character. Unlike traditional village development methods, Smart Village emphasizes the integration of modern technologies with the unique needs of local communities, creating models based on cooperation, flexibility, and sustainability. The basic idea of Smart Village is to enable rural communities to fully use their potential by introducing digital solutions that can improve access to services, education, health care, or the labor market. Thanks to information and communication technologies (ICT), such as the Internet of Things (IoT), big data, or mobile applications, villages can become more self-sufficient and better integrated with regional and global networks. A key element of this concept is supporting sustainable development, which means protecting the environment, using energy efficiently, and supporting the local economy based on ecological and innovative solutions.

Examples of Smart Villages implementation include various projects adapted to the specific needs of a given region. In Indonesia, digital rural information systems are being implemented, enabling better organization of local government work and residents' access to key data and public services (Aziiza, 2020; Zavratnik et al., 2020).

In Europe, Smart Villages focus on aspects such as developing local markets, digitalizing education and health care, and sustainable agriculture. In Poland, examples include projects related to renewable energy, the construction of smart infrastructure, and the development of e-government services (Wolski, 2018; Lee, 2024). One of the key challenges in implementing Smart Villages is the availability of technology. Many rural regions lack appropriate digital infrastructure, such as fast internet or energy systems supporting information technologies. Another problem is the development of digital competencies among residents, which requires educational support and appropriate training (Emerllahu, 2024; Gerli, 2022). However, Smart Villages are not just about technology. The essence of this idea is also building social ties, strengthening the sense of community, and promoting grassroots activities that consider local needs and traditions. A key element is the involvement of residents in the decision-making process, which leads to greater acceptance and durability of the implemented solutions (Manapa Sampetoding, 2024; Lučan, 2024).

4. Examples of using the Smart Villages concept

Smart Villages is a concept that is gaining importance in developing rural areas, especially in Poland, where a significant part of society lives in the countryside. The idea of Smart Villages is to use modern technologies, social innovations, and sustainable practices to address problems such as depopulation, limited access to public services, or economic inequalities. The aim is to improve residents' quality of life and ensure the sustainable development of rural areas. One of the applications of digital technologies is the Internet of Things. The use of the Internet

of Things in agriculture has promising prospects. Thanks to the collection and analysis of data, farmers can plan processes related to the cultivation and harvesting of crops much more precisely, while optimizing cooperation with the recipients of their products.

Additionally, machine learning algorithms allow the development of more effective cultivation methods, increasing the efficiency and sustainability of production. The Internet of Things can also be used in medical and uniformed services. There are many applications of digital technologies in villages. However, smart villages are not only digital services but, above all, people and their involvement in the development of the local community.

Malaysia can boast of using digital technologies, and over 20 modern villages have been created. In these villages, it was decided to fight poverty by building cheap, modern houses, providing education, and optimizing farms. Ultimately, this resulted in a threefold increase in the village population's income.

Finland has been implementing the Smart Villages concept for a dozen or so years now. In 2008, the first national strategy for fast broadband Internet in rural areas was implemented. Finland is a country where the Smart Village movement met with a very positive response due to the long tradition of local activity. In 1997, SYTY (Finnish Village Activities Association) was established. Eskola is one of the Finnish villages considered to be the forerunner of the smart ideology. Eskola is a small village of about 400 inhabitants, focusing on development and self-sufficiency while providing residents with access to key public services. Despite the challenges related to limiting these services, it was possible to establish Eskola Village Service Ltd., associating with 130 shareholders and employing seven people. The company conducts various activities, including kindergarten, dinner service, kiosk, home services, library and an application that enables vehicle rental. As part of an innovative approach to education, the primary school (grades 0-6) in Eskola is run by the Lapinjärvi municipality, 500 km away, as part of a three-year experiment. Thanks to digital solutions, Eskola residents can access public services, making the village an example of modern, sustainable development in rural areas.

Despite the lack of a formal legal and strategic framework for developing smart villages in Montenegro, it is possible to rely on the "Smart Specialization Strategy of Montenegro 2019-2024". The Smart Villages concept is still at an early stage of development, and the lack of appropriate regulations, financial incentives, and legal support makes its implementation difficult. Nevertheless, some initiatives support the development of this idea. Examples are the activities of the Ministry of Economy, the UNDP initiative's energy efficiency activities, and the implementation of the LEADER approach. An important undertaking is the Technopolis initiative, which aims to strengthen cross-border innovation networks through the Fertilization Innovation Laboratories in the agri-food sector, which allows for better linking of research with the activities of small and medium-sized enterprises. Another important project is the FILA Innovation Lab, which supports the development of smart solutions for agriculture, agricultural producers, and villages, focusing on implementing modern technologies.

An interesting example of the use of technology is the website www.seljak.me, which is the platform of the first digital village in Montenegro. It enables contact between farmers and potential consumers, providing a fast flow of information and offering the most extensive online offer of products and services in nine categories. The site also includes an educational section "farmer.me/ tips", which provides information materials from the world of agriculture. This initiative has enabled innovative solutions such as calving sensors, GPS collars for monitoring livestock, and bee sensors, which are examples of the effective digitalization of agriculture in Montenegro.

Denmark is another country that can boast a very dynamically developing concept of Smart Villages. An example is the village of Ryslinge. The village of Ryslinge, located in the municipality of Faaborg-Midtfyn, has shown dynamic development over the past five years. Thanks to local initiatives, 28 new jobs and three companies have been created there, and the number of residents has increased by 20-25 people per year during this period. To support settlement, the local council has appointed community ambassadors to promote the business offer and the possibility of settling in Ryslinge. The village currently has around 1700 inhabitants. In turn, Gludsted, a village in the municipality of Ikast-Brande, has taken decisive steps to counteract its potential depopulation, implementing activities under the slogan "Effort is useful." Thanks to the involvement of the local community, a kindergarten and a grocery store have been maintained, and free schools and large building plots have been created. Despite its small size – only around 300 inhabitants – Gludsted has retained key functions that have enlivened local community life.

A Polish example of Smart Village activities undertaken in Polish villages is the village of Ostoja (Olsztynek commune, Warmian-Masurian Voivodeship). The village of Ostoja implements the idea of Smart Village as an innovative agricultural ecosystem of the future, combining traditional methods with modern technologies. The aim is to create self-sufficient and ecological solutions that support sustainable agriculture, production, and life in rural areas. Key activities include implementing ecological agricultural practices, such as crop rotation, natural fertilization, and permaculture cultivation methods. A seed bank and a nursery of organic plants are being created in Ostoja to support local farmers in producing organic food. Precision farming technology automates and supports the processes, increasing crop efficiency and quality. An important element is using renewable energy sources, such as biogas plants, solar panels, and biomass, which is part of the 360 farm model - a closed resource circulation system. Waste-free, self-sufficient village settlements are also being created, combining modern construction solutions with traditional materials, such as moon wood. Product distribution is based on an innovative "farm-to-table" platform, enabling online ordering of fresh food. Ostoja is also developing an educational system that promotes ecology among children, youth, families, and professionals. Education is supported by Ostoja Natury TV, which popularizes ecological knowledge and traditional crafts. The village is involved in recreating traditional professions, such as beekeeper and blacksmith, and promotes local products.

Similarly, in the village of Piaseczna Górka, which implements the Smart Village concept (Morawica commune, Kielce district, Świętokrzyskie province). The commune implements innovative projects supporting sustainable development and social integration. In 2017, a rain garden was created, improving rainwater retention and supporting biodiversity and public space aesthetics. Autonomous solar lamps were also installed, illuminating sports and recreational infrastructure. In 2018, an outdoor library was created in a replica of a telephone booth, promoting reading and bookcrossing, and a questing path, combining historical education with entertainment. In addition, residents use a Facebook group, which improves communication and social consultations.

Another village that can be a Polish example of a smart village is Mniszek (Dragacz commune, Kuyavian-Pomeranian Voivodeship). Since 2011, over 40 projects have been implemented in the village, including intergenerational workshops, programming, robotics, 3D printing classes, handicrafts, and culinary workshops. An important achievement was establishing a village community center as an education and integration center, where cultural events, training, science festivals, and classes for children and adults are organized. Implemented projects, such as digitization of local history, ecological and artistic workshops, and activities for a healthy lifestyle, have contributed to the development of the community and increased awareness of residents. Mniszek is also distinguished by cultivating tradition, e.g. through workshops related to the culture of Kociewie, handicraft and regional cuisine. The village focuses on innovation, including digital development, organizing classes using modern technologies, and creating websites. Projects such as "Books Connect Generations" or "Detectives on the Trail of Science" integrate the community and educate interestingly.

5. Conclusions

The conclusions from the Smart Villages concept analysis indicate that this model can significantly contribute to the development of rural areas in Poland, responding to contemporary demographic, economic, and environmental challenges. Thanks to the integration of modern technologies, such as the digitization of public services and the use of renewable energy sources, Smart Villages offers solutions that improve residents' quality of life and increase the attractiveness of rural areas. This model supports sustainable development, reduces digital and spatial exclusion, and promotes social innovations that strengthen the local economy and social ties. The key element of success is the involvement of local communities in the decision-making process and cooperation with the public and private sectors. At the same time, implementing the Smart Villages concept requires overcoming significant barriers, such as the lack of appropriate digital infrastructure, limited technological competencies of residents, and difficulties in obtaining financing. In Poland, the development of Smart Villages

is not only a chance to solve problems related to the depopulation and marginalization of rural areas but also a way to use the potential of local communities and traditions in a modern, innovative way. A coherent support strategy at the national and regional level, including the effective use of European funds, is of key importance for the success of this concept. The development of Smart Villages can be an important step towards harmoniously combining sustainable development, environmental protection, and improving the quality of life in rural areas.

References

1. Aziiza, A.A., Susanto, T.D. (2020). The Smart Village Model for Rural Area (Case Study: Banyuwangi Regency). *IOP Conference Series: Materials Science and Engineering, 722(1)*. Retrieved from: https://doi.org/10.1088/1757-899X/722/1/012011.
2. Defe, R., Matsa, M. (2024). The significance of stakeholder engagement towards building sustainable climate-smart villages in Mwenezi District. *Environmental Challenges, 14*. Retrieved from: https://doi.org/10.1016/j.envc.2024.100855.
3. Distefano, C., Zhu, M., Mîndrilă, D. (2009). Understanding and Using Factor Scores: Considerations for the Applied Researcher – Practical Assessment. *Research & Evaluation, 14.*
4. Emerllahu, V., Bogataj, D. (2024). Smart Villages as infrastructure of rural areas: Literature review and research agenda. *IFAC- PapersOnLine, 58(3)*, pp. 268-273. Retrieved from: https://doi.org/10.1016/j.ifacol.2024.07.162.
5. Ezquerro, L., Coimbra, R., Bauluz, B., Núñez- Lahuerta, C., Román-Berdiel, T., Moreno-Azanza, M. (2024). Large dinosaur egg accumulations and their significance for understanding nesting behavior. *Geoscience Frontiers, 15(5)*. Retrieved from: https://doi.org/10.1016/ j.gsf.2024.101872.
6. Kalinowski, S., Komorowski, Ł., Rosa, A. (2021). *The concept of smart villages: Examples from Poland.* Warszawa: Institute Development Rural and Agricultural Sciences PAN. Retrieved from: https://doi.org/10.53098/9788389900623.
7. Lučan, J., Pokmajević, M., Kunčič, U. (2024). Impact of Technology on the Quality of Life of Elderly People in Smart Villages: Literature Review. *IFAC- PapersOnLine, 58(3)*, pp. 262-267. Retrieved from: https://doi.org/10.1016/j.ifacol.2024.07.161.
8. Manap Sampetoding, E.A., Er, M. (2024). Digital Transformation of Smart Village: A Systematic Literature Review. *Procedia Computer Science, 239,* pp. 1336-1343. Retrieved from: https://doi.org/10.1016/j.procs.2024.06.304.
9. Omotayo, A.O., Omotoso, A.B. (2025). Climate-smart agricultural technology and gender-differentiated food and water security: Evidence from smallholder sunflower (Helianthus

annuus L.) Farmers. *Agricultural Water Management, 308, 109276*. Retrieved from: https://doi.org/10.1016/j.agwat.2024.109276

10. Ostaszewski P. *Ostoja wioska 3.0.* Retrieved from: https://smart.irwirpan.waw.pl/pdf/Piotr%20Ostaszewski_Ostoja%20Wioska%203.0.pdf, 20.07.2024.
11. Shahzad, M.F., Xu, S., Lim, W.M., Yang, X., Khan, Q.R. (2024). *Artificial intelligence and social media on academic performance and mental well-being: Student perceptions of positive impact in the age of smart learning*. Retrieved from: https://doi.org/10.1016/j.heliyon.2024.e29523.
12. Tavakol, M., Wetzel, A. (2020). Factor Analysis: a means for theory and instrument development in support of construct validity. *International journal of medical education, Vol. 11,* pp. 245-247, Retrieved from: https://doi.org/10.5116/ijme.5f96.0f4a.
13. Wan, S., Zhang, P., Chen, S., Yang, Y. (2025). Digital village construction and depressive symptoms in rural middle-aged and older adults: Evidence from China. *Journal of Affective Disorders, 372,* pp. 200-209. Retrieved from: https://doi.org/10.1016/j.jad.2024.12.026.
14. Zavratnik, V., Podjed, D., Trilar, J., Hlebec, N., Kos, A., Duh, E.S. (2020). Sustainable and community-centered development of smart cities and villages. *Sustainability*, *12(10)*. Retrieved from: https://doi.org/10.3390/SU12103961.
15. Zhang, W., Xu, M., Feng, Y., Mao, Z., Yan, Z. (2024). The Effect of Procrastination on Physical Exercise among College Students—The Chain Effect of Exercise Commitment and Action Control. *International Journal of Mental Health Promotion, 26(8),* pp. 611-622. Retrieved from: https://doi.org/10.32604/ijmhp.2024.052730.