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DIGITAL TRANSFORMATION AS A DRIVER FOR SUSTAINABLE DEVELOPMENT OF SMALL AND MEDIUM-SIZED ENTERPRISES

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Abstract. This article examines the critical barriers to the digital transformation of Ukrainian small and medium-sized enterprises (SMEs), based on an analysis of statistical data from the last fifteen years. The main issues identified include the disparity between existing digital infrastructure and innovative enterprise activity, the difference between capital expenditure and investment in research and development, and the insufficient use of ICT for environmental practices. The dynamics of enterprise profitability and the structure of innovation costs are analysed. The article substantiates the role of European digital innovation hubs as a mechanism for overcoming the identified gaps through technological consulting, training, and ecosystem cooperation. Tools for integrating green-digital technologies to boost the international competitiveness of SMEs are also suggested.

Keywords: *digital technologies, innovation, sustainable development, investments, small and medium-sized enterprises, economic efficiency, environmental issues, transformation.*

JEL code: *O32, M21, Q52.*

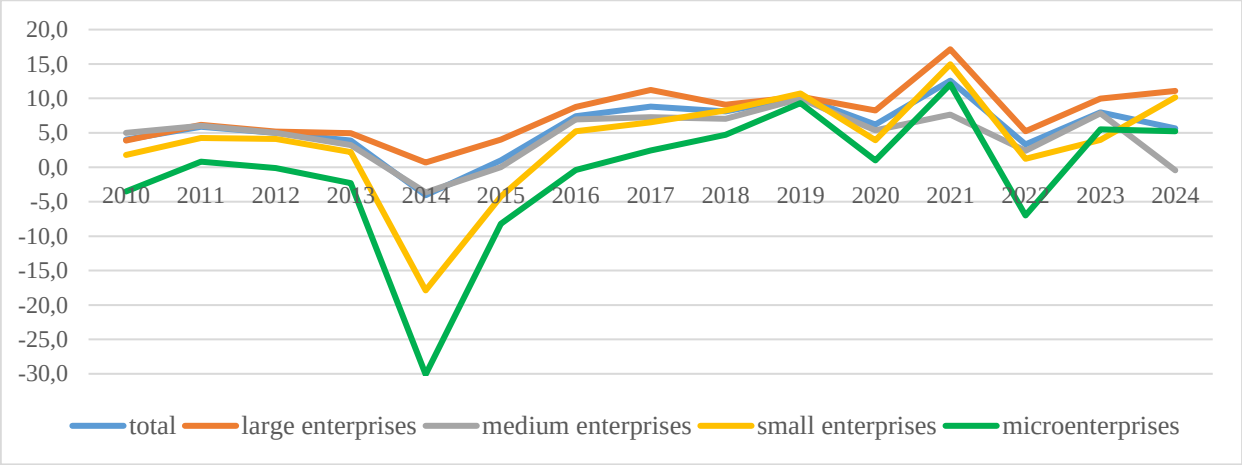
The concept of sustainable development, defined by the United Nations in 1987 as development that meets the needs of the present without compromising the ability of future generations to meet their own needs, is undergoing radical transformation in the digital age. The traditional triad of sustainable development – economic growth, environmental responsibility and social justice – can no longer function without a fourth dimension: technological innovation. Information and communication technologies (ICTs) have evolved from being merely an enabling tool to becoming critical infrastructure for sustainable development. Research by the World Bank shows a positive correlation between the expansion of broadband internet access and economic growth in developing countries [3]. For small and medium-sized enterprises (SMEs), which according to the OECD and the World Bank account for over 90% of global business and provide 50-70% of employment, digital technologies have become a critical factor in competitiveness. Artificial intelligence optimises resource consumption and has the potential to reduce CO_2 emissions by 10–40% in specific applications, according to estimates by the Boston Consulting Group [5]. The Internet of Things (IoT) is transforming energy management and reducing operational costs by 10–30%, according to IEA research [6].

Sustainable development is no longer just the responsibility of large corporations. For small and medium-sized enterprises (SMEs), compliance with the principles of sustainable development is critical for survival in the modern economy [7, 8]. SMEs form the basis of most countries' economic structures and are therefore faced with the need to integrate economic efficiency, environmental responsibility and social justice into their business models. For SMEs, the economic dimension is ensuring long-term profitability through optimising resources, reducing operating costs and increasing productivity. Energy efficiency, waste minimisation and the rational use of materials directly affect enterprise profitability, particularly in the context of rising resource and energy costs. Environmental responsibility is becoming a competitive advantage in global markets. An increasing number of consumers are choosing products from environmentally responsible manufacturers, and international supply chains are setting strict environmental standards for suppliers. SMEs that ignore environmental practices risk losing access to promising markets. The social dimension involves creating decent working conditions, staff development, and community responsibility. Companies

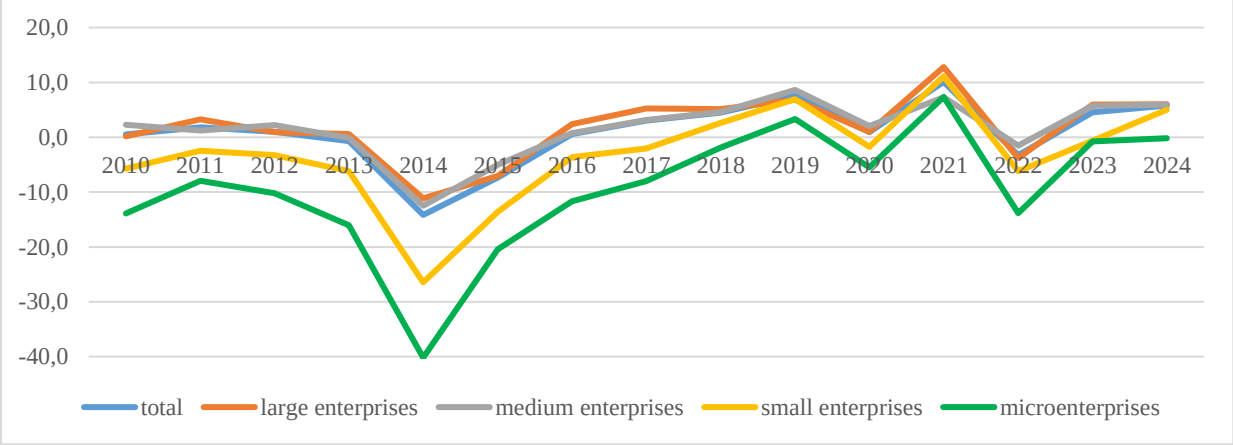
that invest in human capital demonstrate higher productivity and lower staff turnover, which is critical for SMEs with limited resources.

Information and communication technologies have become a key tool in implementing sustainable development principles for small and medium-sized enterprises (SMEs). Digitalisation creates synergy between economic efficiency, environmental responsibility and social inclusion, providing the basis for SMEs to grow competitively.

The practice of applying ICT and its impact on the sustainable development of SMEs was studied using Ukrainian enterprises as an example. Analysis of statistical data from Ukraine indicates variability in income and, consequently, financial results for enterprises within the sector and over time. Figure 1 shows data on the level of operating profitability (1a) and overall profitability (1b).



1a. Profitability of operational activity of enterprises



1b. Profitability of all activity of enterprises

Figure 1. Profitability of operational and all activity of enterprises

Source: compiled based on data from [9]

The data in Fig. 1 show the crisis years of 2014 and 2022, as well as the economic upswing of 2021, in terms of operational activities and all enterprise activities. The general trends in economic activity are the same for large, medium, small, and micro enterprises. However, the distribution of profitability levels, one of the basic indicators of enterprise efficiency, suggests that large enterprises are more economically efficient than small and medium-sized businesses. Large enterprises demonstrate more stable dynamics, whereas small enterprises are more volatile and micro enterprises are the most vulnerable to external threats. A general analysis of the situation suggests that the low profitability of micro and small enterprises limits their ability to invest in research and development of innovations. At the same time, the volatility of profitability indicators creates uncertainty for long-term planning and negatively affects the formation of strategic prospects for enterprise development, innovative activities and adherence to the concept of sustainable development. Negative profitability in economic sectors inhibits technological modernisation. As Fig. 1 shows, economic instability

significantly limits innovation potential, particularly among small businesses. One possible solution is to intensify support for SMEs through financial instruments and stimulate innovative projects in profitable and socially significant sectors of the economy.

One of the components of sustainable development is environmental. The dynamics of capital investments of Ukrainian enterprises in environmental protection for 2006-2024 is shown in Figure 2. The peaks of investment in relevant environmental protection measures fall on 2019 (16.3 billion UAH, 2016 (13,4 billion UAH), 2021 (14,1 billion UAH), 2011 (6,5 billion UAH). A drop in investments was observed in 2022 due to a full-scale invasion (6,4 billion UAH or -54% from 2021), in 2010 as a post-crisis period (2,8 billion UAH). At the same time, investment resumed in 2023 (8,3 billion UAH or +29% from 2022) and in 2024 (7,8 billion UAH), which indicates a relative stabilization of this direction of investments in war conditions. According to the structure of capital investments, according to 2024, investments in waste management (44,9%), wastewater collection and treatment (24,6%), and protection of atmospheric air and climate prevail (14,3%). Regarding the impact of the identified trend on the formation of sustainable development of enterprises, positive trends should be noted, namely:

- priority of waste management: almost 45% of investments, which corresponds to global trends of the circular economy;
- stabilization of spending on environmental protection measures and restoration: in 2023 +29% after the shock of 2022;
- allocation of investments to support critical infrastructure even during the war.

However, it should be noted the general trend of reducing investments in environmental protection in recent years, which are associated with the war. The country's destroyed infrastructure requires significant investments in post-war reconstruction, which should be determined on the principles of sustainable development and circular economy. Of course, this requires intensification of innovative activities, which will allow “jumping over” outdated technologies and immediately building digital-ecological infrastructure.

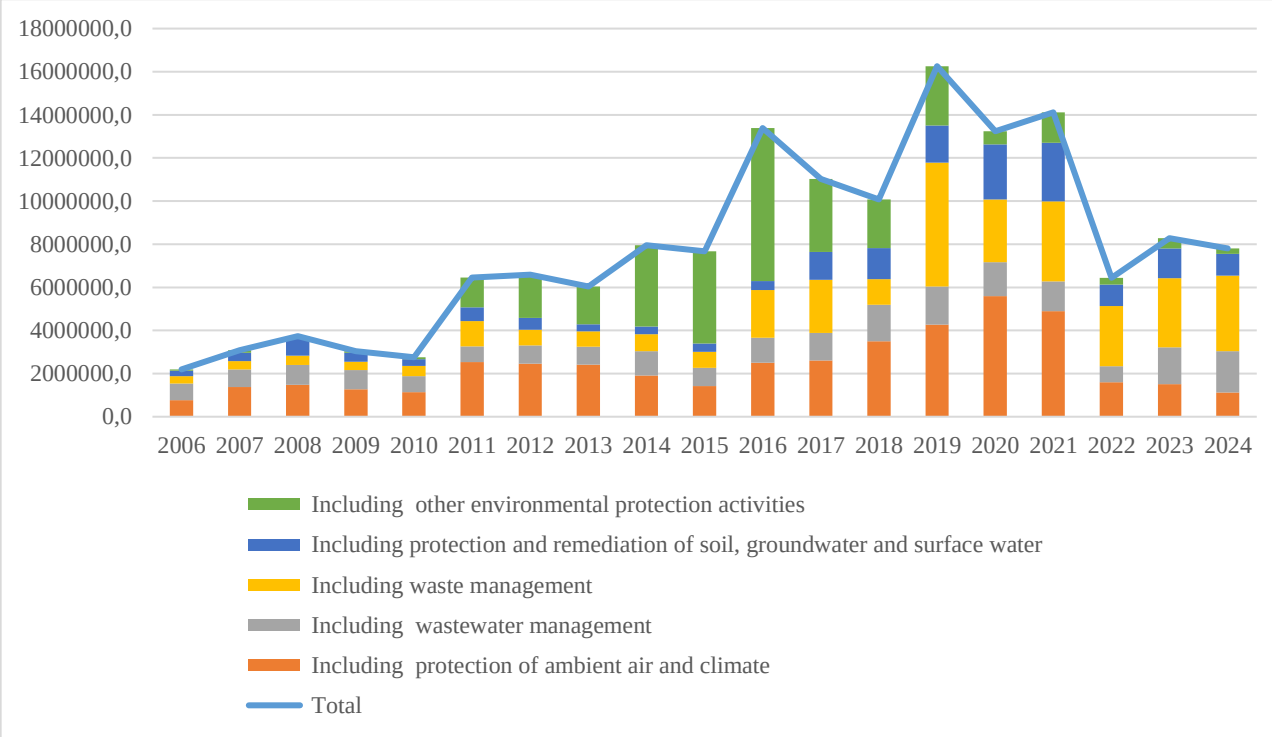


Figure 2. Capital investments on environmental protection, by type of environmental domain (at current prices, thsd. UAH)

Source: compiled based on data from [9]

The dynamics of statistical data on the innovative activity of Ukrainian enterprises is shown in Figure 3.

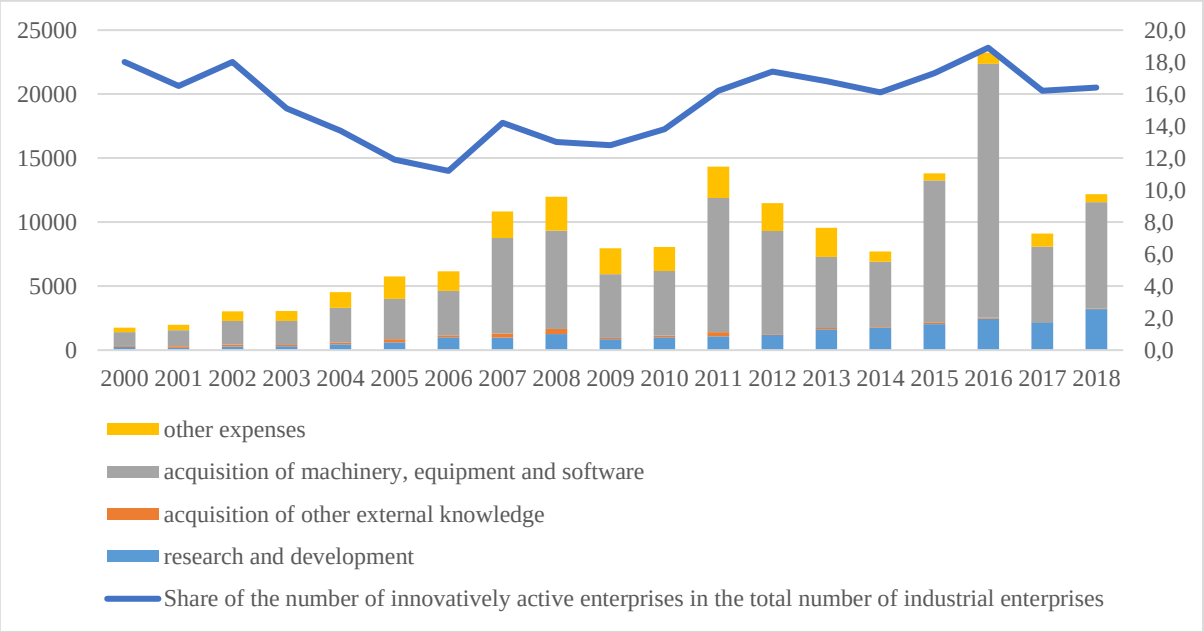
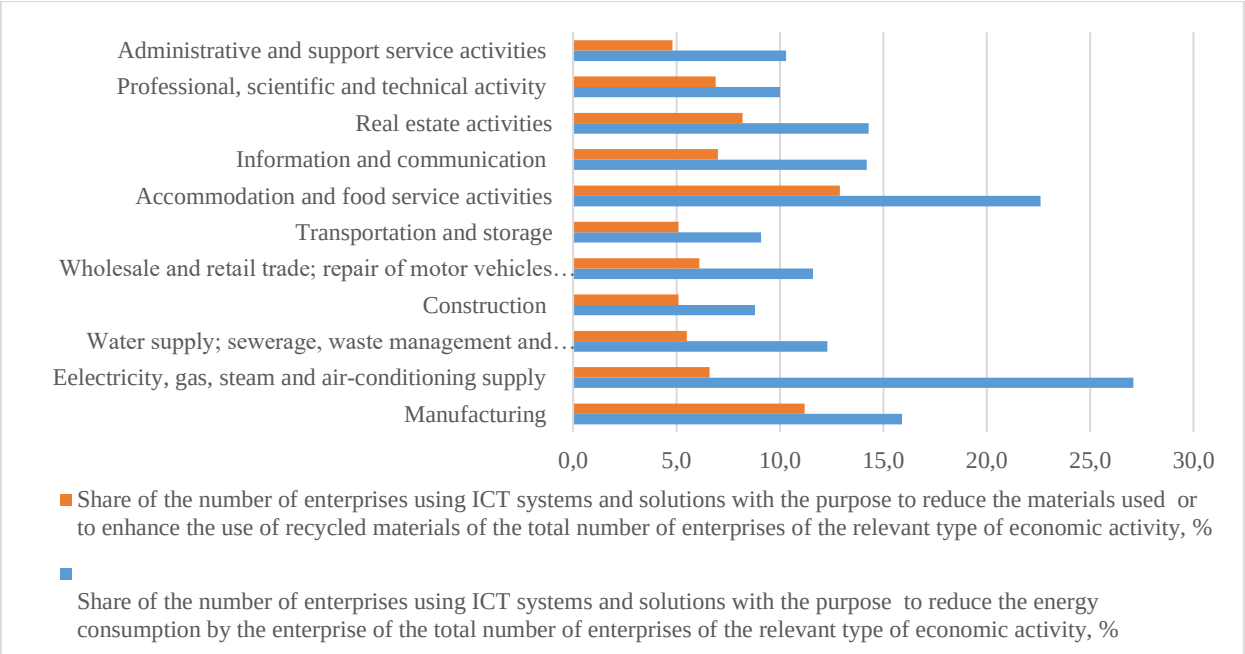


Figure 3. Total expenditure by areas of innovation activity of industrial enterprises (million UAH)

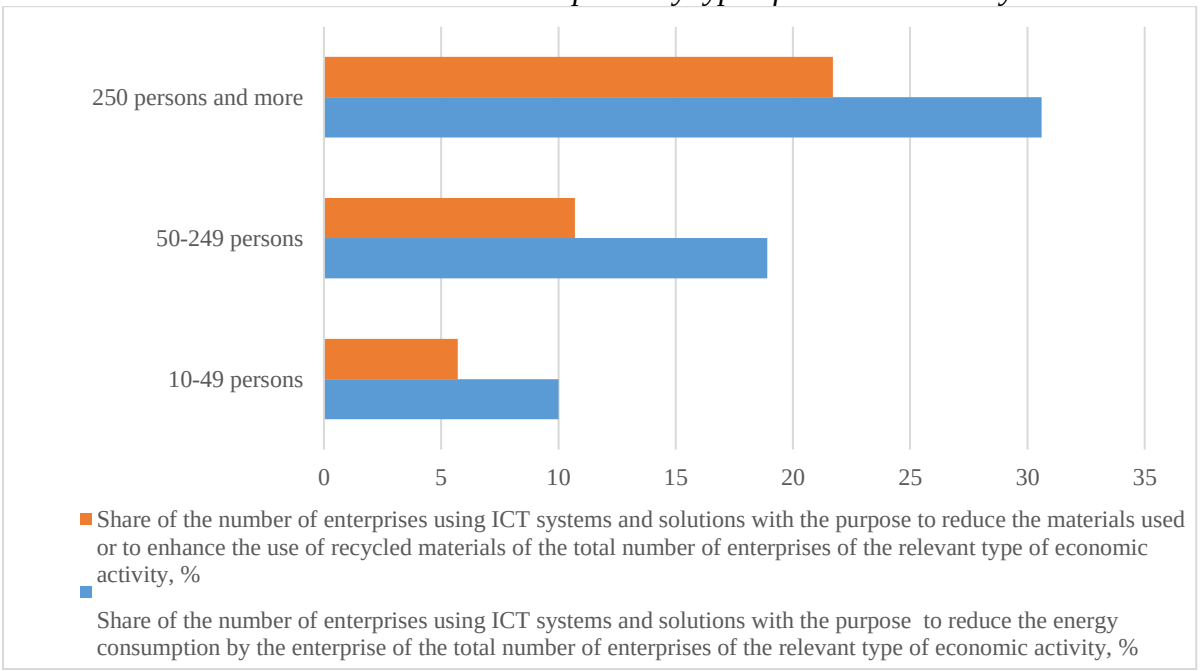
Source: compiled based on data from [9]

Analysis of statistical data indicates pre-crisis growth in spending on innovation activities in 2007 – 2008 (10,8 – 12,0 billion UAH), post-crisis recovery in 2011 (14,3 billion UAH) and maximum investment in 2016 (23,2 billion UAH) during the analysed period. In terms of the structure of innovative investments, the predominant share in 2018 was the cost of purchasing machinery and equipment (8,3 billion UAH, accounting for 68,1% of the total), followed by research and development (3,2 billion UAH, accounting for 26,3%). Analysis of the structure of investments indicates a preference for spending on the modernisation of outdated equipment rather than the development of new equipment. During the analysed period, the share of innovatively active enterprises does not exceed 20%. Unfortunately, the low level of spending on research and development reduces the country's potential for innovative development.

In the context of Industry 4.0/5.0, information and communication technologies are becoming increasingly important and are penetrating all spheres of socio-economic life. Their application improves the technical and economic performance of enterprises while simultaneously impacting the environment. Analysis of statistical data for Ukraine (Figure 4) shows that the average proportion of enterprises using ICT systems and solutions to reduce energy consumption is 12,8%. Leaders in this area include enterprises in the electricity, gas, steam and air conditioning supply sector (27.1%) and the temporary accommodation and catering sector (22,6%), while the lowest figures are found in construction (8,8%) and transportation and storage (9,1%) (Figure 4a). On average, 7,5% of enterprises in the country use ICT systems and solutions to reduce the amount of materials used or increase the use of secondary raw materials. The leaders in this area are the accommodation and food service industries (12,9%) and manufacturing (11,2%). Additionally, it should be noted that enterprise size significantly affects an enterprise's ability to invest in this area (Figure 4b). Large enterprises (250+ employees) perform best, while small enterprises (10 – 49 employees) perform worst.



4a. ICT and the environment at enterprises by type of economic activity in 2025



4b. ICT and the environment at enterprises with a breakdown by the number of persons employed in 2025

Figure 4. ICT and the environment at enterprises by type of economic activity and with a breakdown by the number of persons employed in 2025

Source: compiled based on data from [9]

Among the positive features, it is worth noting the significant potential of digitalisation for ecology, the use of ICT to increase energy efficiency and the green transformation that is beginning to take place in industry. However, small enterprises are lagging behind due to limited financial and human resources, which results in a lower level of implementation of innovative solutions [10]. Nevertheless, SMEs form a powerful foundation for the development of e-commerce and digital services. There is infrastructural readiness today for the implementation of cloud technologies, the Internet of Things (IoT) and Industry 4.0, big data analytics and remote working models. Nevertheless, significant sectoral disparities are evident, with many industries failing to leverage the full potential of green ICT solutions. To overcome these challenges, targeted subsidies should be

provided for the implementation of energy management systems in SMEs. There should be active development of IoT and AI for resource monitoring, and the exchange of experience should be organised between the high-tech IT sector and traditional industries. Standardised forms of reporting on environmental impact should also be introduced through digital platforms.

A comprehensive analysis of the opportunities and barriers to increasing the competitiveness of domestic businesses through innovative development, in line with sustainable development requirements, indicates the feasibility of expanding the implementation of European Digital Innovation Hubs (EDIHs). These are centres created within the framework of the Digital Europe Programme (2021 – 2027) to support the digital transformation of businesses, particularly SMEs [10]. The key functions of EDIH include testing technologies according to the “test before invest” principle, training personnel, supporting the search for financing and creating innovation networks. These mechanisms allow SMEs to overcome traditional barriers to entry into innovation by reducing financial risks and providing access to expertise.

The development of the EDIH network in Ukraine lays the groundwork for solving a number of critical problems. Firstly, demonstration centres help to bridge the digital divide by showing SMEs how to use existing ICT to organise and improve business processes. Secondly, the model of free testing of advanced technologies – ranging from artificial intelligence to 3D printing and robotics – reduces the cost and risk of innovation for enterprises with limited resources. Thirdly, EDIHs democratise access to expensive infrastructure and equipment, thereby reducing the gap between the capabilities of large corporations and small businesses. Fourthly, the hubs demonstrate the integration of green and digital technologies, showing how AI can optimise resource and waste management and increase energy efficiency, and how blockchain can provide material tracking in a circular economy. Cooperating with an EDIH provides SMEs with multiple strategic advantages. Market entry for innovative products is significantly accelerated due to the shortened “idea-implementation” cycle. The presence of confirmed proof-of-concept increases investor appeal, and partnership networks are formed with universities, scientific institutions, and large corporations. In terms of the environment, the practical implementation of circular economy principles is achieved through digital equipment sharing platforms, secondary materials tracking systems and increased waste recycling. Economic efficiency is achieved through process optimisation, reduced operating costs, and entry into international markets with competitive products. The social aspect is realised through employee training programmes, the creation of quality jobs, and the application of inclusive principles in access to technology and knowledge. The experience of the Centre 4.0 KPI DIH [11], which was created based on the Igor Sikorsky Kyiv Polytechnic Institute, demonstrates the effectiveness and potential of the proposed solutions for the sustainable, competitive development of SMEs in the Ukrainian context. This confirms the possibility of scaling up the digital innovation hub model at a national level.

Therefore, the study confirms the important role of digital innovations in ensuring the sustainable development of SMEs. Analysis of statistical data from 2010 to 2025 revealed issues concerning business transformation, such as the discrepancy between a high level of digital infrastructure and low innovation activity, imbalances in investment structures with a preference for capital investments over research and development, and the partial implementation of environmental practices. The study also found that information and communication technologies create synergy between economic efficiency, environmental responsibility, and social inclusion. Digitalisation provides resource optimisation, emission reduction, market expansion and access to knowledge for SMEs. European Digital Innovation Hubs (EDIHs) play a significant role in overcoming the identified challenges. EDIHs reduce financial and knowledge barriers through the “test-before-invest” model, accelerate time to market, provide access to advanced infrastructure and expertise, and facilitate connections within ecosystems between SMEs, research institutions, and the state. Demonstrating the integration of green and digital technologies for the practical implementation of the principles of the circular economy is of particular importance.

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