

Synergy of Digital Economy and Sustainable Development in the Transformation Context: EU Case for Ukraine

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Abstract

In the article, the relationship between the development of the digital economy (DE) and the achievement of the Sustainable Development Goals (SDGs) in the transformation context taking place in Ukraine and the countries of the European Union. The aim of the article is to substantiate the relationship between the DE and the SDGs, identify the potential for their synergy in the transformation context in Ukraine, and develop recommendations for strengthening the digital resilience of regions and integration into the European digital space. Within the study, the comparative analysis of macroeconomic indices (Digital Economy and Society Index – DESI, Digital Transformation Index - DTI), the structural-functional approach to assessing the digital economy, as well as the logical-semantic analysis of scientific approaches to its interpretation are used. The interdisciplinary approach was used to study the relationship between digitalization and sustainable development (SD) through the prism of socio-economic and institutional factors. Based on the DESI, the comparative analysis of the indicators of Poland, Estonia, and Germany was conducted, which allowed assessing the development level of digital skills, infrastructure, digitalization of business and public services. The DTI of Regions of Ukraine for 2022–2024 was also analyzed, revealing regional disparities, digital inequality, and the dynamics of the decline in average values, in particular against the backdrop of security challenges and limited investment resources. Particular attention is paid to establishing links between the components of the DE and the relevant SDGs, including: SDG 4, SDG 8, SDG 9, SDG 11, SDG 12, SDG 13, SDG 16 etc. It is substantiated that the synergy of digitalization with the SDG's can become a strategic platform for Ukraine's post-crisis recovery and building an inclusive, competitive and resilient economy. Based on the identified vulnerabilities - low level of digital skills, weak digitalization of SMEs, regional digital divide - practical recommendations are formulated to strengthen the digital SD of Ukraine. In particular, it concerns investments in digital education, support for small and medium-sized enterprises in the implementation of ICT, expansion of

interoperability of public digital services and strengthening of regional infrastructure. The results of the study can be used to form a national digital strategy of Ukraine, harmonized with the principles of the European Union.

Keywords: digital economy, sustainable development, digital transformation, Digital Economy and Society Index, Digital Transformation Index of Ukrainian Regions, Sustainable Development Goals, synergy, digital strategies.

Introduction

In the 21st century, digitalization has become the leading vector of transformation of the world economy, changing not only business models, but also the principles of functioning of states, markets and social institutions. The DE, which is based on the use of digital technologies, data and network infrastructure, is rapidly integrating into all sectors of economic activity. At the same time, more and more attention is paid at the global level to issues of SD - socially responsible economic growth that takes into account environmental and institutional dimensions. In the context of global challenges - from climate change to military conflicts - the search for points of intersection between digital transformation and the achievement of the SDGs formulated by the UN is becoming particularly relevant. It is the synergy between these processes that can ensure not only economic efficiency, but also inclusiveness, transparency of management, environmental rationality and regional cohesion.

Literature review

Research on the development of digital transformation as a driver for achieving the SDGs is increasingly active in the global scientific community. Kholiavko et al. (2023) analyze how digital technologies contribute to improving economic development, quality of life and the implementation of the SDGs, in particular through the “network economy”. Popelo et al. (2021) consider digital technologies among the key drivers of sustainable development. Kychko et al. (2023) investigate how digital transformation in the EU affects social sustainability.

Djakona et al. (2021) systematizes the components and technologies that play a role in digital transformation and

analyzes infrastructural, regulatory, and digital inequality barriers. It also explores how digital transformation can increase business resilience during wartime, and what policies facilitate this.

The issue of synergy between the DE and the SDGs has come to the fore due to the simultaneous digital transformation of economies and global environmental/social challenges (Shlapak et al. (2025)). In the EU context, numerous policies (digital market, European Green Deal, digital skills programs) offer a framework for integrating digital tools into SD practices; for Ukraine, this is of particular importance in the European integration and transformational reforms (Tulchynska et al. (2021)). Scientists consider digital technologies as a tool for accelerating the achievement of the SDGs (resource optimization, monitoring, “smart” infrastructure), but also highlight the risks (energy consumption of data centers, e-waste, digital inequality).

Research by Zhavoronok et al. (2022) shows that the DE has the potential to accelerate the implementation of the SDGs by increasing efficiency using resources, improvement monitoring and expanding access to services . At the same time, Zybareva et al. (2022) and Shaposhnykov et al. (2021) warn of risks, including: increased energy consumption of data centers, recycling of electronics, and the threat of increasing social inequality due to the digital divide. Therefore, in policies not so important unconditional digitalization, how much integrated a strategy that combines digital tools with climate and social objectives – the approach that is actively promoted by the EU and which is relevant for transformational processes in Ukraine.

Methodology

The article examines the DESI, used internationally to monitor digital transformation, which allows assessing how ready a country is for digital transformation, whether it is actively implementing digital technologies into the economy and society, and whether it is developing infrastructure, digital skills, the business environment, and public administration in a digital format.

DESI structure (4 components):

1. Digital skills – digital literacy of the population, share of ICT specialists, level of digital skills.
2. Digital infrastructure – availability and quality of the Internet, 5G deployment, broadband coverage.
3. Digitalisation of businesses – the use of digital tools by businesses (cloud services, e-commerce, artificial intelligence).
4. Digital Public Services – the digitalization level of government services, e-government, open data.

The data source is national statistics of countries, surveys, data from Eurostat, the European Commission, telecom regulators, etc. Each component is assessed on a 100-point scale. The overall DESI score is an integrated indicator calculated as a weighted average of the four components, and the weight of each component in the actual value of the country index is also determined. Thus, DESI is a reliable and multidimensional tool for strategic management of digital changes, which allows you to see both overall progress and weaknesses of digital policy in individual areas of the economy.

DESI is formed based on 9 main components covering key areas of digital development of regions:

1. Institutional capacity – the presence of CDTOs, digital strategies, digitalization teams.
2. Internet development – coverage with high-speed Internet and mobile communications.
3. Development of the ASC is the digitalization level of administrative services.
4. Implementation of a “paperless” regime - document flow, internal processes, integration with Action.
5. Digital education – coverage of digital educational programs.
6. The region's calling card is its digital presence and up-to-date online resources.
7. Penetration of basic e-services – citizens' access to electronic government services.
8. Sectoral digital transformation – digitalization in education, healthcare, housing and utilities, etc.
9. Individual CDTO projects – implementation of unique digital transformation initiatives.

The total index value for each region is determined as the arithmetic mean of 9 components. The scale is formed from 0 to 1, where: 0 - no digital changes in the sector; 1 - full implementation of digital solutions. As a result, a ranking list of regions is formed.

The purpose of the study is to identify the potential and areas of synergy between the development of the DE and the achievement of the SDGs, taking into account both European experience (using the example of EU countries) and regional disparities within Ukraine.

To study the synergy of DE development and sustainable growth, Ukraine, Poland, Estonia, and Germany were selected for comparison, which is fully justified and scientifically appropriate given several key reasons - geopolitical, socio-economic, and institutional-digital.

First, these countries have geographical and historical kinship. Ukraine and Poland are immediate neighbors that have gone through a similar path of post-socialist transformations, albeit with different dynamics of integration into European institutions. Estonia, despite its small size, also shares a Soviet past with Ukraine, but has managed to make a digital breakthrough and become one of the recognized leaders in e-government, in particular thanks to the e-Residency project (Global Compact Network Ukraine) and full digitalization of public services. Germany, in turn, is not only the political and economic leader of the EU, but also a reference point in shaping the policy of digital transformation within the European digital space. This choice of countries allows us to compare Ukraine both with states that are at a similar stage of development and with those that have already achieved significant progress in digitalization, which opens up opportunities for identifying the so-called “digital divide” and potential ways to overcome it.

Second, these countries represent different models of digital transformation. In Germany, digitalization is largely focused on industrial processes, the development of high-tech production and the Industry concept 4.0, relying on a powerful IT infrastructure. Estonia, on the contrary, is an example of administrative-oriented digital transformation, where the digitalization of public services has covered almost all areas of life. Poland has chosen a gradual model

of integration into the European digital market, accompanied by reforms in the field of ICT, education and business. Ukraine, in the face of external challenges, demonstrates the dynamic development of a digital state, in particular thanks to the “Diya” project and a powerful private IT sector, however, the low level of digital coverage of regions and the population remains, which indicates the fragmentation of processes.

Another important factor is the status of the countries in the European Union. Germany, Poland and Estonia are members of the EU, which allows us to include in the comparison the indicators of the DESI, which is published annually by the European Commission. Ukraine, although not a member of the EU, has the status of a candidate country and is already integrating into the common digital market. Therefore, a comparison with EU countries helps to determine how close Ukraine has come to European digital standards.

In addition, it is important to consider the political and economic weight of these states in the region. Germany is the main driver of digital change in Europe, Poland is actively developing digital infrastructure in Eastern Europe and is an example of the successful transformation of a post-socialist country, Estonia is an example of a “successful digital leap” in the post-Soviet space, and Ukraine demonstrates a unique experience of digital transformation in conditions of war and crisis, with the potential for technological leapfrogging (jumping through the stages of traditional development).

Therefore, comparing Ukraine with Poland, Estonia, and Germany allows us to simultaneously assess the progress of digitalization within the post-socialist legacy, the impact of EU membership on digital policy, various models and strategies of digital transformation, and outline realistic guidelines for the development of Ukraine's digital economy.

Results

In modern scientific literature, researchers emphasize that the DE is not just a set of electronic tools, but a structural change in the model of economic development that covers all spheres of society and the economy.

The DE is a form of economy based on digital technologies, in particular, on the use of the Internet, big data, artificial intelligence, blockchain solutions, cloud computing, digital platforms, business process automation, etc. In such an economy, the key resources are data, digital skills and digital infrastructure, and its main drivers are digital innovation, digital services and online interaction between business, government and consumers.

One of the first researchers of this concept was D. Tapscott (1996) defined the DE as: “that component of the economic system that operates on the basis of business models built on the creation, transmission, and consumption of products created using exclusively or predominantly digital technologies.” His vision emphasized networked intellectual interaction and the potential of information flows.

V. Baranov (2021) in his research, considers the DE as: “a systemic set of economic relations (production, distribution, exchange and consumption of goods and services), which is based on the mandatory use of electronic networks and digital technologies.” This approach emphasizes the comprehensiveness of digital transformations, which cover both the private and public sectors.

H. Chmeruk (2019) emphasizes the institutional autonomy of the digital economy, considering it as: “a sector of economic activity related to information and communication technologies, in particular the production and sale of goods, services and digital content.”

M. Knickrehm, V. Berthon and R. Daugherty proposed a more operational definition: “The digital economy is the share of total economy output derived from a number of broad “digital” inputs. These digital inputs include digital skills, digital equipment (hardware, software and communications equipment) and the intermediate digital goods and services used in production. Such broad measures reflect the foundations of the digital economy”. This definition allows us to quantitatively measure the contribution of digital components to the national economy.

M. Rouse (2016) “digital economy is the worldwide network of economic activities enabled by information and

communication technologies (ICT). It can also be defined more simply as an economy based on digital technologies”.

A more systematic and flexible definition is formulated by R. Bukht and R. Heeks (2018). They understand the DE as: “part of economy output derived solely or primarily from digital technology with a business model based on digital goods or services”.

Finally, at the global level, the G20 in 2020 established an expanded understanding of the DE as: “a system that includes technologies, digital infrastructure, digital services and data; it concerns all producers and consumers, including government, that use these digital resources in their economic activities” (Ministerial Declaration).

Thus, scientific approaches to defining the DE demonstrate

an evolution from narrow technocratic interpretations to systemic interdisciplinary concepts, which allows us to take into account the social, technological, and economic aspects of digital transformations.

In his scientific work “Defining, conceptualising and measuring the digital economy”, Bukht and R. Heeks (2018) proposed a hierarchical conceptual model of the DE to overcome the problems of blurred boundaries, confusion between the ICT sector and digital innovation, and the difficulty of measuring new digital forms of business. They introduce a three-level model of the DE coverage. This approach helps researchers to delineate the depth of digital integration in the economy and see where the digital component is truly defining and where it is supporting (Table 1).

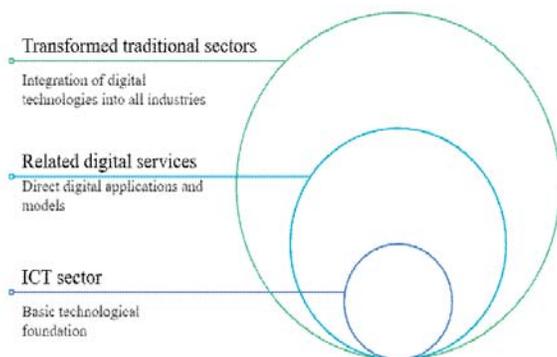
Table 1. Levels of digital economy coverage according to the degree of integration of digital technologies

Coverage level	Name	Content
Core	The core of the digital economy	The ICT sector itself: equipment manufacturing, telecommunications, software
Narrow	Narrow understanding	Activities directly based on digital products and services (digital platforms, e-business , digital financial services)
Broad	Broad understanding	All economic activities where digital technologies are integrated into traditional sectors: industry, transport, agriculture , education, healthcare, etc.

Source: systematized by the authors based on R. Bukht and R. Heeks (2018)

In the future, it is worth adapting the approach of R. Bukht and R. Heeks into a visual model, focusing not on sectors, but on the depths of penetration of digital technologies into the economy (Fig. 1).

Fig. 1. Structural model of the digital economy by the extensiveness level



Source: developed by the authors

Fig. 1 illustrates three levels of building the digital economy, each of which is an interconnected stage of digitalization development. The interpretation of each DE level in the functioning of the Ukrainian economy includes:

1. The basic technological foundation is the narrowest internal level, which includes: communication infrastructure (fiber optic networks, 4G/5G, satellite communications); digital skills of the population; availability of digital identification (e.g., Diya ID); basic computerization of government and business; access to the Internet.

In Ukraine, this level has been developing intensively since 2020 (thedigital.gov.ua). The opening of digital registries, the launch of the “Diya” platform, and 4G coverage in over 90% of settlements are examples of the formation of this foundation. However, significant regional disparities remain, particularly in rural communities.

2. Direct digital applications and models – this middle level includes: digital platforms (government and commercial), e-commerce, financial technology (FinTech), online education (EdTech), digital services in healthcare, transport, and public services.

In Ukraine, the following are implemented at this level:

- the “Diya” platform as a model of digital interaction between a citizen and the state (e-services, documents, digital registration, business registration);
- development of the domestic FinTech sector – monobank, Portmone, Settle, etc.;
- active growth of the e-commerce market, especially after 2020;
- digital education projects – “Action.Digital Education”, distance learning during wartime.

This level is already actively functioning in Ukraine, but there are problems with scaling models, lack of stable demand among part of the population, and insufficient level of digital skills among vulnerable groups.

3. Integration of digital technologies into all industries is the broadest external level – full digitalization of the economy: smart manufacturing (smart factories, Industry 4.0); digital agriculture (precision agriculture); digital logistics management; Big Data and AI in public administration and business; digital modeling in energy, construction, and environmental protection.

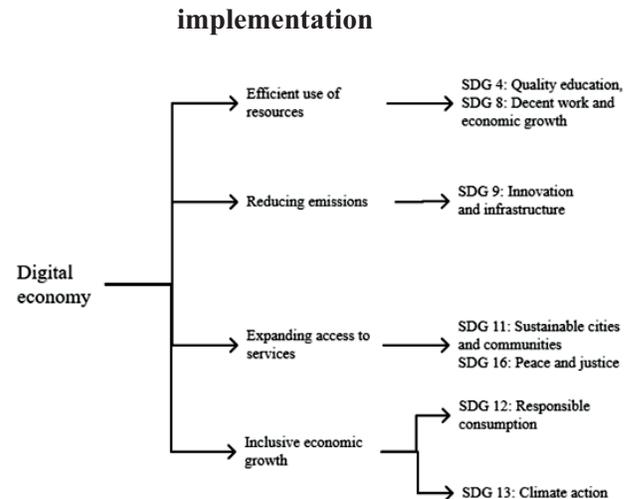
In Ukraine, this level is still fragmented and limited. Some examples include:

- introduction of drones and satellite monitoring in the agricultural sector (for example, in agricultural holdings);
- use of AI/ML analytics in the banking sector;
- separate initiatives on the digitalization of logistics and healthcare;
- Smart pilot projects City in Kyiv, Lviv, Dnipro.

The link between the DE and SD is extremely important and multifaceted. Digital technologies not only transform production, business and services, but also create new opportunities for achieving the SDGs. Digitalization contributes to more efficient use of resources, reduced emissions, expanded access to services and inclusive

economic growth, i.e. it is directly linked to the SDGs (Figure 2).

Fig. 2. The impact of the digital economy on the SDGs



Source: developed by the authors

Therefore, the DE plays a powerful role as a catalyst for sustainable development, as it directly contributes to the achievement of the key SDGs. It ensures the rational use of resources, innovative breakthroughs in infrastructure and industry, inclusiveness of the economy, and also creates conditions for environmental efficiency and reduction of carbon footprint. This makes digitalization not only a technological but also a socio-ecological phenomenon of strategic importance.

Given the multi-level structure of the digital economy, which encompasses both the technological basis and the sectoral integration of digital solutions, there is a need for a systemic approach to its assessment. To do this, it is advisable to turn to integral indicators that allow measuring not only individual components of digitalization (infrastructure, skills, services, innovations), but also the overall level of digital development of the state in a dynamic and comparative context.

DESI is a key integrated indicator that measures the level of digital maturity of EU member states, and at the same time acts as an analytical tool for monitoring the progress of digital transformation in the context of socio-economic

development. DESI is extremely relevant for assessing the relationship between the DE and sustainable economic growth. It assesses the DE not only from a technical perspective, but also through its social impact, which

directly correlates with several SDGs. Table 2 shows the relationship between the DESI components and the corresponding SDGs.

Table 2. Relationship of the DESI index components with the UN SDGs

DESI component	What does it measure?	Link to the SDGs
1. Human Capital (Digital skills)	Digital skills of the population, ICT specialists	SDG 4 (Quality Education), SDG 8 (Decent Work and Economic Growth)
2. Communication (Digital infrastructures)	Access to high-speed internet, 5G, coverage	SDG 9 (Innovation and Infrastructure), SDG 10 (Reduced Inequality), SDG 11 (Sustainable Urban and Community Development)
3. Integration of digital technologies into business (Digitalisation of business)	E- commerce , cloud services, Big Data	SDG 9 (Innovation and Infrastructure), SDG 12 (Responsible Consumption), SDG 13 (Combating Climate Change)
4. Digital government services (Digital Public Services)	E-government, open data	SDG 16 (Peace and Justice), SDG 17 (Partnerships for Sustainable Development)

Source: developed by the authors

The DESI index is a valuable benchmark for Ukraine, as it reflects in detail the level of digitalization of EU countries by key components, allowing for the assessment of gaps and adaptation of successful practices to the national context.

Based on the data in Fig. 3 for 2019–2022 for Poland, Estonia, Germany, and the EU average, it is possible to conduct an analytical assessment of the level of digital development of countries, identify imbalances in the components of the digital economy, and also derive guidelines for Ukraine from the perspective of achieving the SDGs.

The analysis of the dynamics of key components of the DESI for 2019–2022 allows us to more deeply assess the level of digital transformation in individual EU countries and identify how this progress correlates with the achievement of the SDGs.

In the field of digital skills, the most significant growth was demonstrated by Germany, which increased its indicator from 10.63 to 15.95 in four years. This indicates a targeted state policy on human capital development, which directly supports SDG 4 and SDG 8. Estonia maintained consistently high values during this period (about 13.5), which is the result of consistent digital inclusion of the population. Poland, on the contrary, demonstrates slow growth dynamics - only 0.78 points in four years, remaining the weakest among the analyzed countries, which indicates the presence of a structural barrier to the spread of digital skills among the population. On average, there is a positive trend in the EU: from 10.71 to 11.44.

Fig. 3. Dynamics of DESI index components in Poland, Estonia, Germany and the EU



Source : developed by the authors based on <https://digital-decade-desi.digital-strategy.ec.europa.eu>

In terms of digital infrastructure, Poland has shown a significant increase: from 6.59 in 2019 to 11.63 in 2022. This is a result of the active implementation of broadband internet and preparation for the implementation of 5G. Estonia has been steadily increasing its infrastructure capacity, reaching 11.11. At the same time, Germany has seen a decrease in this indicator from a peak of 10.09 in 2020 to 8.96 in 2022, which indicates limited new

investment in ICT infrastructure. In contrast, the EU average has almost doubled, from 7.65 to 14.98, demonstrating the pan-European priority in the development of digital communications. This component directly supports SDG 9 and SDG 10.

In the business digitalization, the highest growth rates were recorded in Germany - from 6.61 to 16.83, which is the result of the implementation of the "Industrie 4.0" strategy

and the active introduction of cloud services, Big Data, e-commerce and automation in industry. Estonia is also gradually increasing the digital maturity of the business environment. Poland, however, shows extremely slow progress – only from 4.16 to 5.72, which indicates a weak integration of digital solutions into the activities of small and medium-sized businesses. The EU average has increased from 6.73 to 9.02. This component is critically important for achieving SDG 9, SDG 12 and SDG 13, as the introduction of digital technologies into business chains allows for the optimization of resources and a reduction in environmental burden.

Digital public services remain the most developed area in Estonia: from 19 points in 2019 to 22.79 in 2022. This confirms the country's leadership in e- government and the full integration of digital tools into public administration. Poland is slowly but steadily improving its indicators (from

10.55 to 13.94), although it is still significantly behind. In Germany, on the contrary, there is a decline in 2022 to 11.24 after a previous increase, indicating bureaucratic or organizational difficulties with further digitalization of public services. The EU as a whole shows positive dynamics: from 13.55 to 16.84. This component is critical for ensuring effective governance, transparency and institutional capacity, which directly supports SDG 16 and SDG 17.

An analysis of the countries' positions in the DESI ranking for 2019–2022 allows us to draw conclusions about the overall competitiveness of the digital economies of Poland, Estonia, and Germany compared to the EU average, as well as to identify the dynamics of digital progress in an integrated dimension, i.e., taking into account all key components (Table 3).

Table 3. Change in country positions in the DESI ranking

Country	2019	2020	2021	2022	Δ place (2019 – 2022)
Estonia	9	9	9	8	+1 (stable leadership)
Germany	18	17	12	12	+6 (sustained improvement)
Poland	25	25	25	25	0 (steadily low)
EU (average)	17	18	15	14	+3 (overall progress)

Source: developed by the authors based on <https://digital-decade-desi.digital-strategy.ec.europa.eu>

Poland has remained in 25th place out of 28 overall for four years, which is an indicator of chronic lagging behind in digital transformation. Despite some growth in individual indicators (infrastructure, public services), the inertia of changes and the weak dynamics in the digitalization of business and the development of human capital do not allow it to leave a low position among EU countries. This position is of strategic importance - it signals systemic barriers in managing the digital transition, which hinder economic development and the achievement of the SDGs.

Estonia is consistently among the top ten and has even strengthened its position from 9th to 8th place. This is the result of a consistent digital policy that covers all levels: from digital skills to e-government. Estonia demonstrates institutional stability, flexibility and innovation , which allows not only to achieve high positions in the rankings, but also to effectively implement the SDGs, in particular in

the context of inclusion , transparency and digital equality.

Germany has moved from 18th to 12th place in four years, one of the most dynamic jumps among major European economies. Particularly significant growth occurred between 2020 and 2021, when the country moved from 17th to 12th place. The main driver was the large-scale digitalization of business (in particular, within the framework of the “Industrie 4.0” concept (www.it.ua)) and the development of digital skills. At the same time, there are some declines in digital infrastructure and public services , which limits further advancement in the ranking.

The EU also shows positive dynamics on average, moving up from 17th to 14th place. This reflects the pan-European mobilization of efforts to reduce the digital divide, in particular in the context of the implementation of the Digital Agenda. Decade 2030 (Europe 's Digital Decade :

digital targets for 2030 – Documents) and providing funding for digital projects within the framework of the COVID-19 recovery plan (Recovery plan for Europe).

Thus, DESI for 2019-2022 shows that digital transformation in Europe has both structural successes (Estonia, Germany in certain components) and slowdowns (in particular, Poland – in digital skills and business).

Ukraine, as a candidate for EU accession, should focus on Estonia's successful cases in the field of digital state and the pace of business digitalization similar to Germany's, while taking into account Polish challenges in order to avoid similar "digital stagnation". The analysis of the positions of countries in the DESI ranking shows that a high place in the ranking is directly related to the achievement of the SDGs - through the development of digital infrastructure, the development of innovative business, educational practices and e-government.

For Ukraine, these results can serve as a guide to combining Estonian experience in digital governance, German industrial digitalization, and the EU infrastructure strategy as a way to synchronize digital policy with the SDGs.

In modern conditions, digital transformation has become a key direction of socio-economic development in Ukraine. For effective management of this process, it is extremely important to regularly assess the pace of digitalization at both the national and regional levels. For this purpose, a number of indicators and indices have been introduced in Ukraine that reflect the state and dynamics of the digital economy, the level of digital skills of the population, the development of infrastructure and the effectiveness of the implementation of electronic services.

The most indicative tool for monitoring digital development is the DTI of Regions (DTR) of Ukraine. The index was developed by the Ministry of Digital Transformation of Ukraine and UkraineInvest, a state institution for attracting investments.

The DTI of Ukrainian Regions is a tool for assessing the level of digital development of Ukrainian regions according to criteria such as the availability of digital services, infrastructure development, digital competence, etc. The DTI of Ukrainian Regions is the closest in structure

and logic to the DESI among the national tools for assessing digitalization in Ukraine. Both indices have a multi-component structure and measure digital transformation not only as a technical infrastructure, but also as a set of digital skills, services, and technologies in public administration and the economy.

Analysis of the dynamics of the DTI of Ukrainian regions for 2022-2024 based on Fig. 4 demonstrates a general decrease in the average level of digital development of regions and an increase in the digital asymmetry between leaders and lagging territories.

Fig. 4. Dynamics of the Digital Transformation Index of Ukrainian regions



Source: developed by the authors based on <https://thedigital.gov.ua>

In the period from 2022 to 2024, the ICTD of Ukraine demonstrates a clearly pronounced downward trend. The average value of the index for the country decreased from 0.651 in 2022 to 0.497 in 2024. This indicates a general weakening of digital activity in the regions and a loss of digitalization dynamics. This decline is due to a number of factors, including the ongoing war, the destruction of infrastructure, a reduction in investments in digital services, as well as the weakening of institutional coordination of digital programs at the regional level. Another factor affecting the situation is the decrease in community activity in the field of digital transformation.

Even among the leaders, there is a decline. Thus, in 2022 and 2023, the highest indicator was demonstrated by the Dnipropetrovsk region (0.916 and 0.908, respectively), and in 2024 its place was taken by the Lviv region with an indicator of 0.850. Despite the fact that these regions maintain their leading positions, a noticeable decrease in the absolute value of the index indicates a slowdown in the

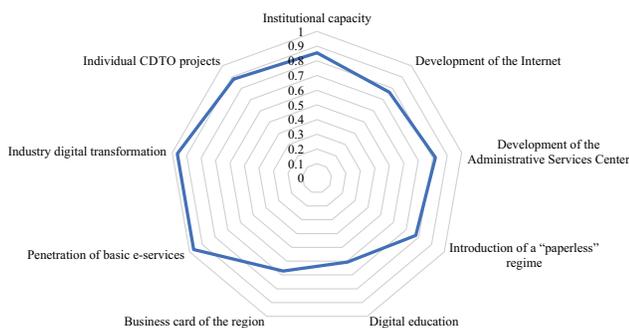
pace of digital transformation even in relatively developed regions.

At the same time, the most backward regions demonstrate even more alarming dynamics. In 2022, the lowest value was recorded in Zaporizhia region (0.370), in 2023 - in Sumy (0.178), and in 2024 - in Donetsk (0.129). Thus, the digital lag of regions with a complicated security situation or border location is increasing. In these regions, the digital infrastructure is collapsing, and opportunities for the implementation of services, digital services and educational initiatives are limited.

Another alarming signal is the deepening digital asymmetry between the leading and lagging regions. If in 2022 the difference between the highest and lowest index values was 0.546, then in 2023 it increased to 0.730, and in 2024 it remained at a high level of 0.721. This trend indicates that instead of leveling the digital space in the country, there is a gap that can have serious socio-economic consequences. The growing digital inequality exacerbates territorial disparities, complicates access to modern services for residents of remote and affected regions, and also reduces the inclusiveness of overall digital development. This creates serious challenges for state policy focused on digital transformation and SD in all regions of Ukraine without exception.

A comparison of the components of the DTI of Ukraine's regions in 2024 for Lviv and Donetsk regions demonstrates striking contrast and at the same time reveals several key trends and interesting facts (Fig. 5, 6).

Fig. 5. Comprehensive assessment of the digital transformation of Lviv region according to the components of the DTI of Ukraine's Regions, 2024



Source: developed by the authors based on <https://thedigital.gov.ua>

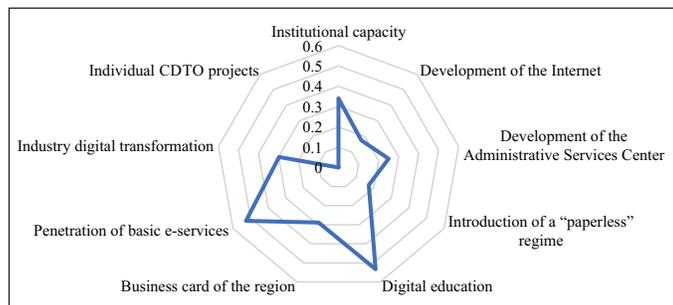
The data in Fig. 5 reflect the high level of digital maturity of the Lviv region, with particularly strong positions in the areas of industry digital transformation and basic e-services.

The data in Fig. 6 indicates a critically low level of digital transformation in the Donetsk region in 2024, which is due to active hostilities, destruction of infrastructure, and limited opportunities for implementing digital initiatives.

Lviv region has consistently high indicators in all areas, which puts it among the leaders among the regions. Donetsk region has the lowest result in Ukraine in 2024. This sharp difference indicates not only the different level of development of digital infrastructure, but also deep spatial inequality, caused by both military and institutional factors.

Digital coverage and internet access in Donetsk Oblast are critically limited – less than a quarter of the level in Lviv Oblast. This hampers citizens' ability to use digital services and connect to online education, medicine, and administrative services. In Lviv, the digitalization of public services has become a widespread practice, while in Donetsk Oblast, less than one in five digital processes has been implemented, depriving residents of basic administrative conveniences. Despite the general lag, Donetsk region has a relatively good digital education indicator, close to the leaders. This is probably the result of humanitarian aid, educational initiatives of international donors and adaptive programs for teachers and youth in war conditions. Lviv region has practically implemented all basic digital services, in particular in healthcare, housing and utilities, and education. Donetsk region has half as many. The difference here clearly illustrates the different degrees of citizens' access to the e-state. Donetsk region completely lacks personal initiatives of digital transformation leaders (CDTO). This may indicate: evacuation of teams, lack of management resources, lack of conditions for the implementation of local projects.

Fig. 6. Comprehensive assessment of the digital transformation of Donetsk region according to the components of the DTI of Ukraine's Regions, 2024



Source: developed by the authors based on <https://thedigital.gov.ua>

A comparison of Lviv and Donetsk regions demonstrates not only the difference in digital maturity, but also the deep digital inequality that is formed under the influence of war, infrastructure destruction, but also managerial capacity. Despite the difficult circumstances, Donetsk region retains educational potential that should be strengthened, as it can become the basis for the restoration of the DE after the war.

Based on the analysis of the digital transformation of the regions of Ukraine and the comparison of Lviv and Donetsk regions, generalized conclusions can be drawn that highlight the synergy between the DE and the SDGs:

1. Developed digital infrastructure, access to e-services and digital education create the prerequisites for more inclusive economic growth, especially in less developed or war-affected regions. This is directly related to SDG 10 and SDG 11. However, currently in Ukraine we are observing the opposite trend – a deepening digital divide between leaders and outsiders.
2. Digital literacy indicators are critical for achieving SDG 8, SDG 4 and developing an innovative economy. Even in critical conditions (as in Donetsk region), maintaining elements of digital literacy is a resource for future recovery. Investment in digital skills is a universal tool for both digital transformation and sustainable development.
3. Where digital institutions and e-services function effectively (as in Lviv region), citizens' trust in government increases, access to public services improves, and local activism is stimulated. This directly supports SDG 16 and SDG 17.

4. DE tools – from cloud technologies to smart infrastructure – enable resource consumption reduction, emissions reduction and digital-green cities. High digital maturity of regions opens up opportunities for implementing SDG 12 and SDG 13.

The sharp contrast between Lviv and Donetsk regions demonstrates that sustainability and digitalization are not automatic processes, but require targeted efforts, including: supporting digital education in vulnerable communities, developing infrastructure even in border or frontline areas, and creating incentives for digital initiatives at the local level.

The DE and SD in Ukraine are mutually reinforcing. Combining them is not just a technical or social challenge, but a strategic goal of national recovery. To avoid deepening imbalances and ensure a truly sustainable digital transformation of the economy, it is necessary to focus on inclusion, equal access, and long-term digital literacy in all regions of the country.

The analysis of the state of digital transformation in Ukraine has shown significant achievements in some areas, but also revealed deep structural vulnerabilities that hinder the synergy of the DE and sustainable development. This especially applies to regional inequality, limited access to digital infrastructure, as well as insufficient digital skills among the population and business. In the context of war and decentralization, these vulnerabilities become even more critical and require targeted solutions.

The following problem areas remain the most relevant for Ukraine: low digital literacy coverage among broad segments of the population (especially the elderly and rural population), slow digitalization of small and medium-sized businesses, a pronounced digital divide between urban and rural areas, and weak IT infrastructure in some regions, particularly frontline ones. These vulnerabilities not only hinder digital modernization, but also undermine the potential for achieving the SDGs in Ukraine.

Conclusions

Based on the comprehensive analysis of the levels of digital transformation of the Ukrainian economy, as well as based on the basis of comparison with EU countries and the principles of sustainable development, the following recommendations can be formulated for Ukraine to strengthen the synergy of the DE and sustainable development:

1. Invest in digital education and reskilling – human capital development is key to an inclusive digital transformation of the economy. National digital literacy programs need to be scaled up, with special attention to: rural communities, older age groups, internally displaced persons. This will contribute to the implementation of SDGs 4, 8 and 10.
2. Support for the digitalization of SMEs – the small and medium-sized business sector remains insufficiently integrated into the digital economy. It is recommended: subsidizing the implementation of cloud services, access to e-commerce tools, digital accelerators in communities. This will strengthen the local economy and contribute to SDGs 9 and 12.
3. Continue the digitalization of public services - ensure the interoperability of the “Diya” platform with European systems, increase the accessibility level of services for citizens with special needs, and improve the functioning of the ASC at the ATC level. A transparent state is the basis for achieving SDGs 16 and 17.
4. Implement regional programs for the development of digital infrastructure - the digital divide between urban and rural areas remains a significant threat. It is recommended: to direct funds to the development of Internet networks in rural areas, to improve the quality of mobile coverage, to involve the private sector through public-private partnerships. This directly affects SDGs 9, 10 and 11.
5. Stimulate sectoral digital transformation. Healthcare, education, ecology, transport are priority sectors for the implementation of digital solutions. It is necessary to create sectoral CDTOs that will implement innovations

on the ground. This will allow achieving SDGs 3, 4, 13 and 11.

6. Institutional strengthening of digital policy at the local level – strengthen the functioning of digital leaders (CDTO) in communities, create a network of interregional cooperation, and ensure sustainable budgets for digital initiatives. This will ensure the long-term sustainability of digital transformations.

The development of the DE must become not only a technological, but also a socially just and sustainable process. It must be based on inclusion, trust, accessibility and effective governance, which are prerequisites for sustainable reconstruction and integration of Ukraine into the EU.

Reference

- Sustainable Development Goals. Global Compact Network Ukraine. <https://globalcompact.org.ua/tsilistijkogo-rozvytku/>
- Baranov, V. V. (2021). Digital management as a mandatory component of the digital economy: monograph. Kherson: Helvetica Publishing House, https://www.researchgate.net/profile/VasylGorbachuk/publication/356424141_Innovative_behavior_in_digital_markets/links/619ab37107be5f31b7a8a3ad/Innovative-behavior-in-digital-markets.pdf#page=98.
- Bukht, R., Heeks, R. (2018). Defining, conceptualising and measuring the digital economy. *International Organisations Research Journal*, 13(2), 143-172. DOI:10.17323/1996-7845-2018-02-07.
- Chmeruk, G. G. (2019). Digital economy as a separate sector of the national economy of the state. *Scientific Bulletin of Uzhgorod National University*, 27(2), 92-97. http://www.visnyk-econom.uzhnu.uz.ua/archive/27_2_2019ua/18.pdf.
- Digital Decade DESI visualisation tool. European Commission. <https://digital-decade-desi.digital-strategy.ec.europa.eu/>.

- Digital transformation index of regions of Ukraine. Ministry of Digital Transformation of Ukraine. <https://thedigital.gov.ua/storage/uploads/files/page/community/reports/%D0%86%D0%9D%D0%94%D0%95%D0%9A%D0%A1%202024%202%201.pdf>.
- Djakona, A., Kholiavko, N., Dubyna, M., Zhavoronok, A., & Fedyshyn, M. (2021). Educational dominant of the information economy development: a case of Latvia for Ukraine. *Economic Annals-XXI*, 192(7-8(2)), 108-124. <https://doi.org/10.21003/ea.V192-09>
- E-Residency. Republic of Estonia. <https://www.e-resident.gov.ee/>.
- Europe's Digital Decade: digital targets for 2030 – Documents. European Commission. (2023). https://commission.europa.eu/europes-digital-decade-digital-targets-2030-documents_en.
- G20 Digital Economy Ministers Meeting. Ministerial Declaration. (2020). Wednesday. https://www.g20.utoronto.ca/2020/G20SS_Declaration_G20_Digital_Economy_Ministers_Meeting_EN.pdf.
- Kholiavko, N., Popelo, O., Hryhorkiv, M., Kosmii, O., Oleksienko, O., & Zhavoronok, A. (2023). EU Higher Education Institution Toward the Sustainable Development. *Management Theory and Studies for Rural Business and Infrastructure Development*, 45(2), 124–132. <https://doi.org/10.15544/mts.2023.13>
- Knickrehm M., Berthon B., Daugherty P. (n.d.). *Digital Disruption: The Growth Multiplier*. Accenture, Dublin. <http://www.metalonia.com/w/documents/Accenture-Strategy-Digital-Disruption-Growth-Multiplier.pdf>.
- Kychko, I., Shaposhnykova, I., Shaposhnykov, K., Popelo, O., Tochylina, Y., Stoika, V. (2023). The Role of Digital Technologies in Balancing the Labor Market in the Conditions of the Post-War Recovery of the Ukraine's Economy. *Review of Economics and Finance*, 21, 1991-2002. <https://doi.org/10.55365/1923.x2023.21.214>
- Popelo, O., Tulchynska, S., Kharchenko, Y., Dergaliuk, B., Khanin, S., Tkachenko, T. (2021). Systemic Approach to Assessing Sustainable Development of the Regions. *Journal of Environmental Management and Tourism*, (Volume XII, Summer), 3(51), 742-753. [https://doi.org/10.14505/jemt.v12.3\(51\).13](https://doi.org/10.14505/jemt.v12.3(51).13)
- Projects of the Ministry of Digital Transformation of Ukraine. <https://thedigital.gov.ua/ministry>.
- Recovery plan for Europe. European Commission. (2021). https://commission.europa.eu/strategy-and-policy/recovery-plan-europe_en.
- Rouse M. *Digital Economy* [Newton: Techtargert]. (2016). <http://searchcio.techtargert.com/definition/digitaleconomy>.
- Shaposhnykov, K., Kochubei, O., Grygor, O., Protsenko, N., Vyshnevskaya, O., Dzyubina, A. (2021). Organizational and Economic Mechanism of Development and Promotion of IT Products in Ukraine. *Estudios de economía aplicada*, 39(6). <https://doi.org/10.25115/eea.v39i6.5264>
- Shlapak, A., Zhavoronok, A., Vdovenko, N., Bilousov, O., Horban, D., Krylov, D. (2025). The Impact of Digital Technologies and Artificial Intelligence on Management of Socio-Economic Processes in the Context of Sustainable Development. *RISUS - Journal on Innovation and Sustainability*, 16(2), 180-193. <https://doi.org/10.23925/2179-3565.2025v16i2p180-193>
- Tapscott, D. (1996). *The Digital Economy : Promise and Peril in the Age of Networked Intelligence*. New York: McGraw-Hill.
- The concept of "Industrie 4.0". IT-Enterprise. URL: <https://www.it.ua/>.
- Tulchynska, S., Popelo, O., Revko, A., Butko, M., Derhaliuk, M. (2022). Methodological Approaches to the Evaluation of Innovation in Polish and Ukrainian Regions, Taking into Account Digitalization. *Comparative Economic Research. Central and Eastern*

- Europe, 25(1), 55-74. <https://doi.org/10.18778/1508-2008.25.04>.
- Zhavoronok, A., Chub, A., Yakushko, I., Kotelevets, D., Lozychenko, O., Kupchyshyna, O. (2022). Regulatory Policy: Bibliometric Analysis Using the VOSviewer Program. *International Journal of Computer Science and Network Security*, 22(1), 39-48. <https://doi.org/10.22937/IJCSNS.2022.22.1.7>
 - Zybareva, O., Shylepnytskyi, P., Ozarko, K., Kravchuk, I., & Nahorniuk, O. (2022). The organizational and economic mechanism of attraction of digital technologies in the innovation activity of companies in the conditions of international competition. *Revista De La Universidad Del Zulia*, 14(39), 415-431. <https://doi.org/10.46925//rdluz.39.23>