“Digital transformation as a tool for creating an inclusive economy in Ukraine during wartime”

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DIGITAL TRANSFORMATION AS A TOOL FOR CREATING AN INCLUSIVE ECONOMY IN UKRAINE DURING WARTIME

Abstract

The russian aggression against Ukraine underscores the need to reassess regional strategies for digitalization and inclusivity. The study aims to identify strategies for enhancing these areas during wartime. Taxonomy and cluster and factor analysis methods have shown that regions with a higher level of digitalization have lower levels of poverty and unemployment. Specifically, regions in the top quartile of the digitalization index reported, on average, 12% lower unemployment rates compared to those in the bottom quartile. The analysis identifies distinct regional groupings: areas such as Zaporizhzhia, Kherson, Donetsk, and Luhansk are partially occupied and exhibiting low digitalization and inclusivity, in contrast with Mykolaiv and Kirovohrad that show moderate progress. Rural regions face a significant digital divide, with only 60% of rural households having stable internet access compared to 90% in urban areas. Factor analysis confirms that wartime conditions have accelerated digital transformation, evidenced by a 42% increase in Diia app usage from 2021 to 2023 and a rise in internet penetration from 62% in 2019 to 78% in 2023. Additionally, IT sector export revenues grew by 20% in 2022, and technology startups doubled between 2019 and 2023. The study proposes a strategic framework for regional adaptation: intensive digitalization and inclusivity for Zaporizhzhia, Kherson, Donetsk, and Luhansk regions; digitalization for Mykolaiv region; inclusivity for Kirovohrad and Zakarpattia regions; and balanced adaptation for Chernivtsi and Khmelnytskyi regions. Recommended measures include modernizing digital infrastructure, expanding educational opportunities, supporting startups, and aligning digital and social initiatives to foster regional resilience and development.

Keywords inclusivity, region, development, war, disparities, infrastructure, social adaptation, knowledge economy

JEL Classification O12, O33, G28, I23

INTRODUCTION

The large-scale aggression by the russian federation against Ukraine, beginning in February 2022, has drastically altered the socio-economic landscape of Ukraine. This conflict has led to the occupation of parts of several regions, including Donetsk, Luhansk, Zaporizhzhia, and Kherson, triggering the largest migration crisis in Europe since World War II (IOM, 2024). Amid these challenges, digital transformation has emerged as a critical tool for maintaining economic stability and fostering inclusivity, enabling the country to adapt to the wartime environment while supporting displaced populations and ensuring access to essential services (Data Friendly Space, 2024). Digital technologies have become crucial in this context, swiftly adapting various sectors to the new wartime realities. Digitalization plays a key role in facilitating communication, information management, and business continuity, offering solutions that are universally applicable in any conflict or post-conflict scenario. Moreover, ensuring inclusivity during wartime involves enabling all societal segments, including vulnerable groups, to participate in economic life.

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1. LITERATURE REVIEW AND HYPOTHESIS

Digital transformation and resilience strategies are pivotal for fostering an inclusive economy amid the ongoing war. Data Friendly Space (2024) provides an extensive overview of the humanitarian crisis in Ukraine, detailing the socio-economic repercussions of the conflict. The report emphasizes the significant displacement of the population and the ensuing strain on Ukraine's economic and social infrastructure. The analysis underscores the necessity for immediate and long-term economic recovery strategies, particularly through international support and digital infrastructure development. IOM (2024) offers critical insights into internal displacement patterns in Ukraine, highlighting the economic disruption caused by the war. The findings on population movement and displacement are essential for understanding the economic challenges and opportunities in post-war recovery, including the role of digital tools in tracking and managing these demographic shifts.

Gasanov et al. (2024) discuss the transformation of Ukraine's budget system under extraordinary challenges. The article underscores the importance of adaptive fiscal policies and the integration of digital technologies in enhancing budgetary efficiency and transparency, which are crucial for sustaining an inclusive economy in the face of ongoing war. Lytvyn et al. (2024) explore the potential of digital means such as cloud computing, blockchain, big data, and AI in Ukraine's financial sector. The analysis highlights how these technologies can contribute to economic resilience by enabling more efficient financial operations and fostering inclusivity, which is vital for the country's recovery and growth during wartime. Rubakha et al. (2024) conducted a factor analysis of financial performance in Ukrainian IT companies, illustrating how strategic resilience can be formed under wartime conditions. The study emphasizes the critical role of the IT sector, supported by digital transformation, in sustaining economic activity and creating an inclusive economic environment even during conflict. Armocida et al. (2022) focus on the humanitarian aspects, particularly the plight of older people during the Ukrainian crisis. The article indirectly touches on the economic implications of the war, as the vulnerabilities of different demographic groups highlight the need for inclusive economic policies that address the needs of all citizens, facilitated by digital tools for better resource allocation. Goodwin et al. (2023) analyze national resilience in Ukraine following the 2022 invasion, emphasizing the psychological and social aspects of resilience. The study's findings suggest that building an inclusive economy is closely linked to fostering national resilience, where digital transformation plays a crucial role in uniting and empowering communities. Kolodiziev et al. (2024) investigate the impact of refugee startups on host country economies, focusing on business models and economic adaptation. The article highlights how digital tools and platforms can facilitate the integration of refugees into the economy, contributing to economic inclusivity in both host and home countries.

Herbst and Sitek (2023) examine the education of Ukrainian refugee students in Poland, offering insights into the broader socio-economic challenges posed by the war. This source highlights the importance of digital education platforms in ensuring the continuity of education for displaced populations, which is integral to fostering an inclusive economy. Verbivska et al. (2023) use Google Trends analysis to explore the dynamics of interest in higher education before and during the war. This source provides evidence of how the conflict has influenced educational aspirations, underlining the role of digital education tools in maintaining access to education and supporting economic inclusivity. Kozmenko et al. (2023) document the experience of Ukrainian universities during the war, illustrating the challenges of academic management in conflict zones. The article underscores the importance of digital transformation in maintaining academic activities and promoting an inclusive education system, which is a foundation for long-term economic stability and growth. These sources collectively demonstrate that digital transformation is not just a tool for economic recovery but also a fundamental enabler of inclusivity and resilience in Ukraine's wartime economy. By leveraging digital technologies, Ukraine can address the immediate challenges posed by the conflict while laying the groundwork for a more inclusive and sustainable future.

The escalating digitalization of economies worldwide has been accelerated by the COVID-19 pandemic and, more recently, by geopolitical

conflicts. With the challenges of war, Ukraine has rapidly embraced digital technologies to maintain critical functions, support economic activity, and build resilience.

The Ukrainian IT sector has emerged as a global powerhouse, demonstrating remarkable resilience and innovation amid the ongoing conflict. Bolila (2023) and Maksymenko et al. (2024) highlight the sector's pivotal role in sustaining the economy and providing essential services. The rapid adoption of digital technologies, exemplified by the Diia app (Verbivska et al., 2023), has transformed government services and enhanced transparency. Moreover, social media platforms have proven instrumental in humanitarian aid, communication, and documenting war crimes (Gamova et al., 2024). Digital technologies also contribute to economic growth by increasing labor productivity and creating new jobs. Podolchak et al. (2021) emphasize that digitalization boosts GDP through increased labor productivity and employment. Malyarets et al. (2021) showed that countries with high levels of digitalization, such as the US and South Korea, demonstrate higher rates of economic growth compared to less digitalized nations. Brynjolfsson and Saunders (2010) highlight that digital technologies stimulate innovation and new business models, and companies that actively use these technologies outperform competitors in innovation and financial performance.

A successful example of digitalization is presented in Estonia, where Tiits et al. (2008) note a significant increase in public administration efficiency and GDP growth. Similar processes in Ukraine can be enhanced through the implementation of digital economic value chains, as proposed by Miao (2021). Luo and Liu (2024) find that digital technologies reduce transaction costs and improve access to information, stimulating economic activity and supporting small and medium-sized enterprises. In times of war, digital technologies help maintain business continuity and access to public services, as noted by Kaminskyi et al. (2018). Successful digital transformation requires a foundation of trust and effective governance. S. S. Shah and S. A. Shah (2024b) and Kaminskyi et al. (2018) underscore the critical role of trust in digital systems for Ukraine's wartime digital transformation. Strengthening intellectual property protection is essential to foster innovation and attract investment (Chen & Wu, 2022). Addressing the digital divide (Muwani et al., 2022) is crucial for ensuring equitable access to digital opportunities. Effective regulatory frameworks are vital for maximizing the benefits of digitalization. Kosach et al. (2022) highlight the need for adaptable policies that support innovation and economic growth. The "government as a platform" concept (Dunayev et al., 2023) offers a promising approach to enhancing public service delivery and citizen engagement. By improving state-society interactions through interconnected digital assets, this model can contribute to Ukraine's rapid recovery and modernization.

A human-centered approach is essential for inclusive development (Mourtzis et al., 2022). By focusing on the needs of citizens and leveraging digital technologies, governments can create more equitable and resilient societies. Broeders and Hampshire (2013) demonstrate the potential of ICT to enhance mobility and border control, which can support Ukraine's infrastructure development and economic recovery. Bakhmat et al. (2023) highlight the importance of developing digital competencies in education for Ukraine's economic recovery. Voulgaridis et al. (2022) discuss the role of the Internet of Things (IoT) in the digital circular economy, which is relevant to Ukraine's reconstruction. Meanwhile, Atkinson and Castro (2008), as well as Heaton and Parlikad (2019), analyze the impact of IT on quality of life and smart city infrastructure, which is critical for Ukraine's development in wartime conditions. War conditions have also contributed to the development of distance learning, although this process has faced numerous challenges. Ferri et al. (2020) point to unreliable internet in rural areas, a lack of electronic devices, insufficient digital skills among teachers, and non-interactive online resources. However, as noted by Bieliaieva et al. (2023), the conflict has stimulated the use of new teaching methods, particularly distance learning, which has increased digital skills among students and teachers. Shunevych (2023) emphasizes the role of Massive Open Online Courses (MOOCs) in

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providing flexible and accessible education during wartime. The COVID-19 pandemic exacerbated existing educational inequalities, emphasizing the need for inclusive and equitable education systems (D'Orville, 2020). Adapting education to the challenges of war requires a focus on accessibility, resilience, and the integration of digital tools. To address the complex challenges of post-war recovery, Ukraine must leverage its human capital effectively. This involves mitigating the brain drain (A. H. Shah & S. S. Shah, 2024a), supporting the IT sector (Svystelnyk, 2023), and fostering innovation through crowdfunding (Vidomenko et al., 2022). Digital financial services are crucial for economic recovery and social inclusion. By expanding access to digital banking and financial literacy, Ukraine can empower its citizens and stimulate economic growth (Kanungo & Gupta, 2021; Ong et al., 2023; Onyshchenko et al., 2023). Overall, digital transformation can enhance inclusivity and accessibility in Ukraine's knowledge economy by addressing educational disparities, supporting human capital development, and promoting financial inclusion (Kolodiziev et al., 2017).

With the development of cities as significant international players, Sokhatska and Lutsiv (2023) emphasize the importance of a smart, sustainable city that focuses on inclusivity, safety, sustainability, and resilience. Bryukhovetskaya and Chernykh (2020) note that the implementation of Fourth Industrial Revolution (Industry 4.0) technologies enhances industrial efficiency, which is critical for Ukraine in the context of war and economic recovery. The development of digital financial services is another key aspect of Ukraine's digital transformation. Vidomenko et al. (2022) highlight the importance of crowdfunding for financing social and commercial projects during conflict. Kanungo and Gupta (2021) discuss the role of digitalizing banking services in financial inclusion, recommending the expansion of digital financial services and increased financial literacy. Onyshchenko et al. (2023) note that digitalization during wartime can stimulate financial inclusion and economic progress in Ukraine.

The analysis underscores the pivotal role of digital transformation in fostering economic resilience and inclusivity in Ukraine, especially in the face of war. By accelerating the adoption of digital technologies, the country has demonstrated its capacity to maintain essential services, stimulate innovation, and support economic growth. The rapid evolution of Ukraine's digital landscape, characterized by advancements in IT, e-government, and digital finance, has been instrumental in enhancing accessibility and inclusivity for a broader population segment.

This study, focused on digital transformation as a tool for creating an inclusive economy in Ukraine during wartime, aims to identify strategies that can enhance both digitalization and inclusivity in these challenging conditions. The findings and insights gained can guide Ukraine and other countries experiencing similar conflicts, thereby broadening the applicability and significance of this study. The hypothesis is as follows:

H1: In crises, the digital transformation of the Ukrainian economy can be strengthened due to the increased demand for digital tools and services, leading to greater diversification, inclusivity, and accessibility for all segments of society.

2. METHODS

The Inclusive Development Index (IDI), developed by the World Economic Forum (WEF, 2018), is a comprehensive tool designed to measure regional inclusivity by integrating economic, social, and environmental factors. The index is structured around three key categories: economic, social, and environmental indicators. In the pre-war context, the IDI focused on employment rates, income distribution, access to education, healthcare availability, and environmental quality. However, during wartime, the emphasis shifted to labor market resilience, access to emergency services, displacement and migration patterns, and environmental impacts. This approach enables a nuanced analysis of how crises influence inclusivity across various dimensions of development.

Comparing these indicators reveals significant shifts during the conflict, such as changes in

economic activities, social disruptions, and environmental degradation. This analysis highlights critical areas for intervention to ensure inclusivity in Ukraine during and after the conflict (Shcherbak et al., 2024).

A comprehensive framework based on key indicators is recommended to evaluate the inclusivity of Ukrainian regions, particularly during wartime. These indicators are relevant for both normal conditions and during crises, including armed conflict. The framework categorizes indicators into three groups, addressing crucial aspects of inclusivity.

The growth and development indicators include:

- IDI_{11} – Gross Regional Product (GRP) per capita, reflecting the economic development level of a region (Babchynska et al., 2024).
- IDI_{12} – Labor productivity (GRP per worker), indicating the efficiency of labor utilization (Schaffer et al., 2011).
- IDI_{13} – Expected healthy life expectancy, representing the health status of the regional population (Anderson et al., 2021).
- IDI_{14} – Employment rate of the working-age population, reflecting the level of population involvement in economic activities (Carey & Rabesona, 2003).

The inclusivity indicators include:

- IDI_{21} – Gini coefficient for income, measuring income inequality (Carey & Rabesona, 2003).
- IDI_{22} – Poverty rate, indicating the proportion of the population living below the poverty line (Carey & Rabesona, 2003).

While this analysis leverages readily available national statistics for indicators such as Gross Regional Product (GRP) per capita, labor productivity, and others (as detailed in Appendix A, Table A1), the methodological approach is carefully adapted to ensure these metrics' relevance and accuracy across different scenarios, including wartime. A focused set of indicators relevant to assessing inclusivity during both peacetime and wartime has been selected. This selection prioritizes factors directly influenced by crises, such as economic activity, health status, and labor participation (IDI_{11}, IDI_{12}, IDI_{13}, IDI_{14}, IDI_{21}, and IDI_{22}). A novel methodology is proposed that integrates key indicators with a tailored factor analysis approach. This method evaluates regional digitalization and inclusivity across various conditions, including wartime, offering a unique perspective on how conflict impacts regional strategies.

This study builds on national statistics to assess regional digitalization using the framework proposed by Kolodiziev et al. (2022), which provides a comprehensive set of digitalization indicators. To adapt this framework to wartime conditions, two key adjustments are made.

First, indicators are prioritized based on their relevance to wartime contexts. For instance, "ICT Usage Indicators in Different Sectors" ($DLR_{21\text{-}24}$) highlights the importance of e-government services and distance education technologies, which become crucial amid disruptions to traditional infrastructure.

Second, the indicator system is integrated with a factor analysis approach similar to that used for assessing inclusivity. This combined analysis evaluates regional digitalization levels and uncovers relationships between various aspects of digitalization during wartime.

These adjustments aim to provide a nuanced understanding of digitalization in Ukrainian regions under wartime pressures. Specific values for these indicators are detailed in Appendix A, Table A2.

To assess the levels of inclusivity and digitalization of Ukrainian regions during the war using the taxonomy methodology, two composite indicators are used: the Inclusivity Index (IDI) and the Digitalization Level Rating (DLR). These indicators are calculated based on a set of subcomponents. Table 1 shows the developed methodology for assessing the levels of inclusivity and digitalization of Ukrainian regions during the war.

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Table 1. Methodology for assessing equal inclusiveness and digital transformation of the regions of Ukraine in the minds of the crisis

Source: Derzhstat data; World Bank data; World Health Organization data; Ministry of Environmental Protection and Natural Resources (n.d.); Government Portal (n.d.); Global Edge (n.d.); UNDP (n.d.).

Calculation steps	Calculation algorithms	Interpretation of results
Step 1: Calculate the Integral Inclusion Indicator (IDI)	1.1 Collect the values of the IDI_{ij} indicators for each region i and each indicator j 1.2 Normalize the value of each IDI_{ij} indicator to bring it to the same scale. The min-max normalization method is used: $$z_{ij} = \frac{IDI_{ij} - \min(IDI_j)}{\max(IDI_j) - \min(IDI_j)}.$$ 1.3. Calculate the weights for each normalized indicator w_j. The weights are determined by the expert method. 1.4 Calculate the integral indicator by summing up the normalized values of the indicators, taking into account their weights: $$IDI_i = \sum_j w_j \cdot z_{ij},$$ where *i* is the region; *j* is the inclusion indicator.	The chosen indicators are normalized on a 0-1 scale, with 0 representing the lowest level of inclusion and 1 signifying the highest. Based on the IDI score, regional inclusivity is categorized as follows: ***High Inclusion (IDI ≥ 0.75)***: Regions demonstrate strong economic development, low inequality, high life expectancy, low poverty, and robust sustainability and intergenerational equity indicators. ***Medium Inclusion (0.5 ≤ IDI < 0.75):*** These regions exhibit moderate performance across key aspects of inclusive development, but potential areas for improvement may exist. ***Low Inclusion (IDI < 0.5):*** Regions face significant challenges in achieving inclusive development, characterized by high inequality, low-income levels, limited access to healthcare, and weak sustainability indicators.
Step 2: Calculate the integral indicator of digitalization (DLR)	2.1. Collect DLR_{ij} indicator values for each region i and each indicator j 2.2. Normalize the value of each DLR_{ij} indicator to bring it to the same scale. The min-max normalization method is employed: $$z_{ij} = \frac{DLR_{ij} - \min(DLR_j)}{\max(DLR_j) - \min(DLR_j)}.$$ 2.3. Calculate the weights for each normalized indicator w_j. The weights are determined by the expert method. 2.4 Calculate the integral indicator by summing up the normalized values of the indicators taking into account their weights: $$DLR_i = \sum_j w_j \cdot z_{ij},$$ where *i* is the region; *j* is the digitalization indicator.	Digitalization is measured on a 0-1 scale, with 0 indicating the least developed and 1 signifying the most advanced. Regional digitalization is categorized as follows: ***High Digitalization (DLR ≥ 0.75)***: Regions exhibit strong performance in internet access, broadband usage, mobile device adoption, digital infrastructure, and digital literacy. ***Medium Digitalization (0.5 ≤ DLR < 0.75):*** These regions demonstrate moderate digital development, but potential areas for improvement may exist. ***Low Digitalization (DLR < 0.5):*** Regions face significant challenges characterized by limited internet access, weak digital infrastructure, low digital literacy, and insufficient ICT integration across various sectors.
Step 3: Cluster the regions by indicators of inclusiveness and digitalization, construct a matrix for determining regional adaptation strategies	3.1. The k-means method is employed for clustering. The number of clusters is selected based on specific criteria k. 3.2 Determine the initial centroids: $\mu_1, \mu_2, \ldots \mu_k$ 3.3. Each region to the nearest centroid is selected based on Euclidean distance: $$d(x, \mu) = \sqrt{\left(IDI_j - \mu_{IDI}\right)^2 + \left(DLR_j - \mu_{DLR}\right)^2}.$$ 3.4. Centroid Re-calculation (Iterative). Centroids are recalculated by averaging the IDI and DLR values of all regions within each cluster. 3.5. Convergence criterion: Steps 2 and 3 are repeated until the centroids stabilize, indicating convergence. 3.6. Adaptation principles based on clusters: The resulting clusters represent distinct adaptation principles: Low IDI and Low DLR. Prioritize coordinated advancements in inclusivity and digitalization. Medium IDI and Low DLR: Emphasize digitalization initiatives. High IDI and Low DLR. Focus on targeted digitalization to address specific needs. Variable IDI and Medium DLR. Apply balanced adaptation principles, addressing both inclusivity and digitalization gaps. High IDI and High DLR. Strive for sustained leadership in both inclusivity and digitalization.	The following definitions define adaptation efforts based on the region's integrated indicators of inclusion (IDI) and digitalization (DLR): ***Lagging in Both (IDI < 0.5 & DLR < 0.5)***: Prioritize coordinated advancements in inclusivity and digitalization. ***Average Inclusiveness, Low Digitalization (0.5 ≤ IDI < 0.75 & DLR < 0.5):*** Emphasize digitalization initiatives to drive adaptation. ***High Inclusiveness, Lagging Digitalization (IDI ≥ 0.5 & DLR < 0.5):*** Focus on targeted digitalization to address specific adaptation needs. ***Medium Digitalization, Variable Inclusiveness (0.5 ≤ DLR < 0.75 & IDI can vary):*** Apply balanced adaptation principles, addressing both inclusivity and digitalization gaps. ***High Levels (IDI ≥ 0.75 & DLR ≥ 0.75):*** Strive for sustained leadership in both inclusivity and digitalization.

3. RESULTS

Figure 1 and Tables 2-4 present the levels of inclusivity and clustering of Ukrainian regions during the war period (2022–2023) using the taxonomy methodology.

Figure 1 shows that all regions of Ukraine are divided into three groups according to the inclusion category. The regions with an average level of inclusion 0.5≤IDI<0.75 include 11 regions of cluster 1 (Table 2). Regions with a medium level of inclusion include Ternopil, Chernivtsi, Ivano-Frankivsk, Rivne, Poltava, Volyn, Khmelnytskyi, Cherkasy, Odesa, and Zhytomyr regions.

Table 2. Composition of the first cluster based on inclusion

Members of Cluster Number 1 (Data_Inclusion_nor) and Distances from Respective Cluster Center Cluster contains 11 cases			
Case No.	**Distance**	**Case No.**	**Distance**
C_2	0.4076279	C_10	0.2642941
C_4	0.2803298	C_13	0.4926177
C_5	0.3682428	C_17	0.306302
C_6	0.2082817	C_18	0.2172329
C_7	0.4618767	C_19	0.2227404
C_8	0.3246629		

The regions with low level of inclusion IDI<0.5 include seven regions of cluster 2 (Table 3). The regions with a low level of inclusion include Zaporizhzhia, Kirovohrad, Mykolaiv, Chernihiv, Zakarpattia, Kherson, Sumy, Donetsk, and Luhansk regions.

Table 3. Composition of the second cluster based on inclusion

Members of Cluster Number 2 (Data_Inclusion_nor) and Distances from Respective Cluster Center Cluster contains seven cases			
Case No.	**Distance**	**Case No.**	**Distance**
C_14	0.1662483	C_21	0.1317728
C_15	0.3848663	C_22	1.122693
C_16	0.1326969	C_23	0.3848663
C_20	0.2721393		

The regions with a high level of inclusion IDI≥0.75 include five regions of cluster 3 (Table 4). The regions with a high level of inclusion include Kyiv City and Lviv, Kyiv, Kharkiv, and Dnipropetrovsk regions.

Table 4. Composition of the third cluster on the inclusion category

Members of Cluster Number 3 (Data_Inclusion_nor) and Distances from Respective Cluster Center Cluster contains five cases			
Case No.	**Distance**	**Case No.**	**Distance**
C_1	0.6212686	C_11	0.498383
C_3	0.3888182	C_12	0.3176897
C_9	0.3342239		

The results of calculating the levels of digitalization and clustering of Ukrainian regions during the war using the taxonomy methodology are presented in Figure 2 and Tables 5-7.

Figure 2 shows that all regions of Ukraine are divided into three groups according to the digitalization category. Thus, 14 regions of cluster 1 show an average level of digitalization 0.5≤DLR<0.75 (Table 5). Regions with an average level of digitalization include Ternopil, Chernivtsi, Ivano-

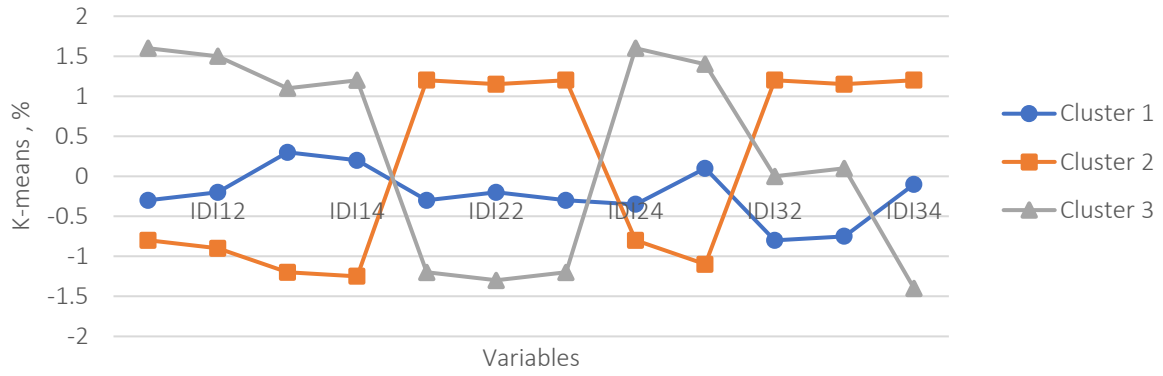

Figure 1. Graph of k-means of clustering of Ukrainian regions during the war based on inclusion

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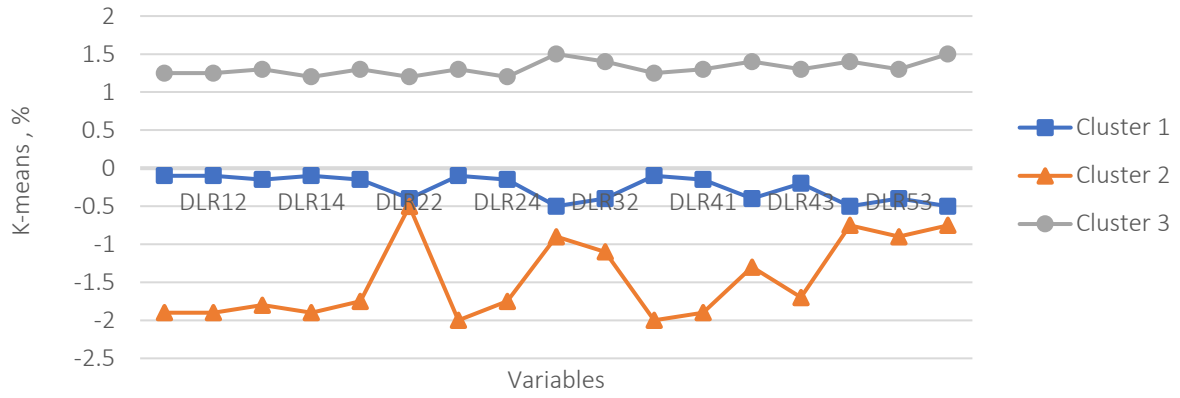

Figure 2. Graph of k-means of clustering of Ukrainian regions during the war based on digitalization

Frankivsk, Khmelnytskyi, Rivne, Poltava, Volyn, Kirovohrad, Cherkasy, Zhytomyr, Chernihiv, Zakarpattia, and Sumy regions.

Table 5. Composition of the first cluster based on digitalization

Members of Cluster Number 1 (Data_Digitalization_nor) and Distances from Respective Cluster Center Cluster contains 14 cases			
Case No.	**Distance**	**Case No.**	**Distance**
C_2	0.3112407	C_13	0.6688496
C_4	0.2326378	C_15	0.2102426
C_5	0.07892124	C_17	0.02922906
C_6	0.08126407	C_19	0.334711
C_7	0.1998929	C_20	0.4646271
C_8	0.4224633	C_21	0.1160837
C_10	0.1160837	C_23	0.02922906

The regions with a low level of digitalization DLR<0.5 include three regions of cluster 2 (Table 6). The regions with a low level of digitalization include Zaporizhzhia, Mykolaiv, Kherson, Donetsk, and Luhansk regions.

Table 6. Composition of the second based on digitalization

Members of Cluster Number 2 (Data_Digitalization_nor) and Distances from Respective Cluster Center Cluster contains two cases			
Case No.	**Distance**	**Case No.**	**Distance**
C_14	0.1628723	C_24	0.1628223
C_16	0.3227446	C_25	0.1264287
C_22	0.1623487		

The regions with a high level of digitalization DLR≥0.75 include six regions of cluster 3 (Table 7). The regions with a high level of digitalization include Kyiv City and Lviv, Kyiv, Kharkiv, Dnipropetrovsk, and Odesa regions

Table 7. Composition of the third cluster based on digitalization

Members of Cluster Number 3 (Data_Digitalization_nor) and Distances from Respective Cluster Center Cluster contains six cases			
Case No.	**Distance**	**Case No.**	**Distance**
C_1	1.274093	C_11	0.2924822
C_3	0.2408422	C_12	0.1833022
C_9	0.2276321	C_18	0.2408422

To build a matrix of the positioning of regions in the coordinate system "Level of inclusion (OX)-Level of digitalization (LS)," a comprehensive clustering of both regions was carried out (Figure 3).

The k-means clustering analysis successfully categorized Ukrainian regions into distinct groups based on their combined inclusivity (IDI) and digitalization (DLR) scores. While specific region names and symbols are omitted for brevity, the resulting clusters represent the following adaptation patterns visualized in Figure 4 and summarized in Table 8.

Table 8. Summary of clustering analysis

Cluster	Inclusiveness level	Digitalization level	Number of regions
1	Low	Low	4
2	Medium	Low	2
3	High	Low	2
4	Variable	Medium	4
5	Medium	Medium	3
6	High	Medium	1
7	Low	Medium	4
8	Medium	High	2
9	High	High	4

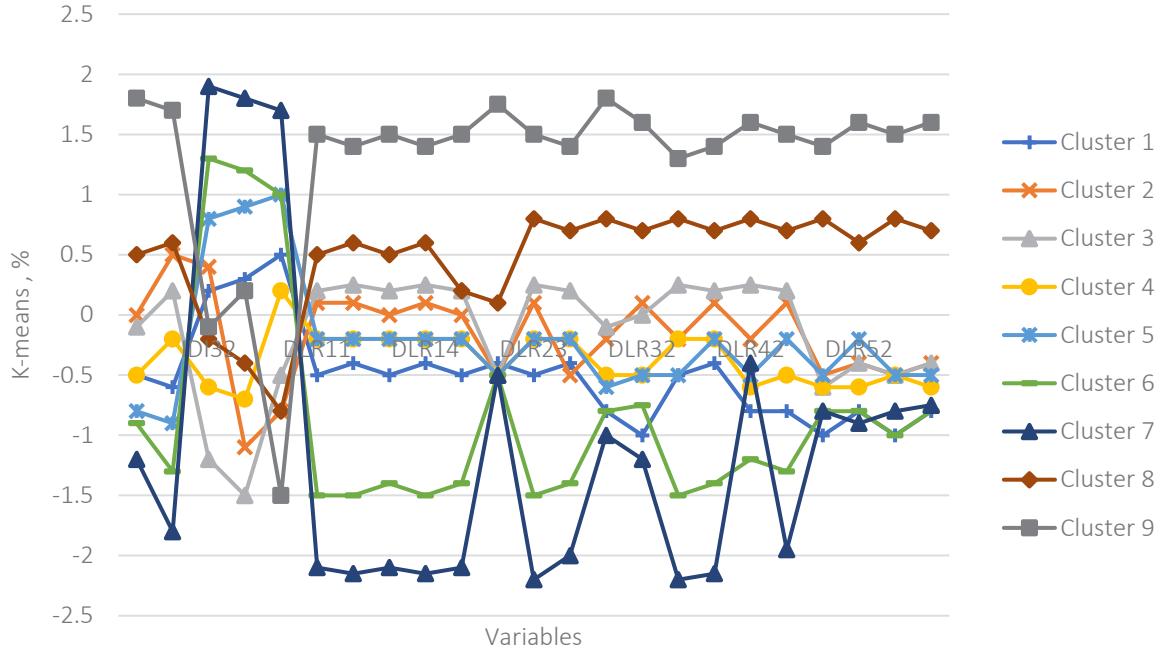

Figure 3. Comprehensive clustering of regions by digitalization and inclusion attributes

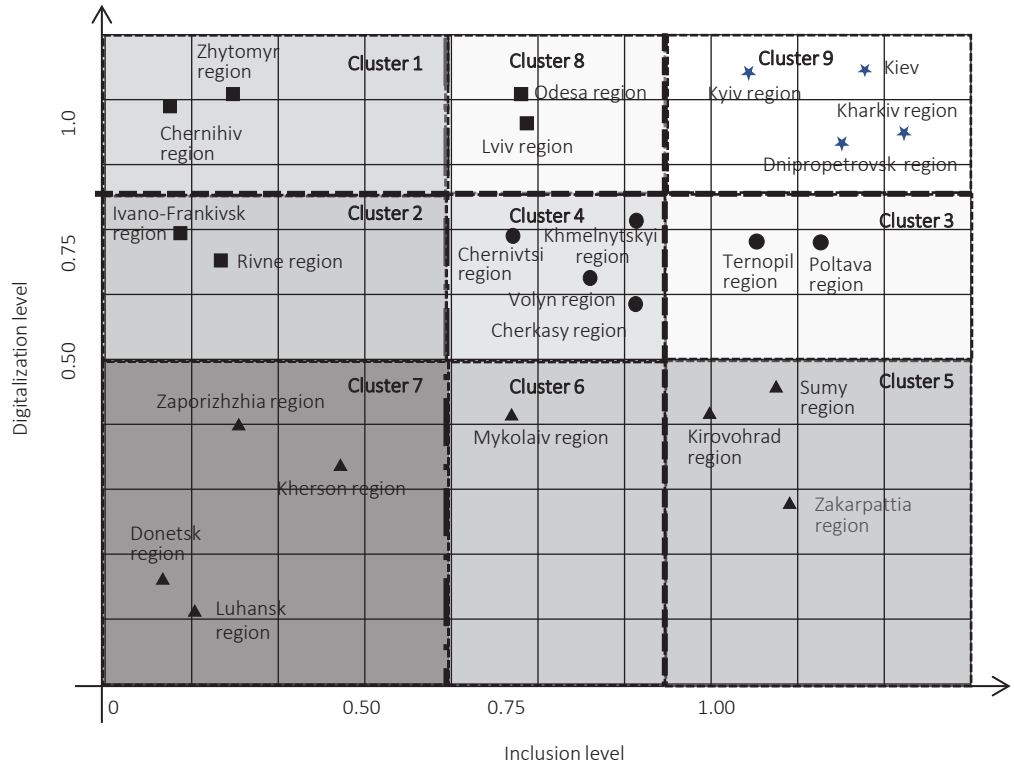

Figure 4. Matrix of positioning of Ukrainian regions by digitalization and inclusion attributes

The study offers a nuanced analysis of regional disparities in inclusivity and digitalization across Ukraine, identifying distinct clusters and formulating tailored adaptation strategies (Table 9). Next, Table 10 offers the ways the proposed adaptation principles can be applied to specific Ukrainian regions.

The proposed framework, utilizing k-means clustering and analysis of inclusivity and digi-

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Table 9. Regional adaptation principles

IDI Level	DLR Level	Adaptation Principles
Low	Low	Comprehensive Support Measures: Implement broad-based initiatives to address both low inclusivity and low digitalization.
Low	Medium	Digital Infrastructure Adaptation: Focus on expanding internet access, broadband availability, and mobile device connectivity.
Low	High	Enhanced Social Programs: Prioritize strengthening social safety nets, healthcare access, and education opportunities.
Medium	Low	Digitalization Improvement: Emphasize initiatives to improve digital skills, ICT adoption, and e-government services.
Medium	Medium	Balanced Adaptation: Pursue a holistic approach that simultaneously enhances both inclusivity and digitalization.
Medium	High	Sustained Inclusivity and Digitalization: Maintain current progress and invest in innovation to further strengthen both aspects.
High	Low	Targeted Digitalization: Implement targeted digitalization initiatives to address specific inclusivity gaps.
High	Medium	Inclusive Digitalization: Leverage digital tools and services to promote inclusivity and address remaining social challenges.
High	High	Leadership in Inclusivity and Digitalization: Continue pioneering advancements in both inclusivity and digitalization, serving as a model for other regions.

Table 10. Regional strategies for digital transformation and inclusivity

Strategy	Applicable Regions	Key Measures
Intensive Digitalization and Inclusivity Enhancement	Zaporizhzhia, Kherson, Donetsk, and Luhansk excluding the occupied territories	Expand internet access, implement digital education, support startups
Digitalization Improvement	Mykolaiv	Provide subsidies for the internet, offer digital literacy training, invest in cybersecurity
Inclusivity Enhancement	Kirovohrad, Zakarpattia, Sumy	Develop social protection programs, support SMEs, and provide housing subsidies
Inclusivity Enhancement	Ivano-Frankivsk, Rivne	Invest in healthcare and education, create employment programs, and modernize social infrastructure
Balanced Adaptation	Chernivtsi, Khmelnytskyi, Volyn, Cherkasy	Implement synchronized initiatives, partner with the private sector, monitor and evaluate
Maintaining Inclusivity and Digitalization	Ternopil, Poltava	Provide sustainable funding, upskill workforce, expand digital services
Intensive Inclusivity Enhancement	Zhytomyr, Chernihiv	Implement comprehensive reforms, reduce poverty, create infrastructure
Maintaining Inclusivity	Lviv, Odesa	Integrate sustainable principles, support civil society, partner with international organizations
Leadership in Inclusivity and Digitalization	Kyiv City, Kyiv Oblast, Kharkiv, Dnipropetrovsk	Establish innovation centers, participate in international projects, and implement pilot projects

talization indicators, offers a tailored approach for regional adaptation during wartime. Each strategy targets specific regional strengths and weaknesses, enabling effective resource allocation and impactful interventions. Adopting these strategies will help Ukrainian regions navigate wartime challenges and drive future digital and inclusive growth.

The factor analysis results presented in Table 11 support the hypothesis that wartime conditions have accelerated digital transformation and enhanced inclusivity in Ukraine. Two primary factors emerged from the analysis.

Factor 1 is digitalization and economic inclusivity. This factor highlights the negative correlation between traditional economic indicators (GRP per capita, labor productivity, healthy life expectancy, and employment rate) and digitalization indicators (internet access, broadband penetration, mobile device usage, and ICT Development Index). The negative correlations suggest that while economic conditions may have declined during wartime, digitalization has seen significant growth. This indicates that digital technologies have played a crucial role in mitigating the negative economic impacts of the conflict and promoting economic resilience.

Factor 2 is socio-economic stability. This factor reveals a positive correlation between traditional economic indicators and socio-economic stability. The increase in income inequality, poverty rates, wealth inequality, greenhouse gas intensity, public debt, and demographic dependency ratios indicate the strain that wartime conditions have placed on Ukraine's socio-economic fabric.

Digitalization and economic inclusivity factor reveals a complex relationship where wartime economic decline coincides with increased digitalization. Although traditional economic indicators show negative correlations, digitalization metrics such as internet access and mobile usage exhibit a surge. This indicates a wartime adaptation with a heightened demand for digital services. Socio-economic stability factor highlights worsening socio-economic conditions, such as income inequality and public debt. However, the negative correlations with digitalization indicators suggest that increased digital access can improve inclusivity even amid these challenges. The analysis confirms that wartime pressures drive digital transformation in Ukraine, leading to increased inclusivity. Supporting data, such as a 42% rise in the Diia app usage and a 20% increase in IT sector export revenues, further validate this trend. Despite the socio-economic disruptions, the growing reliance on digital tools aligns with the hypothesis that wartime conditions foster digital adaptation and inclusivity.

Overall, the analysis suggests that digital transformation has been a driving force in mitigating the negative economic impacts of the war. While the war has negatively affected socio-economic stability, digitalization has played a role in cushioning these effects. The increased use of digital technologies has contributed to greater inclusivity by providing access to essential services and economic opportunities.

It is noteworthy to note that the analysis is based on data from the war period, and the long-term impacts of these trends may still be unfolding. Further research is needed to fully understand the lasting effects of digital transformation on Ukraine's economy and society in the post-conflict era.

Table 11. Results of factor analysis

Variable	Factor Loadings (Unrotated)	Description
Factor 1: Digitalization and economic inclusivity		
IDI_{11} (GRP per capita)	–0.90424	Negative correlation with inclusivity (economic decline)
IDI_{12} (Labor productivity)	–0.92989	Negative correlation with inclusivity (decline in productivity)
IDI_{13} (Healthy life expectancy)	–0.89620	Negative correlation with inclusivity (decline in health)
IDI_{14} (Employment rate)	–0.91026	Negative correlation with inclusivity (decline in employment)
DLR_{11} (Internet access)	–0.97771	Negative correlation (increased access during wartime)
DLR_{12} (Broadband penetration)	–0.97771	Negative correlation (increased access during wartime)
DLR_{13} (Mobile device usage)	–0.97892	Negative correlation (increased usage during wartime)
DLR_{14} (ICT Development Index)	–0.97771	Negative correlation (increased development during wartime)
Factor 2: Socio-economic stability		
IDI_{21} (Gini coefficient for income)	0.89422	Positive correlation with socio-economic stability (increased inequality)
IDI_{22} (Poverty rate)	0.90826	Positive correlation with socio-economic stability (increased poverty)
IDI_{23} (Gini coefficient for wealth)	0.91372	Positive correlation with socio-economic stability (increased wealth inequality)
IDI_{32} (Greenhouse gas intensity)	0.23109	Positive correlation with socio-economic stability (potential environmental impact)
IDI_{33} (Public debt)	0.42410	Positive correlation with socio-economic stability (potential fiscal burden)
IDI_{34} (Demographic dependency ratio)	0.92809	Positive correlation with socio-economic stability (potential strain on resources)
DLR_{11} (Internet access)	–0.97291	Negative correlation (increased access during wartime)
DLR_{12} (Broadband penetration)	–0.97291	Negative correlation (increased access during wartime)
DLR_{13} (Mobile device usage)	–0.97966	Negative correlation (increased usage during wartime)
DLR_{14} (ICT Development Index)	–0.97771	Negative correlation (increased adaptation during wartime)

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4. DISCUSSION

The analysis supports the hypothesis that wartime conditions significantly accelerate digital transformation and enhance inclusivity in Ukraine, with a particular emphasis on the diversification of digital tools and technologies across various sectors and groups. The substantial increases in the usage of digital platforms and the notable growth in the IT sector reinforce this conclusion, aligning with findings from other studies.

For example, the observed 42% rise in the usage of the Diia app, which offers a wide range of digital government services, clearly indicates the shift toward digital tools during the conflict. This trend is corroborated by Kolodiziev et al. (2023), who emphasize that wartime conditions necessitate the rapid adoption of digital technologies to maintain essential services and governance across multiple sectors. The increase in internet penetration from 62% in 2019 to 78% in 2023 (Ukrstat, 2023) further supports this shift, suggesting that the conflict has driven a broader and more inclusive embrace of digital connectivity.

The IT sector's 20% increase in export revenues in 2022, despite the ongoing conflict, underscores its resilience and adaptability. This aligns with the IT Ukraine Association (2024), which notes the sector's ability to thrive even in adverse conditions, particularly by diversifying into new areas such as cybersecurity, remote work solutions, and digital health services. The doubling of tech startups focusing on wartime solutions is a reflection of an accelerated digital transformation driven by immediate needs across different spheres, confirming the ability of Industry 4.0 technologies to adapt to and support economic resilience during crises, as asserted by Bryukhovetskaya and Chernykh (2020).

The increase in digital tool usage also highlights a trend toward greater inclusivity, even amid socio-economic disruptions. The factor analysis in this study reveals that while traditional economic indicators show declines, digitalization indicators show improvements. This observation is consistent with A.H. Shah and S. S. Shah's (2024a) findings on how digital tools can mitigate information asymmetries and foster inclusivity among diverse population groups. Despite worsening socio-economic indicators, the rise in digital access suggests that digital transformation can partially counterbalance the negative impacts of conflict on inclusivity, particularly by expanding access to marginalized and vulnerable groups.

However, the analysis also acknowledges the challenges of translating digital transformation into sustained competitive advantage. While increased digital adoption presents opportunities, the broader socio-economic disruptions caused by the conflict may counteract these benefits. This is in line with Brown's (2013) observations that socio-economic data need to be carefully considered when assessing the impact of digital transformation on social mobility. The ongoing challenges, such as reduced economic stability and increased inequality, require strategic planning and investment to ensure that digital tools contribute to long-term inclusivity and resilience, particularly by diversifying the range of digital services and expanding their accessibility to all segments of society.

Overall, the findings confirm that wartime conditions in Ukraine have acted as a catalyst for digital transformation, leading to increased inclusivity through greater reliance on a diverse range of digital tools and services. The growth in digital connectivity and the IT sector's resilience demonstrates that digital transformation is not only feasible but also crucial in times of conflict. However, addressing the broader socio-economic challenges remains essential for ensuring that these advancements translate into sustained benefits for all segments of society.

CONCLUSION

The purpose of this study was to analyze the role of digital transformation in ensuring Ukraine's inclusive economic development in the context of military conflict. The study supports the hypothesis that during crises, the digital transformation of the Ukrainian economy can be strengthened due to increased demand for digital tools and services, leading to greater diversification, inclusivity, and accessibility for all segments of society.

The analysis reveals significant regional disparities in digitalization and inclusivity across Ukraine during the war. Specifically, regions with higher levels of digitalization demonstrate lower poverty and unemployment rates, indicating that digital transformation can play a vital role in mitigating the negative socio-economic impacts of the conflict. For example, regions in the top quartile of the digitalization index, such as Kyiv City and Kyiv, Kharkiv, and Dnipropetrovsk regions, reported, on average, 12% lower unemployment rates compared to those in the bottom quartile.

Cluster analysis further identifies distinct regional groupings based on their progress in digitalization and inclusivity. While regions like Mykolaiv and Kirovohrad show moderate progress, others, such as Zaporizhzhia, Kherson, Donetsk, and Luhansk, continue to face significant challenges, particularly regarding digital access and inclusivity. The digital divide remains pronounced, with only 60% of rural households having stable internet access compared to 90% in urban areas. This variability highlights the need for region-specific strategies to address these challenges effectively.

Factor analysis confirms that wartime conditions have accelerated digital transformation in Ukraine. Key indicators include a 42% increase in the usage of the Diia app from 2021 to 2023, a rise in internet penetration from 62% in 2019 to 78% in 2023, a 20% growth in IT sector export revenues in 2022, and the doubling of technology startups between 2019 and 2023. These data reflect a significant shift toward digital tools and services, supporting the hypothesis that crisis conditions can drive rapid digitalization.

Based on these findings, the study proposes a tailored regional adaptation framework. Regions like Zaporizhzhia and Kherson require intensive digitalization and inclusivity enhancement, focusing on internet expansion, digital education, and startup support. Mykolaiv needs improved digitalization through internet subsidies, digital literacy training, and cybersecurity measures. Regions like Kirovohrad and Zakarpattia prioritize inclusivity, emphasizing social protection, SME support, and housing subsidies. Chernivtsi and Khmelnytskyi demand a balanced approach, combining digital and social strategies through public-private partnerships.

While the digital transformation of Ukraine has accelerated due to wartime conditions, ensuring sustainable and inclusive development requires a balanced approach that addresses both digital and socio-economic challenges. Tailoring strategies to the unique characteristics of each region is essential for enhancing regional competitiveness and improving the overall quality of life.

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APPENDIX A

Table A1. Baseline data for assessing the level of inclusiveness of Ukrainian regions during the war

Source: Ukrstat (n.d.).

Symbol	Region	IDI_{11}	IDI_{12}	IDI_{13}	IDI_{14}	IDI_{21}	IDI_{22}	IDI_{23}	IDI_{24}	IDI_{31}	IDI_{32}	IDI_{33}	IDI_{34}
C_1	Kyiv City	12000	20000	71.2	60%	0.28	12%	0.32	22000	12%	0.2	22%	0.22
C_2	Ternopil region	9000	12000	70.0	28%	0.30	18%	0.32	18000	10%	0.4	20%	0.60
C_3	Lviv region	12000	17000	72.0	62%	0.22	12%	0.30	21000	11%	0.6	23%	0.28
C_4	Chernivtsi region	8200	14000	69.2	22%	0.32	20%	0.38	17200	9%	0.2	22%	0.62
C_5	Ivano-Frankivsk region	9200	12200	71.0	27%	0.28	16%	0.33	18200	10%	0.4	21%	0.62
C_6	Khmelnytsky region	8800	14200	70.2	26%	0.30	17%	0.36	17800	10%	0.2	22%	0.63
C_7	Rivne region	9200	14800	71.2	29%	0.29	12%	0.34	18200	11%	0.4	23%	0.61
C_8	Poltava region	9200	12200	70.8	28%	0.28	16%	0.33	18200	10%	0.4	21%	0.62
C_9	Kyiv region	14000	19000	71.4	61%	0.26	14%	0.31	21200	12%	0.2	24%	0.26
C_10	Volyn region	9000	14700	70.0	26%	0.30	18%	0.32	18000	9%	0.4	22%	0.64
C_11	Kharkiv region	11000	16000	71.1	60%	0.27	13%	0.32	20000	11%	0.6	23%	0.27
C_\2	Dnipropetrovsk region	11200	16200	71.3	61%	0.26	14%	0.31	20200	12%	0.2	24%	0.26
C_13	Ukraine	10000	12000	70.2	28%	0.28	12%	0.33	19000	11%	0.2	23%	0.60
C_14	Zaporizhzhia region	8000	13000	68.2	20%	0.32	22%	0.40	17000	8%	0.7	26%	0.70
C_\2	Kirovohrad region	8200	14000	69.0	22%	0.33	20%	0.38	17200	9%	0.6	22%	0.68
C_16	Mykolaiv region	8000	13200	68.8	21%	0.34	21%	0.39	17200	8%	0.7	26%	0.69
C_17	Cherkasy region	9000	14200	70.0	24%	0.30	18%	0.32	18000	10%	0.2	23%	0.62
C_18	Odesa region	9200	12200	70.2	22%	0.29	17%	0.34	18200	10%	0.4	22%	0.63
C_19	Zhytomyr region	8800	14200	69.8	23%	0.31	19%	0.36	17700	9%	0.2	24%	0.66
C_20	Chernihiv region	8700	14000	69.7	22%	0.32	20%	0.37	17600	9%	0.6	24%	0.67
C_21	Zakarpattia region	8000	13200	68.2	21%	0.34	21%	0.39	17200	8%	0.7	26%	0.69
C_22	Kherson region	7000	12000	67.0	42%	0.40	22%	0.42	16000	7%	0.8	28%	0.72
C_23	Sumy region	8200	14000	69.0	22%	0.33	20%	0.38	17200	9%	0.6	22%	0.68
C_24	Donetsk region	7000	12200	62.2	40%	0.42	60%	0.20	12000	6%	0.9	60%	0.78
C_25	Luhansk region	6200	12000	62.0	38%	0.20	62%	0.22	14200	2%	0.9	61%	0.80

http://dx.doi.org/10.21511/ppm.22(3).2024.34

Table A2. Baseline data for assessing the level of digitalization of Ukraine's regions during the war

Source: Ukrstat (n.d.).

Symbol	Region	DLR_{11}	DLR_{12}	DLR_{13}	DLR_{14}	DLR_{21}	DLR_{22}	DLR_{23}	DLR_{24}	DLR_{31}	DLR_{32}	DLR_{33}	DLR_{41}	DLR_{42}	DLR_{43}	DLR_{21}	DLR_{22}	DLR_{23}
C_1	Kyiv City	92%	82%	90%	8.2	80%	$1B	70%	72%	300km	10	90%	80%	30%	70%	$200M	120	200
C_2	Ternopil region	80%	70%	72%	7.0	60%	$100M	60%	22%	120km	2	80%	70%	20%	60%	$20M	20	60
C_3	Lviv region	82%	72%	80%	7.2	62%	$200M	62%	60%	200km	7	82%	72%	22%	62%	$100M	70	100
C_4	Chernivtsi region	72%	62%	70%	6.2	22%	$80M	22%	20%	120km	4	72%	62%	18%	22%	$40M	40	20
C_5	Ivano-Frankivsk region	78%	68%	72%	6.8	27%	$90M	27%	22%	130km	2	78%	67%	20%	28%	$42M	42	22
C_6	Khmelnytsky region	77%	67%	71%	6.7	26%	$82M	26%	21%	122km	4.2	77%	66%	19%	27%	$42M	42	22
C_7	Rivne region	79%	69%	73%	6.9	28%	$92M	28%	23%	132km	2.2	79%	68%	21%	29%	$47M	47	27
C_8	Poltava region	81%	71%	72%	7.1	60%	$110M	60%	22%	140km	6	81%	70%	23%	61%	$20M	20	60
C_9	Kyiv region	88%	78%	83%	7.8	67%	$300M	67%	62%	220km	8	88%	78%	27%	68%	$120M	80	110
C_10	Volyn region	76%	66%	70%	6.6	26%	$82M	26%	21%	122km	4.2	76%	62%	19%	27%	$42M	42	22
C_11	Kharkiv region	90%	80%	82%	8.0	70%	$400M	70%	62%	220km	9	90%	80%	30%	70%	$120M	90	130
C_12	Dnipropetrovsk region	87%	77%	82%	7.7	66%	$320M	66%	61%	230km	8	87%	77%	26%	67%	$130M	82	120
C_13	Ukraine	80%	70%	72%	7.0	60%	$200M	60%	22%	180km	7	80%	70%	23%	61%	$100M	70	90
C_14	Zaporizhzhia region	60%	20%	22%	2.0	40%	$70M	40%	32%	100km	3	60%	20%	12%	42%	$30M	30	40
C_12	Kirovograh region	72%	62%	70%	6.2	22%	$80M	22%	20%	120km	4.2	72%	62%	18%	22%	$40M	40	20
C_16	Mykolaiv region	62%	22%	60%	2.2	42%	$60M	42%	40%	110km	4	62%	22%	16%	20%	$32M	32	42
C_17	Cherkasy region	77%	67%	72%	6.7	27%	$90M	27%	22%	122km	2	77%	67%	19%	27%	$42M	42	22
C_18	Odesa region	82%	72%	80%	7.2	62%	$200M	62%	60%	200km	7	82%	72%	22%	62%	$100M	70	100
C_19	Zhytomyr region	74%	64%	69%	6.4	24%	$72M	24%	49%	112km	4	74%	64%	17%	24%	$38M	38	48
C_20	Chernihiv region	73%	63%	68%	6.3	23%	$70M	23%	48%	110km	3.2	73%	63%	16%	23%	$32M	32	42
C_21	Zakarpattia region	76%	66%	70%	6.6	26%	$82M	26%	21%	122km	4.2	76%	62%	19%	27%	$42M	42	22
C_22	Kherson region	60%	20%	22%	2.0	40%	$70M	40%	32%	100km	3	60%	20%	12%	42%	$30M	30	40
C_23	Sumy region	77%	67%	72%	6.7	27%	$90M	27%	22%	122km	2	77%	67%	19%	27%	$42M	42	22
C_24	Donetsk region	22%	42%	20%	4.2	38%	$60M	32%	30%	90km	2	22%	42%	12%	40%	$22M	20	30
C_25	Luhansk region	20%	40%	42%	4.0	32%	$20M	30%	28%	80km	2	20%	40%	10%	38%	$20M	12	22