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Natalia Ivanova, Doctor of Economics, Associate Professor, Professor of Department of Management, Marketing and Information Technologies, Kherson State Agrarian and Economic University, Ukraine

ORCID ID: 0000-0002-5010-2668
e-mail: nataliaivanova3012@outlook.com

Technological Component of Digital Solutions in Ukraine: Development Trends

Abstract. Introduction*. The processes of digitalization continue to spread and deepen in various spheres of human activity, where the technological component is a critical element. The rapid development of technology and digitalization of the economy pose a significant challenge to identify and analyze current trends in the technological aspects of digital solutions, especially in Ukraine. This need has become particularly urgent due to Russia's full-scale war against Ukraine, which forced the country to expand digital solutions amidst severe disruptions.*

Purpose. *The article aims to analyze Ukraine's technological support in the context of its transition to a network economy. This study focuses on the level of ICT accessibility for citizens, the nature of digital technologies generated in the country, and readiness for future technological paradigms. This analysis is based on the Technology sub-index of the Network Readiness Index (NRI).*

Results. *The article aims to analyze Ukraine's technological support in the context of its transition to a network economy. This study focuses on the level of ICT accessibility for citizens, the nature of digital technologies generated in the country, and readiness for future technological paradigms. This analysis is based on the Technology sub-index of the Network Readiness Index (NRI).*

According to the 2023 results, Ukraine ranks 43rd out of 134 countries in terms of technological readiness, with a GDP per capita of USD 14,326. The study highlights a cyclical dependency in which the adoption and use of innovative technologies boosts GDP, while the cycle of "development-implementation-realization" of technologies requires significant investment of resources. Key barriers to ICT access in Ukraine include the affordability of smartphones and fiber-optic Internet connectivity. The study also identifies weaknesses in digital content creation and software development, despite some progress in computer software spending.

Conclusions. *Between 2019 and 2023, Ukraine significantly improved its position in the Technology subindex, rising from 71st to 43rd place, reflecting significant progress in technological support and adaptation to the latest technologies. The Access dimension showed positive momentum despite the challenges of the war. However, Ukraine still faces critical issues such as low fiber connectivity and availability of mobile devices. Addressing these challenges is essential for the further growth of the digital economy. Overall, Ukraine has made significant progress in digital technologies and the network economy, but further development will require overcoming existing barriers and actively implementing new technological solutions.*

Keywords: *Digitalisation; Network Economy; Technological Support; Technology sub-index; Ukraine; Network Readiness Index (NRI); Future Technologies; Content; Technological Progress; Digital Economy.*

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Іванова Н. С., доктор економічних наук, доцент, професор кафедри менеджменту, маркетингу та інформаційних технологій, Херсонський державний аграрно-економічний університет, Україна

Технологічна складова цифрових рішень в Україні: тенденції розвитку

Анотація*. В умовах швидкого розвитку цифрових технологій та переходу до мережевої економіки, Україна стикається з численними викликами та можливостями. Дослідження технологічного забезпечення та готовності країни до впровадження інновацій є важливим для розуміння потенціалу її розвитку в глобальному контексті. Це дослідження аналізує позиції України за різними субіндексами технологічної готовності, зокрема доступність (Access), зміст (Content) та готовність до майбутніх технологічних проривів (Future Technologies), протягом 2019-2023 років.*

Метою даної статті є аналіз технологічного забезпечення України в контексті її переходу до мережевої економіки. Особливу увагу приділено вивченню рівня доступності ІКТ для громадян, характеристикам цифрових технологій, що генеруються в країні, та готовності до майбутніх технологічних парадигм.

Дослідження показало, що за період 2019-2023 років Україна суттєво покращила свої позиції за рівнем технологічного забезпечення піднявшись з 71 на 43 місце. Позитивна динаміка спостерігається також за вимірником Access, де рейтингові оцінки підвищились з 78 на 43 місце, незважаючи на перешкоди, спричинені війною та руйнуванням інфраструктури. Вимірник Content показує недостатній рівень розвитку цифрових технологій та локального контенту, проте позитивні тенденції свідчать про потенціал для подальшого зростання.

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Отримані результати свідчать про значний прогрес України у сфері цифрових технологій та мережевої економіки. Проте, для подальшого розвитку необхідно вирішити існуючі проблеми, зокрема низький рівень підключень до Інтернету за допомогою оптоволокна та доступність мобільних пристроїв. Порівняльний аналіз міжнародних рейтингів підкреслює необхідність подальших інвестицій в інноваційні технології та інфраструктуру для підвищення конкурентоспроможності України на глобальному ринку. Результати дослідження вказують на необхідність активного впровадження новітніх технологічних рішень для забезпечення успішного переходу до ефективної мережевої економіки.

***Ключові слова**: Network Readiness Index (NRI); цифрові технології; мережева економіка; технологічне забезпечення; інноваційні технології; доступність ІКТ; цифровізація; Україна; технологічна готовність.*

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Formulation of the problem. Digitization processes are spreading and advancing in ever more areas of human activity. The technological component is an important part of these processes and in the creation of an effective network economy. Given the rapid development of technology and digitization of the economy, the challenge is to identify and analyze current trends in the development of technological components of digital solutions, including Ukraine. The need to conduct such a retrospective analysis of Ukraine's technological readiness for the network economy has become especially urgent due to Russia's full-scale war against Ukraine. After all, while other countries were able to resume their offline activities after the COVID-19 quarantine restrictions, Ukraine was forced to expand digital solutions only because of constant blackouts, air-raid alarms, destruction of facilities, occupation of territories, and other horrible consequences of the war in Ukraine.

Analysis of recent research and publications. Since the beginning of computerization and the introduction of Internet technologies into economic processes, the interest in digitalization and its diffusion has been growing steadily, taking on various aspects. This was confirmed by the results of a bibliometric analysis of the Web of Science database. During the period 2000-2023, 1033 scientific documents on the technological aspect of the digital economy were published in the Web of Science database, with an average annual growth rate of 28.03% (Fig. 1).

Figure 1 – **Annual Scientific Production in the direction of "Technolog* Digital Economy" in the scientometric database WoS (2000-2023)**

Source: authors' development via Biblioshiny app ([1], [2], [3])

Ukrainian scientists published the first publication on this topic in 2015 [4]. By the end of 2023, there were 140 scientific documents on technological support of the digital economy. In 2022-2023, the topics of artificial intelligence (AI) and the Internet of Things (IoT) aroused considerable interest among researchers [5]. The emergence of new technologies, such as AI and IoT, requires rethinking and adapting existing business models to current challenges [6, 7]. Therefore, the problem of "business models" has long been a subject of research, as well as the problem of "technology adoption" [8; 9]. In addition to these topics, the topics of

digitization in its various aspects, innovation, big data, etc. remain interesting for scientists. Ukrainian scientists have focused on blockchains [10, 11].

A group of scholars have considered the possibility of introducing and using digital technologies in the circular economy [12, 13]. Assuming that digital technologies (such as IoT, big data, and data analytics) are considered as the main drivers of the circular economy, they proposed a theoretically grounded framework and database of smart circular economy examples and concluded that the smart use of resources in the circular economy can be supported by creating, extracting, processing, and sharing digital technology data, thus ensuring economies of scale. Therefore, it can be argued that the technological capabilities of the transition to an efficient network.

This study is based on analytical material about the Network Readiness Index (NRI), created by a group of researchers from the Portulans Institute and Saïd Business School, University of Oxford. The NRI is presented as a key metric for assessing digital trends and understanding the evolution of online trust in the networked era [14]. The NRI is defined as the degree of readiness of countries to participate in the networked world [15], and consists of four sub-indices that together measure the impact of ICT on the development of countries in various aspects. The NRI rankings reflect the overall level of readiness in different countries. The main NRI sub-indices include technology, people, governance and impact, each of which has a number of components.

Formulation of research goals. Despite the in-depth analysis of digital trends in 134 countries presented in reports for certain periods, it was decided to conduct a more detailed retrospective analysis of the Technology (Ukraine) sub-index, which allows to assess the technological infrastructure crucial for the country's participation in the global network economy. The purpose of this article is to analyze Ukraine's technological support in the context of its transition to a network economy. Particular attention is paid to the level of ICT accessibility for citizens, the characteristics of digital technologies generated in the country, and the readiness for future technological paradigms. The study is based on data from the Technology sub-index of the Network Readiness Index (NRI).

Outline of the main research material. Technology is one of the key aspects in the creation and development of a network economy and is the foundation of the digital environment. Therefore, an adequate level and content of technological support is crucial for the readiness of the network economy.

According to the results for 2023, Ukraine ranks 43rd among 134 countries in terms of technological support, with a GDP per capita of 14326 USD. According to Fig. 2, we can conclude that there is a certain cyclical dependence: the introduction and use of innovative technologies allow for higher GDP, but at the same time the cycle of "development-implementation-implementation" of technologies requires significant investment of resources. The United States ranks first in the Technology sub-index, with an annual GDP per capita of USD 7,580 (the highest value is in Luxembourg). The highest value is in Luxembourg - USD 141587, the 13th highest in the Technology sub-index.

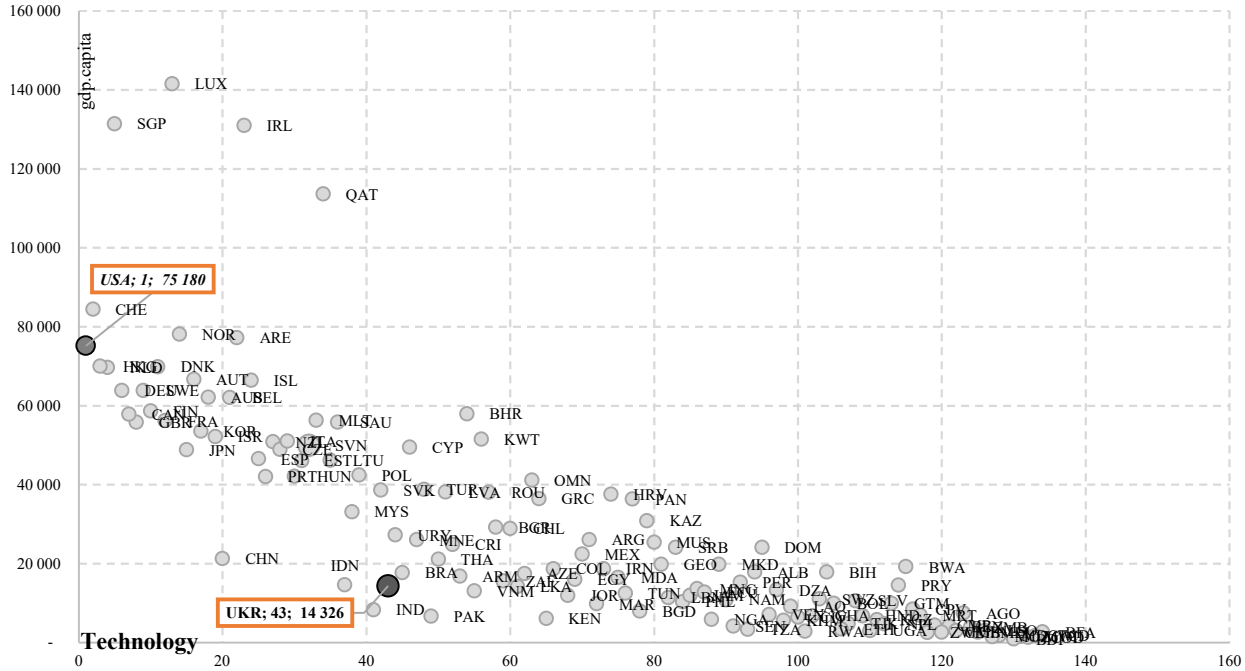


Figure 2 – **Ratio of the level of technological support to the level of GDP per capita, 2023 (134 countries)**

Source: compiled by the author according to [14]

Based on the NRI research data [14] for the period 2019-2023, the Ukrainian aspect of the basic level of ICT accessibility for citizens (Access), the nature of digital technologies and content (Content), and the country's readiness for future trends in the networked economy and new technological paradigms (Future Technologies) were analyzed.

The Technology sub-index, which is an integral part of the NRI, comprehensively describes the components of technological infrastructure assessment [14]. The goals of the Technology sub-index are achieved through three components: Access, Content, Future Technologies, Table 1, Fig. 3.

Table 1 **Triad of Technology Subindex Constituents**

Components	Description	Components (criteria)	Estimated indicator
1. Access	Describes the basic level of ICT accessibility for the citizens of the country in terms of communication infrastructure and cost-effectiveness	Mobile tariffs Handset prices FTTH/building Internet subscriptions Population covered by at least a 3G mobile network International Internet bandwidth Internet access in schools	Mobile tariffs sub-index Cost of cheapest Internet-enabled device (% of monthly GDP per capita) Fibre-to-the-home/building Internet subscriptions (per GDP PPP per capita) (2021) Percentage of the population covered by at least a 3G mobile network International Internet bandwidth (Mbit/s) Proportion of primary schools with access to Internet for pedagogical purposes (%)
2. Content	Describes the nature of the digital technologies that are generated in the country and the local content/applications that are created locally; covers data derived from scientific articles, software costs, GitHub commits, and mobile app development and usage	GitHub commits Internet domain registrations Mobile apps development AI Publications	GitHub commits (per million population, 15–69 years old) (2022) Generic Top-Level Domains (gTLDs) and Country Code Top-Level Domains (ccTLDs) per person (2022) Global downloads of mobile apps (per billion PPP$ GDP, two-year average) (2022) Total number of AI scientific publications, fractional counts (as % of GDP) (2022)
3. Future technologies	Determines the country's readiness for future trends in the network economy and new technological paradigms; covers the adoption of artificial intelligence (AI), the Internet of Things (IoT), and investments in emerging technologies	Adoption of emerging technologies Investment in emerging technologies Robot density Computer software spending	Average answer to survey questions concerning the extent to which companies adopt five types of emerging technology (2023) Average answer to a survey question concerning the extent that companies invest in emerging technologies (2017/2018) Number of robots in operation per 10,000 employees in the manufacturing industry (2022) Total computer software spending (% of GDP) (2022)

Source: compiled by the author according to [14]

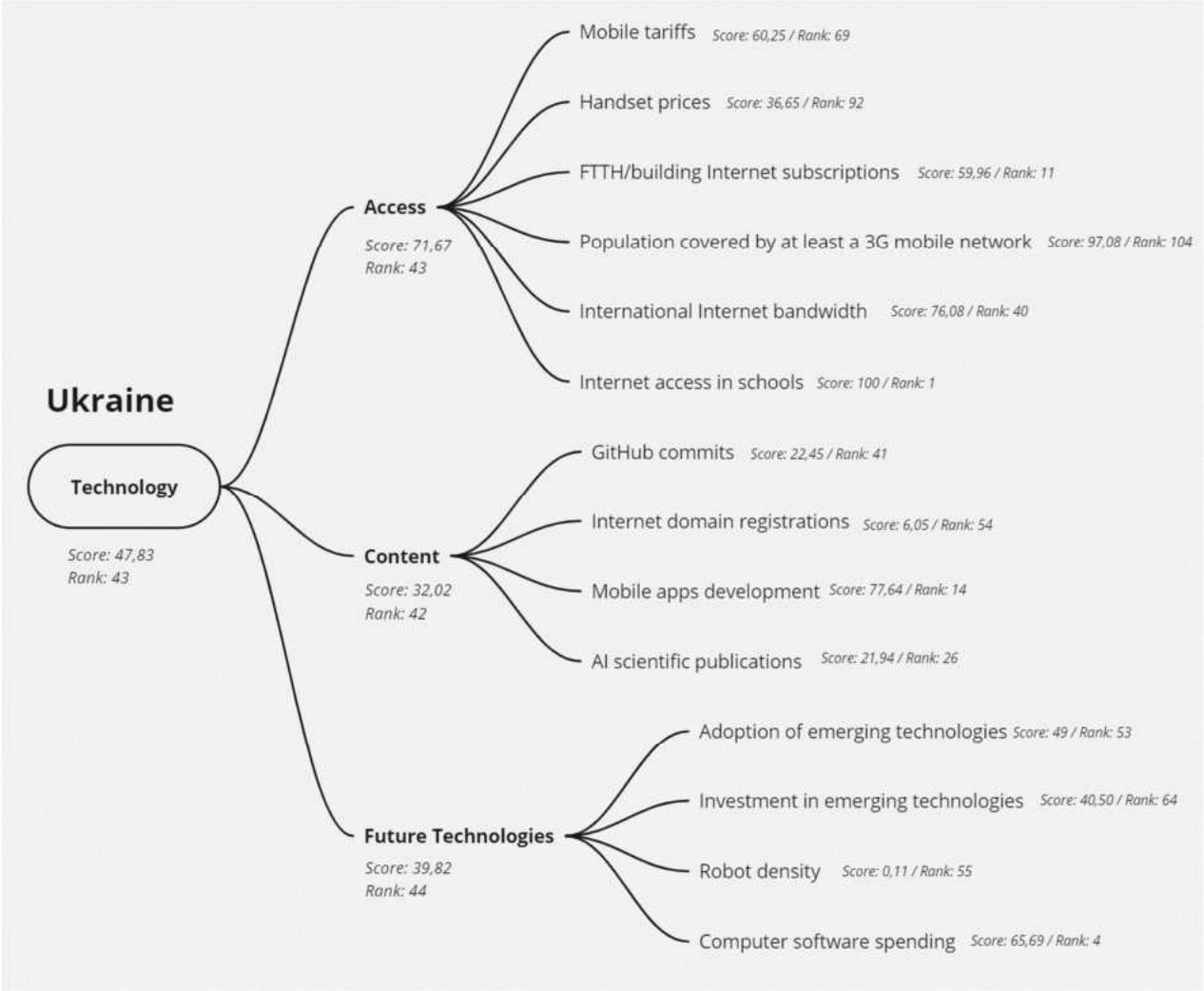


Figure 3 – **the Technology sub-index of Ukraine according to the 2023 assessment**

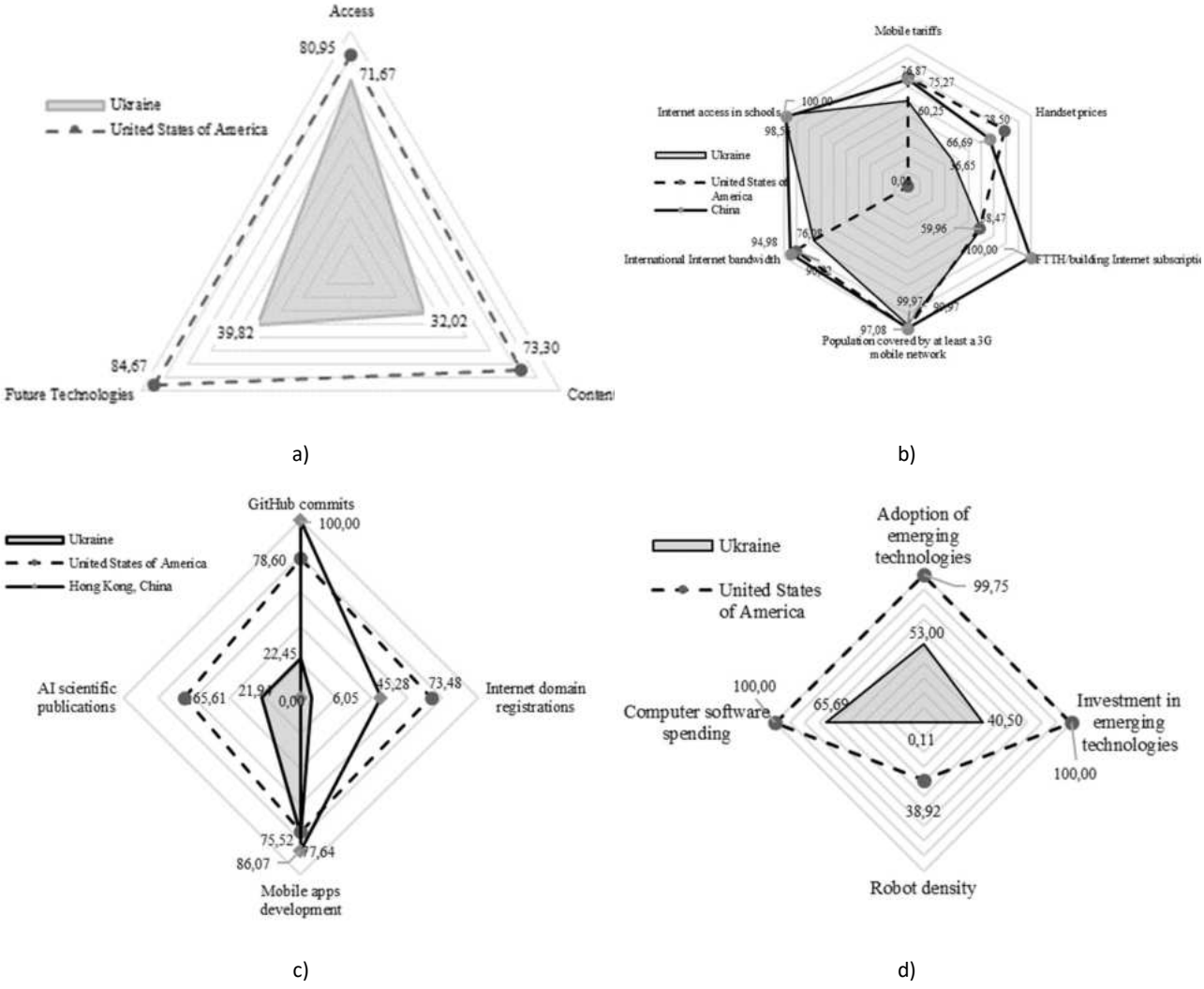
Source: compiled by the author based on data from [16, 17]

Figure 3 shows the results of the calculation of the Technology sub-index of Ukraine according to the 2023 assessment [17] in terms of its components. According to the results for 2023, Ukraine ranked 43rd (47.8) among 134 economies. At the same time, Ukraine ranked 43rd (71.67 points) in terms of ICT accessibility for citizens of the country, 42nd (32 points) in terms of local generation and research of digital technologies, 44th (39.8 points) in terms of the country's readiness for future trends in the network economy and new technological paradigms. Thus, it can be concluded that Ukraine has a rather high position in the ranking; however, at the same time, according to the scoring, it has a rather high level of ICT accessibility for Ukrainians and low values in terms of local research and generation of digital technologies and readiness for future technologies (Fig. 4).

The leader in the Access component is China (Figure 4b), which has the highest scores for the criteria: FTTH/building Internet subscriptions (100 points vs. 59.96 points in Ukraine), population covered by at least one 3G mobile network (99.97 points vs. 97.08 points in Ukraine), mobile tariffs (75.27 points vs. 60.25 points in Ukraine), international Internet bandwidth (94.98 points vs. 76.08 points in Ukraine) and handset prices (66.69 points vs. 36.65 points in Ukraine). However, Ukraine ranks first (100 points) in terms of Internet access in schools, while China ranks 98.56 points and the United States of America ranks 0 points. Thus, we can conclude that the main barriers to expanding ICT access for Ukrainians are: low affordability of the cheapest smartphone or feature phone that allows a user to access the Internet; low level of Internet connections via fiber-to-the-home or fiber-to-the-building with data transfer speeds equal to or greater than 256 kbps. [18].

In the Content component, Hong Kong is the leader (Figure 4c), with the highest scores for the relevant criteria: GitHub commits (100 points vs. 22.45 points in Ukraine) and mobile app development (86.07 points vs. 77.64 points in Ukraine). Ukraine ranks 54th in Internet domain registrations (6.05 points) and 26th in AI scientific publications (21.94 points). Thus, the weaknesses of Ukraine that hinder the development of the network economy are the extremely low number of batch changes received and submitted by projects on GitHub, which are publicly available within the Ukrainian economy, as well as the low number of AI publications in

Elsevier (any article belonging to the areas of "artificial intelligence" and "machine learning" according to the Microsoft Academic Graph (MAG) taxonomy is taken into account).



a) b)

c) d)

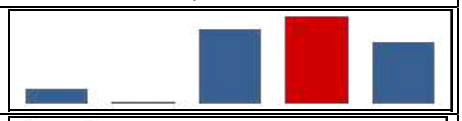
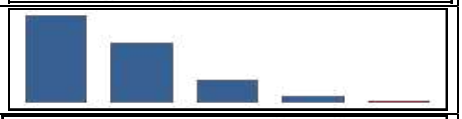
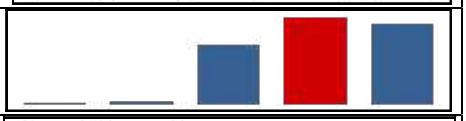
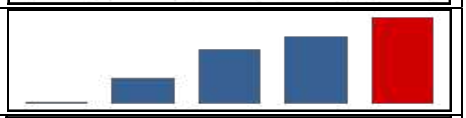
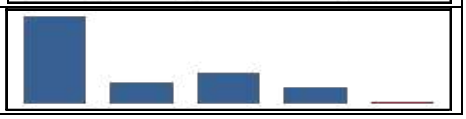
Figure 4 – **Profiles of Ukraine and leading countries in the Technology subindex and its dimensions (4a - the Technology sub-index; 4b – Access; 4c – Content; 4d - Future technologies), 2023**

Source: compiled by the author based on data from [16]

The US leads in the Future Technologies component (Figure 4d), with the highest scores for the set of relevant criteria: Adoption of Emerging technologies (99.75 points vs. 53 points in Ukraine), Investment in Emerging technologies (100 points vs. 40.5 points in Ukraine), and Spending on computer software (100 points vs. 65.69 points in Ukraine). Ukraine scored only 0.11 points in the Robot Density criterion (estimated number of multipurpose industrial robots per 10,000 manufacturing employees). Thus, in order to improve Ukraine's readiness for future trends in the network economy and new technological paradigms, it is necessary to address the issues related to low investment and adoption of various new technologies (including artificial intelligence, robotics, app and web-enabled markets, big data analytics, and cloud computing) in business processes and robotics in industry. In 2019-2023, Ukraine will gradually strengthen its integral network by ensuring citizens' access to ICT and exploring and implementing new technological opportunities (Table 2).

Thus, Ukraine's best position in the Technology sub-index was recorded in 2023-43rd place, which is 28 points better than in 2019. Positive trends were also recorded in the Access component: Ukraine's ranking in 2019 was 78th, and in 2023 it was 43rd, which is five points worse than in 2022. This is largely due to the active phase of russian war against Ukraine, including the destruction of communications infrastructure and energy supply problems.

Table 2 **Dynamics of the Technology sub-index and its dimensions (positive trend: increase in score; decrease in rank) in Ukraine for 2019-2023**

Components	Metric	2019	2020	2021	2022	2023	Dynamics
Technology	score	43,01	41,51	49,2	50,52	47,84	
	rank	71	62	50	45	43	
Access	score	53,72	54,12	67,15	73,24	71,67	
	rank	78	79	60	37	43	
Content	score	48,74	39,9	45,53	41,35	32,02	
	rank	56	46	42	50	42	
Future Technologies	score	26,57	30,5	34,92	36,97	39,82	
	rank	82	53	57	51	44	

Source: constructed by the authors

The dynamics of the content component indicate an insufficient level of digital technologies and local content/applications created in the country, as well as insufficient spending on software. However, in 2023, with the lowest score in the study period, Ukraine is in the best position for 2019-2023, which may indicate a positive trend compared to other countries. Despite the previous conclusions about the insufficient level of research, financing and implementation of new technologies, the data in Table 2 suggest a positive trend: compared to 2019, Ukraine has almost doubled its position - from 82nd to 44th place in 2023. This trend can be explained, in particular, by Ukraine's significant breakthrough in the criterion of spending on computer software (which takes into account the total cost of purchased or leased package software, including operating systems, database systems, programming tools, utilities, and applications). According to the results for 2023, Ukraine ranked 4th in this assessment [17].

Conclusion. The results of this study led to the following conclusions.

In 2019-2023, Ukraine will significantly improve its position in the technology sub-index, rising from 71st to 43rd place. This indicates significant progress in technological support and the country's high potential to adapt to the latest technologies, such as artificial intelligence, the Internet of Things, and blockchain. The Access component score shows positive dynamics, rising from 78th place in 2019 to 43rd place in 2023. This reflects the improvement in citizens' access to information and communication technologies, despite the obstacles caused by the war and the destruction of infrastructure. Ukraine has shown a gradual improvement in digital content creation and software development. Although the overall level is still low, progress in the computer software expenditure ranking indicates the potential for further development.

Despite the overall progress, Ukraine faces important challenges related to the low level of fiber-optic Internet connectivity and the availability of Internet-enabled mobile devices. Addressing these challenges is critical to the further growth of the digital economy. Thus, the results of the study show that Ukraine has made significant progress in the field of digital technologies and the network economy; however, further development requires overcoming existing barriers and actively implementing the latest technological solutions. Considering these factors, Ukraine has the potential for further growth in the technology sector, which in turn

will contribute to economic development and improve the welfare of the population.

References:

1. Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, *11*(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007.
2. R Core Team (2014). R: A language and environment for statistical computing. R foundation for statistical computing, Vienna, Austria. http://www.R-project.org/
3. RStudio Team (2020). RStudio: Integrated development for R. RStudio, PBC, Boston, MA. http://www.rstudio.com/
4. Shevchuk, T. V. (2015). Problems and Development Features of Digital Banking Technologies. *Financial and Credit Activity Problems of Theory and Practice*, *1*(18), 249–255. https://doi.org/10.18371/fcaptp.v1i18.46549.
5. Ivanova, N. (2024). Biblioshiny Report "Technolog* Digital Economy", database WoS (2000-2023) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.12189279.
6. Piotrowski, D., & Orzeszko, W. (2023). Artificial intelligence and customers' intention to use robo-advisory in banking services. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, *18*(4), 967–1007. https://doi.org/10.24136/eq.2023.031.
7. Brzozowska, M., Kolasińska-Morawska, K., Sułkowski, Ł., & Morawski, P. (2023). Artificial-intelligence-powered customer service management in the logistics industry. *Entrepreneurial Business and Economics Review (EBER)*, 11(4), 109–121. https://doi.org/10.15678/EBER.2023.110407.
8. Li, F. (2020). The digital transformation of business models in the creative industries: A holistic framework and emerging trends. *Technovation*, *92-93*, 102012. https://doi.org/10.1016/j.technovation.2017.12.004.
9. Täuscher, K., & Laudien, S. M. (2018). Understanding platform business models: A mixed methods study of marketplaces. *European Management Journal*, *36*(3), 319-329. https://doi.org/10.1016/j.emj.2017.06.005.
10. Kolisnyk, O., Hurina, N., Druzhynska, N., Holovchak, H., & Fomina, T. (2023). Innovative Technologies in Accounting and Auditing: The use of Blockchain Technology. *Financial and Credit Activity Problems of Theory and Practice*, *3*(50), 24–41. https://doi.org/10.55643/fcaptp.3.50.2023.4082.
11. Blikhar, V., Lukianova, H., Komarnytska, I., Vinichuk, M., & Gapchich, V. (2023). Problems of Normative and Legal Regulation of the Process of Applying Blockchain Technology in the Financial System of Ukraine. *Financial and Credit Activity Problems of Theory and Practice*, *3*(50), 410–418. https://doi.org/10.55643/fcaptp.3.50.2023.4088.
12. Kristoffersen, E., Blomsma, F., Mikalef, P., & Li, J. (2020). The smart circular economy: A digital-enabled circular strategies framework for manufacturing companies. *Journal of Business Research*, *120*, 241-261. https://doi.org/10.1016/j.jbusres.2020.07.044.
13. Kristoffersen, E., Mikalef, P., Blomsma, F., & Li, J. (2021). Towards a business analytics capability for the circular economy. *Technological Forecasting and Social Change*, *171*, 120957. https://doi.org/10.1016/j.techfore.2021.120957.
14. Network Readiness Index. (n.d.). https://networkreadinessindex.org/
15. Kirkman, S.G., Osorio, A.C. and Sachs, D.J. (2002). The Networked Readiness Index: Measuring the preparedness of nations for the networked world. In Kirkman (ed.) *The Global Information Technology Report 2001-2002 Readiness for the networked world*. New York, Oxford University Press, pp. 10–29.
16. Dutta, S., & Lanvin, B. (eds.) (2023). The Network Readiness Index 2023: Trust in a Network Society: A crisis of the digital age? Washington DC: Portulans Institute. https://networkreadinessindex.org.
17. NRI: Country Profile. (n.d.). Ukraine. https://networkreadinessindex.org/country/ukraine/
18. International Telecommunication Union. (n.d.). *World Telecommunication/ICT Indicators Database*. https://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx.