Methods of Evaluating Digitization and Digital Transformation of Business and Economy: the Experience of OECD and EU Countries[1]

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Abstract. *This paper contains a co-occurrence analysis of 2 227 articles in English, indexing by Scopus database in 2019–2023, it was designed the «business – digitalization – digital transformation» co-occurrence network, that contains 374 keywords, grouped into 5 clusters. It was defined a research area and main key words for each cluster. It was analyzed 10 more occurring key words of the «business – digitalization – digital transformation» co-occurrence network, it was defined their clusters, total strength, as well as the occurrences indicator. It was conducted a comparison analysis of related terms of the global trend*

[1] This research is performed within the project "Sustainable development and resource security: from disruptive technologies to digital transformation of Ukrainian economy" (No 0121U100470)

of digitalization and digital transformation, such as: digital economy, Industry 4.0, digital transformation, digitalization, digitization. It was analyzed the main advantages and disadvantages of the actual international methods of the digitalization and digital transformation assessment. It was analyzed the world regions markets and it was defined the lead companies-implementors, as well as the lead companies-developers of the digital technologies in such regions as: the North America, Europe, and Asia.

Keywords: *digitalization, digital transformation, business, sustainability, Industry 4.0.*
JEL Classification: *M10, Q56*

1 Formulation of the problem

Digitalization has become critical for businesses seeking long-term sustainability in today's fast-changing economy. Disruptive technologies have changed how a company works: from improving internal business processes to expanding the market and enhancing customer experience. As the COVID-19 pandemic accelerates the transition to digitalization, it's becoming increasingly clear that businesses that don't embrace digital technology risk falling behind their competitors and losing market share.

Digitization can be seen as the latest step in a series of industrial revolutions that have transformed the world economy over the past few centuries. The first industrial revolution (Industry 1.0) was marked by the rise of mechanization and steam power, which was followed by the second industrial revolution (Industry 2.0) with mass production and electrification. The development of computers and automation characterized the third industrial revolution (Industry 3.0). In contrast, the current fourth industrial revolution (Industry 4.0) is marked by the convergence and integration of digital technologies such as artificial intelligence, the Internet of Things, and big data to create disruptive technologies.

Research (Digital 2023: Global Overview Report) shows that today there are 5.16 billion Internet users in the world, i.e., 64.4% of the planet's entire population is now online.

So, as of January 2023, the number:

– the number of mobile device users increased by 168 million (or by 3%) to 5.44 billion;

– active Internet users – by 98 million (or 1.9%) to 5.16 billion;

– users of social networks – by 137 million (or 3%) to 4.76 billion.

As of January 2023, the number of Internet users in Ukraine was 28.57 million people, which is 16.8% (or 5.8 million people) less than in January 2022 (Digital 2023: Ukraine). Although the Internet penetration rate in Ukraine increased to 79.2% compared to 71.8% in 2022 (Digital 2022: Ukraine). However, the increase occurred due to a decrease in the country's population by 7.3 million people (or 16.8%) (Digital 2023: Ukraine) due to the Russian-Ukrainian war.

2 Analysis of recent research and publications

When analyzing recent studies and publications, analyzed English-language publications for 2019–2023. The data set contains 2,227 articles in periodical scientific journals indexed by the Scopus database on business, digitalization, and digital transformation. The array of publications includes four subject areas, namely: business, management, and accounting; social sciences; economics, econometrics, and finance, as well as multidisciplinary sciences. A co-occurrence network was also constructed using the VOSviewer software. The co-occurrence of the «business – digitalization – digital transformation» network includes 374 keywords, which are grouped into five clusters.

The first cluster (highlighted in red) includes 96 items with the main keyword «digital transformation». The group focuses on digital transformation research, innovative business models, digital technologies, competition, and dynamic business opportunities for rapid adaptation.

The second cluster (highlighted in green) contains 79 items with the main keyword «digitalization». The set is focused on the study of digitalization, the development of innovations in small and medium-sized enterprises due to COVID-19, which are based on the application of information and telecommunication technologies.

The third cluster (highlighted in blue) unites 75 elements, with the main keyword «Industry 4.0». The group covers research on the fourth industrial revolution (Industry 4.0), the transformation of production (“smart” production), the development of the Internet of Things, transformation in supply chain management, the development of blockchain, and the implementation of innovative technologies.

The fourth cluster (highlighted in yellow) includes 71 items with the main keyword «sustainability». The set focuses on research on sustainability, digitization, business development, sustainable and technological development, circular economy, and achieving competitiveness.

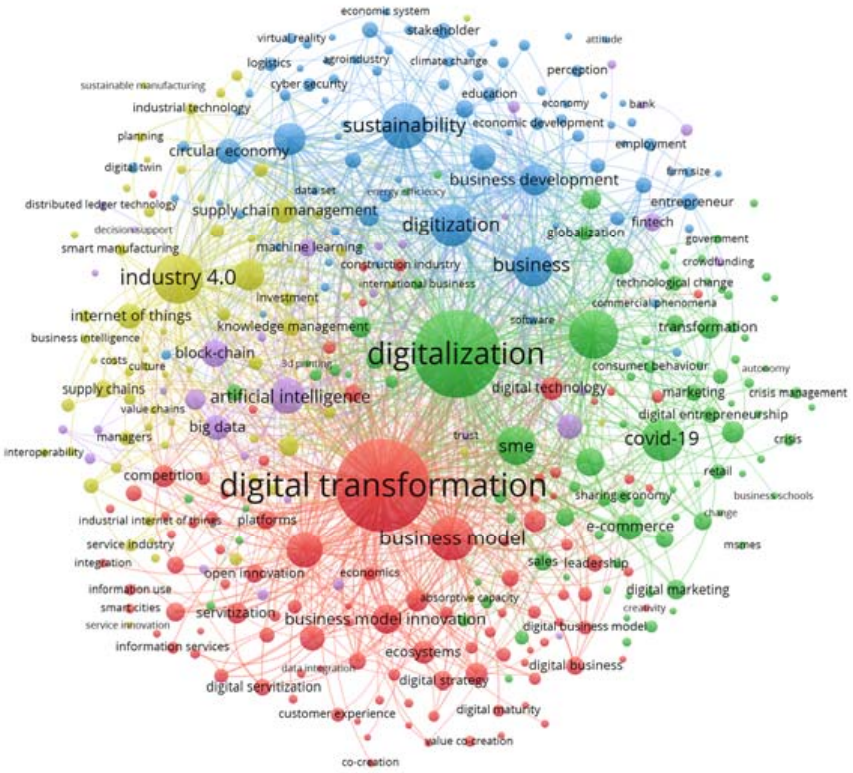

Figure 1 Co-occurrence network «business – digitization – digital transformation»

Source: compiled by the authors using VOSViewer based on Scopus publications

The fifth cluster (highlighted in purple) contains 53 items with the main keyword «artificial intelligence». The group is focused on achieving digital transformation through artificial intelligence development, big data use, and the growth of e-commerce.

The co-occurrence analysis made it possible to identify the key concepts that are part of the conceptual apparatus of the global trend of digitization and digital transformation, namely: digital economy, Industry 4.0, digital transformation, digitization, digitization, etc. The most frequently mentioned keywords from the analyzed array of publications, their belonging to the cluster, the number of mentions, and the indicator of the overall strength of the connection are given in the Table 1.

As can be seen from the Table 1, the term «digital transformation» (699 and 2398, respectively) has the most significant number of occurrences and the highest indicator of the total link strength, followed by the term «digitalization» (610 and 1937, respectively). The third most occurring term is «Industry 4.0» (204), but its total link strength (880) is inferior to the term «innovation» (945), which in turn is the fourth most occurred term among the array of publications (199). The term «sustainability» has the 5th position in terms of occurrences (176) and the total link strength (878) at the same time. The sixth position in terms of the number of occurrences (165) is occupied by the term «business model», but its indicator of the total link strength (736) is inferior to the similar indicator of the terms «digitization» (866) and «business» (759), which, in turn, are the seventh (150) and eighth (131) most occurred terms, respectively. The terms «SME» (123) and «digital technologies» (106) occupy the ninth and tenth places in terms of occurrences. At the same time, the situation is reversed in terms of the overall strength of connection: the term «digital technologies» (575) has ninth place, and the term «SME» (543) is tenth. Of the ten most occurred terms, nine terms belong to clusters 1, 2, 4, and 3 terms each: 1st cluster (digital transformation, business model, digital technologies), 2nd cluster (digitalization, innovations, SME), 4th cluster (sustainability, digitization, business), and only one term (Industry 4.0) – to 3rd cluster.

3 Highlighting previously unresolved parts of the general problem and formulating the goals of the article

Despite the available powerful scientific developments, the differences between related concepts within the global digitization and digital transformation trend have not been sufficiently

Table 1 Analysis of the ten most mentioned keywords of the co-occurrence network «business – digitalization – digital transformation»

Keyword	Cluster	The total strength of the bond	The number of mentions of the term
Digital transformation	1	2398	699
Digitalization	2	1937	610
Innovations	2	945	199
Industry 4.0	3	880	204
Sustainability	4	878	176
Digitization	4	866	150
Business	4	759	131
Business model	1	736	165
Digital technologies	1	575	106
SMEs (small and medium-sized enterprises)	2	543	123

Source: compiled by the authors based on the analysis of Scopus publications using VOSViewer

investigated. The advantages and disadvantages of existing methods of evaluating digitalization and digital transformation are not fully disclosed. Also, the leading companies in producing and implementing digital technologies by region of the world have not been fully identified.

This article is dedicated to solving these problems.

4 Presentation of the primary research material

Table 2 provides key definitions of the global digitization and digital transformation trend and analyzes their content.

The terms analyzed above are closely related and are part of a broader trend of digitization and digital transformation that is changing the global economy and society. A common feature for all analyzed terms is that the activities and processes they describe are based on digital technologies.

Table 3 analyzes the existing international methods of evaluating digitization and digital transformation, and their advantages and disadvantages are determined.

At the international level, digitalization is evaluated by political associations and economic organizations. The digitalization process is studied within the framework of the project Going Digital

Table 2 Comparative analysis of the related terms of the global trend of digitization and digital transformation

Concept	The content of the concept
Digital Economy (DE)	DE is economic activity resulting from the billions of daily online connections between people, companies, devices, data, and processes. IT covers various activities, from e-commerce and digital payments to cloud computing and big data analytics (OECD Digital Economy Outlook 2020).
Industry 4.0	Industry 4.0 is a term used to describe the fourth industrial revolution, characterized by integrating advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), and robotics into manufacturing and other industrial processes. The goal of Industry 4.0 is to create «smart factories « that are more efficient, flexible, and responsive to customer requirements (Shamika Sirimanne).
Digital transformation (DT)	DT is integrating digital technologies into all business areas, leading to fundamental business operations changes. It involves using digital technologies to improve efficiency, provide a better customer experience, and create new business models and sources of income (Salesforce).
Digitalization	Digitalization is using digital technologies to transform and automate business processes, leading to increased efficiency, product improvement, and the opening of new business opportunities (Gartner Glossary).
Digitization	Digitization is converting analog information into digital format, including using digital technologies for data storage, processing, and transmission, which ensures more efficient work (Bloomberg).

Source: compiled by the authors based on (OECD Digital Economy Outlook 2020; Shamika Sirimanne; Salesforce; Gartner Glossary; Bloomberg)

Table 3 Analysis of Digitalization and digital transformation assessment methods

Organization	Research direction	Advantages	Disadvantages
Organization of Economic Development and Cooperation (OECD. Measuring the Digital Transformation)	- a creation of tools for evaluating digital transformation; - data collection for the formation of policy in the field of the digital economy in 7 aspects	- an extensive database of countries; - a comprehensive approach to the subject: accounting for various aspects of sustainable development	- lack of a single generalizing indicator; - lack of data for many countries
European Commission (European Commission. I-DESI 2020	- assessment of the integration of digitalization into the economic and social life of states according to 5 aspects; - comparison of indicators of EU member states with 17 most developed countries	- an integral indicator consisting of 5 sub-indices for 24 indicators; - comparison of the most developed countries by the level of digitization	- not all countries are included in the review; - time lag when collecting information
World Bank (The World Bank)	development of an integral indicator of digitalization assessment	- comparison of 180 countries; - flexibility, the ability to expand the set of indicators	- time lag when collecting information; - a small number of indicators

Source: compiled by the authors based on analysis (OECD. Measuring the Digital Transformation; European Commission. I-DESI 2020; European Commission. Digital Economy and Society Index (DESI) 2022; The World Bank)

(OECD. Measuring the Digital Transformation) Organization for Economic Cooperation and Development (hereinafter – OECD). The project's primary goal is to create tools that can be used to assess various processes occurring in the development of the digital economy, aiming to develop political recommendations for reforms and economic transformations. The OECD notes that a consistent and unified policy for the development of the digital economy should be developed for all countries.

The study examines both the positive aspects and negative consequences of digitalization. Positive factors include stimulating innovation, increasing the efficiency and quality of services, and ensuring intensive sustainable economic growth and social welfare. From the experts' point of view, disadvantages of digitalization are job cuts, lack of education and digital skills, and privacy and security.

Therefore, a direct assessment of digitization in the Going project Digital is only a means of further steps, not the end goal of work. The purpose of the study is not to rank countries or create aggregate indicators – the OECD plans to collect data and provide key indicators to policymakers and analysts and link them to relevant policy instruments.

The European Commission, whose experts developed the International Index of Digital Economy and Society (I-DESI) (European Commission. I-DESI 2020), offers a different approach to digitalization trend research. The purpose of the index is to provide an overall assessment of the progress of the European Union (hereinafter referred to as the EU) towards a digital society and economy compared to the economies of non-EU countries.

I-DESI compares the average performance of EU member states with 18 non-EU countries using a methodology similar to the DESI index (European Commission. Digital Economy and Society Index (DESI) 2022). The Digital Economy and Society Index (DESI) is a composite index published by the European Commission since 2014 that measures the progress of EU countries in the digital economy and society. It combines a set of relevant indicators of the current structure of Europe's digital policy. It assesses the development of digitalization of various socio-economic spheres only among EU member states (Table 4).

The most global study of digitization is conducted by the World Bank, which developed the Digital Adaptation Index (DAI). DAI is an international index covering 180 countries (The World Bank). The generalizing index reflects the level of spread and use of digital technologies by three main subjects of the economy: the enterprise, the population, and the state. Each sub-index includes the technologies relevant agents need to drive growth in the digital age: increasing productivity and accelerating overall business growth, empowering and improving people's well-being, and improving the efficiency of public service delivery.

Table 4 Composition of DESI and I-DESI indices

Component of the index	Content of the index component
I1 is the level of network development	Broadband infrastructure deployment and their quality: cost of connection, Internet coverage, 4G networks, and mobile broadband
I2 – human capital	Skills needed to take advantage of the digital society. For example, I-DESI compares the level of employment in science-intensive industries and the number of graduates in the ICT or Internet field.
I3 – use of Internet services by citizens	In this area, different types of online activities are compared: the use of online content, the level of use of social networks, the number of devices and online transactions made (shopping, banking)
I4 – integration of digital technologies into business	The digitalization of business and the development of online sales (e-commerce) are evaluated
I5 – development of digital public services	Assesses the level of development of electronic government (e-Government) and digital medicine (e-Health)

Source: compiled by the authors based on (European Commission. I-DESI 2020; European Commission. Digital Economy and Society Index (DESI) 2022)

The authors of the methodology draw attention to the need for constant monitoring of indicators to track current information. With the rapid development of digitalization, a temporary lag of 1–2 years significantly distorts the data and reduces the demand for the index. It also requires the inclusion of other indicators to collect data from various national ministries to track areas such as education, health, and social transfers. The DAI methodology provides considerable flexibility for the index – the set of indicators can be supplemented without modifying the methods since all components have the same weight in the corresponding sub-index (The World Bank).

According to data published by Forbes (Marr), the most used digital technologies in the world in 2021 are 3D printing, 5G Internet, artificial intelligence (Artificial Intelligence), augmented reality, automated guided vehicles (AGV), blockchain technologies, cloud technologies, cobots, cyber security, Digital Twin, drones, IoT and IoT platforms, quantum computing and virtual reality.

The analysis of the markets of the regions of the world made it possible to identify the leaders in the implementation of the above digital technologies, as well as the companies that ensure the development of science and technology and the further digitalization of the processes of their activities (Table 5).

Table 5 World leaders in the implementation of digital technologies

Region	Direction	Companies¨
North America	North American manufacturers are likelier to use cloud technologies, IoT technologies, platforms, and other digital technologies.	Leading companies implementing digital technologies are GE (General Electric), Boeing, and Tesla. Leading digital technology developing companies are Microsoft, IBM, and AWS.
Europe	European manufacturers also showed above-average adoption rates of cloud technologies but lagged in adopting Industry 4.0, especially in collaborative robots (cobots) and computing technologies.	Leading companies implementing digital technologies are Siemens, ABB, and BMW. Leading companies developing digital technologies are ABB, Siemens, and SAP.
Asia	Asian manufacturers showed a higher level of use of collaborative robots (cobots) but a significantly lower-than-average level of use of cloud and IoT technologies. However, Asian companies had the lowest overall use of Industry 4.0 technologies.	Leading companies implementing digital technologies are Toyota, Huawei, and Foxconn. Leading companies developing digital technologies are Huawei, Alibaba Group, and Fanuc.

Source: compiled by the authors based on (General Electric Company, 2023; The Boeing Company Official Website, 2023; Tesla, 2023; Microsoft, 2023; IBM, 2023; Amazon Web Services, 2023; Siemens, 2023; ABB Group, 2023; BMW, 2023; SAP, 2023; Toyota, 2023; Huawei, 2023; Foxconn Technology Group, 2023; Alibaba Official Site, 2023; The Factory Automation Company – Fanuc, 2023)

Thus, the Siemens company, which developed the Industry 4.0 strategy, applies new digital business models and introduces Industry 4.0 to its enterprises, mainly using digital technologies. General Electric (GE), which implements Digital Twin, sells digital products and uses its enterprises' latest technologies. International giant Boeing, implementing Digital Twin, performs innovative work with various technologies (3D printing, AR, modeling). The study (Network Readiness Index 2022 Ukraine) evaluates the achievements of countries in the following directions: technologies (access, content, technologies); human resources (citizens, entrepreneurs, government); state (trust, regulation, definition); impact (economy, standard of living, contribution to achieving the goals of sustainable development), Ukraine took 50th place out of 13 1 with an index value of 55,71. This fact indicates the potential for implementing digital technologies in business processes and prospects for the development of digitalization and digital transformation of the country's economy.

5 Conclusions

The following results and conclusions were obtained during the conducted research.

Based on the co-occurrence analysis of 2,227 English-language publications indexed by the Scopus database in 2019–2023, a co-occurrence network «business – digitalization – digital transformation» was constructed, which contains 374 keywords combined into 5 clusters. Each cluster's thematic direction and main keywords have been determined.

The ten most occurred keywords of the «business – digitalization – digital transformation» co-occurrence network, their belonging to the cluster, the indicator of the overall strength of the connection, and the number of mentions of the term in the array of publications were analyzed. Of the ten most mentioned terms, nine belong to clusters 1, 2, and 4, three terms each, and only one belongs to cluster 3.

Based on a comparative analysis of related terms of the global trend of digitalization and digital transformation, such as digital economy, Industry 4.0, digital transformation, digitalization, and digitization, it was established that the common feature of all analyzed terms is that the types of activities and processes are based on the use of digital technologies.

Analysis of digitalization and digital transformation evaluation methods made it possible to determine their advantages and disadvantages. Thus, the main areas for improvement include the lack of a single generalizing indicator, the lack of data for many countries, and the presence of a time lag in collecting information.

Based on the analysis of the markets of the world regions, the leading companies implementing digital technologies and companies developing digital technologies have been identified. Thus, leading companies in the implementation of digital technologies include: in the North American region – General Electric, Boeing, and Tesla; European region – Siemens, ABB, and BMW; in the Asian area – Toyota, Huawei, and Foxconn. In turn, the leading companies developing digital technologies include: in the North American region – Microsoft, IBM, AWS; European – ABB, Siemens, SAP; Asian – Huawei, Alibaba Group, Fanuc.

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