

Mathematical model for digital transformation of business processes in the coordinates of digital marketing*

Olga Pavlova^{1,*†}, Eleonora Zabarna^{2,†}, Marharyta Pierkova^{2,†}, Andrii Kuzmin^{1,†} and Sava Kostiuk^{1,†}

¹ Khmelnytskyi National University, Instytut's'ka str., 11, Khmelnytskyi, 29016, Ukraine

² Odesa Polytechnic National University, Shevchenka str., 1, Odesa, 65044, Ukraine

Abstract

This research introduces a mathematical model designed to optimize the digital transformation of business processes in the domain of digital marketing. The model incorporates critical variables such as the degree of digital transformation, audience engagement, technology integration, and the effectiveness and cost of marketing strategies. Experimental data illustrate that higher levels of digital transformation, combined with advanced technology use and maximized audience engagement, significantly, enhance business outcomes, including increased revenue and conversion rates. The model provides a structured approach for businesses to evaluate and improve their digital marketing strategies, ensuring effective resource allocation and data-driven decision-making. By aligning digital marketing activities with transformation goals, companies can achieve optimal results and efficiency. This study lays the groundwork for further exploration and real-world application of the model to validate and refine its utility in practical business environments.

Keywords

Digital transformation, marketing optimization, data-driven strategies, mathematical model

1. Introduction

Digital transformation is the integration of technology into an organization to create value and competitiveness. By its content, digital transformation goes beyond digitization, i.e. the conversion of analog data into digital format and the introduction of digital technologies in various contexts. Due to the degree of interconnectedness and various accelerations that require organizational change, digital transformation should be seen as a challenge and an opportunity for organizations to achieve core business competencies, succeed in rapidly changing environments, the speed of change refers to a multitude of phenomena, ranging from the acceleration of technological innovation to the need for speed in dealing with changing customer and partner demand or unexpected events. Among the main advantages of digital transformation, the following can be highlighted: customers are six times more likely to try a new product or service from their favorite brand; customers are four times more likely to recommend their favorite brand to their friends, relatives and acquaintances; customers are twice as likely to make a purchase with their favorite brand, even when a competitor has a better product or price. In addition, loyal customers buy 90% more often and spend 60% more. According to Gartner [1], 91% of businesses are engaged in some form of digital initiative, and 87% of senior business leaders say digitalization is a priority. Gartner also admits that 56% of CEOs say

AdvAIT-2024: 1st International Workshop on Advanced Applied Information Technologies, December 5, 2024, Khmelnytskyi, Ukraine - Zilina, Slovakia

* Corresponding author.

† These authors contributed equally.

✉ pavlovao@khnmu.edu.ua (O. Pavlova); zabarna@op.edu.ua (E. Zabarna); margaret.p@ukr.net (M. Pierkova); andriy1731@gmail.com (A. Kuzmin); kostiuk.s@khnmu.edu.ua (S. Kostiuk)

ORCID: 0000-0003-2905-0215 (O. Pavlova); 0000-0002-2659-5909 (E. Zabarna); 0009-0005-6489-225X (A. Kuzmin); 0009-0009-1134-5956 (S. Kostiuk)



© 2024 Copyright for this paper by its authors. Use permitted under Creative Commons License Attribution 4.0 International (CC BY 4.0).

digital improvements have increased revenue. According to Statista [3], in 2023, spending on digital transformation (DX) is projected to reach 2.15 trillion U.S. dollars. By 2027, global digital transformation spending is forecast to reach 3.9 trillion U.S. dollars (Figure 1).

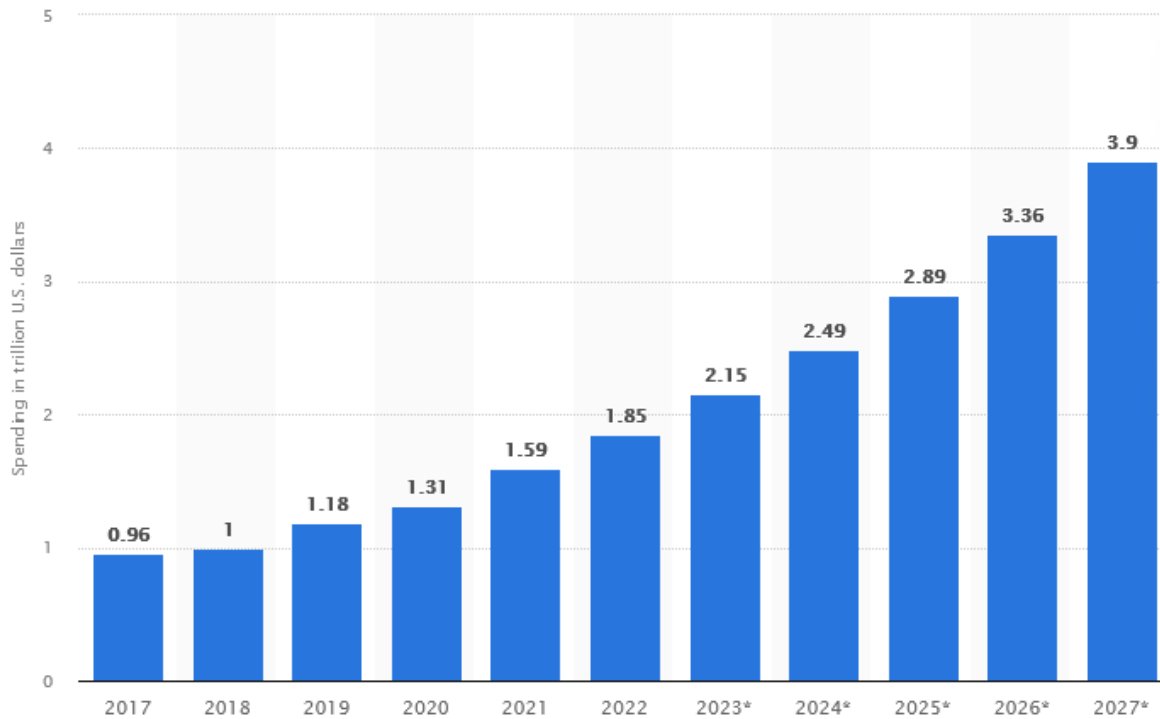


Figure 1: Spending on digital transformation technologies and services worldwide from 2017 to 2027 (in trillion U.S. dollars) [3].

Therefore, the purpose of this research is the analysis of modern trends in the development of information technologies and the processes of marketing digitization, as well as the determination of the advantages of using single-page digital applications in the field of digital marketing.

2. State-of-the-art

Electronic commerce is the fastest growing segment of retail today. Every year, there are more buyers on the Internet. Eight years ago, there were 1.5 billion people, and according to the results of 2023 – 2.64 billion [4]. At the same time, the market volume is also increasing. In Ukraine, the e-commerce market reached almost \$5 billion in 2023 [5].

Digital transformation for retail trade includes automation of processes and digitization of data, as well as the use of cloud technologies for their storage [6]. In addition, you can improve the user experience of the buyer with the help of advanced analytics, augmented and virtual reality, artificial intelligence. It is also possible to pay for goods through biometric POS terminals using face recognition technology [2]. Compared to the past, when shopping on the Internet was done almost exclusively by young people aged 18 to 23 years, now goods and services are also ordered online by users in other age categories, from 25 to 45 years. Another trend is the increasing popularity of shopping via smartphones due to their mobility and convenience, while laptops or desktops are becoming less popular.

The main task of platforms for digital marketing is to create conditions for attracting customers, satisfying their requests and making sales [5]. However, platforms involved in the marketing function must meet the following requirements in order to be flexible and sustainable:

1. Scalability, which determines the effectiveness of attracting investment in a potentially in-demand product with growth potential – for digital business processes, this will mean the ability to withstand a rapid increase in traffic and be ready for modifications and adjustments;
2. Ease of integration with various tools (from Internet acquiring to CRM and other systems);
3. Sociality - taking into account the specifics of work and the possibility of integrating one's work into social networks and influencers;
4. Compatibility with new technologies, in particular such as artificial intelligence (AI), machine learning, AR/VR, large databases, etc.;
5. Security - the ability to protect personal data.

3. Related works

The research [7] uses general and special methods of cognition: content analysis to substantiate the use of quantitative indicators for evaluating marketing effectiveness; induction and deduction for the development of a mathematical approach to evaluating the effectiveness of digital marketing of territories; analysis and synthesis to coordinate projects under conditions of a dynamic transformation of marketing processes.

The study [8] aims to examine the challenges and opportunities in the digital transformation of MSMEs, as well as effective technology management strategies.

The work [9] conducted qualitative research in the form of in-depth interviews with managers working for companies operating in different Italian industries.

This research [10] intends to develop a conceptual framework investigating how IT-related resources, namely IT advancement (ITAD) and IT alignment (ITAG), utilization relates to digital marketing capabilities (DMCs) development, which in turn improves business performance (BP), as well as how digital orientation (DO) and technological turbulence (TT) moderate these effects.

The research [11] aims to analyze the use of CRM systems for the development and implementation of communication strategies for digital brand management and Internet marketing based on the experience of EU countries.

The research [12] investigated several digital technologies, including the Metaverse, artificial intelligence, blockchain, virtual reality, and augmented reality. It is of the utmost importance for businesses to be able to compete in digital and virtual environments within the context of digital transformation to thrive in an increasingly competitive world.

The study [13] findings revealed eight topics that collectively represent the essential features of data economy in the current literature, namely:

1. Data Security.
2. Technology Enablers.
3. Business Implications.
4. Social Implications.
5. Political Framework.
6. Legal Enablers.
7. Privacy Concerns.
8. Data Marketplace.

The study resulting model may help researchers and practitioners to develop the concept of data economy in a structured way and provide a subset of specific areas that require further research exploration.

The studies [14] address the global phenomenon of digital transformation and its impact on the field of sport marketing.

The work [15] validates our theoretical model using 215 responses from a survey with Bangladeshi organizations and tests the research hypotheses using structural equation modelling.

The paper [16] examined the emergence of value creation during digital transformation. The authors used case studies to gather empirical evidence of the phenomenon from an organizational perspective. The study tried to closely link theory and practice by identifying the mechanisms that determined the paths of value creation in 11 companies that had taken concrete steps toward digital transformation.

The study [17] further examined the mediating effects of digital transformation strategy and organizational innovation on the relationship between digital technology usage and firm performance.

The purpose of [18] is discovering the stages, protocols, ways and instruments of becoming the industry 5.0 through the prism of innovation, technology in management of industry and business, and introducing the features that define the new quality of smart industry, smart business, and smart services among which modularity, interoperability, virtual reality.

The paper [19] investigates if and how DT changes relationship dynamics and collaboration efficiency in SCs and distributed manufacturing networks through information sharing and jointly used digital technologies.

The study [20] examines the sustainable adoption of innovative digital technologies (DTs) within digital transformations. The data for this study were collected from 760 stakeholders through a questionnaire survey and analyzed using SPSS software (Version 27). This study's results underscore the significance of considering the efficiency of the transformation process and the long-term sustainability outcomes for organizations.

The work [21] aims to identify how owners or senior managers of MSMEs can initiate a sustainable digital transformation project. A systematic literature review was carried out, including 59 publications from 2019 to 2023.

The study [22] examines the sustainable adoption of innovative digital technologies (DTs) within digital transformations. The data for this study were collected from 760 stakeholders through a questionnaire survey and analyzed using SPSS software (Version 27). This study's results underscore the significance of considering the efficiency of the transformation process and the long-term sustainability outcomes for organizations. The findings of the analysis clarify that integrating sustainability principles and DT has a positive impact on the effectiveness of the transformation, as indicated by environmental, social, and economic performance indicators.

The research [23] aims to analyse the impact of digital transformation on business models and competitive advantage. This is a literature review that uses a qualitative approach, which implies that data will be analysed and interpreted using information and text obtained from various sources.

The study [24] has focused on the pharmaceutical sector of Karachi (Pakistan) to examine the impact of product, process, marketing, and organizational innovations on firm performance. It also examined the moderating role of environmental turbulence.

In [25] the features of the work of agricultural entrepreneurship and mechanisms for their support in the context of global challenges, the implementation of strategic goals of European integration and martial law are presented. It is noted that farms need to optimize business processes based on digitalization in order to obtain maximum profit and rational use of natural resources. This correlates with the goals presented in the "Strategy for the Development of the Sphere of Innovation Activity for the Period up to 2030", "National Economic Strategy for the Period until 2030".

In [26] we propose the digitalization using Web-cartography for logistical infrastructure and for the volunteering tasks in the conditions of military conflict in Ukraine. Also in [26] we consider the possibility of generating digital content by the AI-based systems and conduct the analysis of the existing systems.

4. Mathematical model

To develop a mathematical model for the digital transformation of business processes in the context of digital marketing, we'll create a framework that considers key variables influencing the effectiveness and efficiency of digital marketing activities.

This model will focus on how digital transformation impacts business outcomes through digital marketing efforts. To maximize business outcomes (such as revenue, customer engagement, and conversion rates) through the optimization of digital marketing processes influenced by digital transformation.

Let us identify key variables that influence digital marketing:

- B: business outcome (e.g., revenue, engagement, conversion rate).
- D: degree of digital transformation (a factor representing how much a business has adopted digital technology).
- M_i : digital marketing components or strategies, where $i=1,2,\dots,n$ (e.g., SEO, content marketing, social media, email campaigns, PPC).
- C_i : cost associated with each marketing component M_i .
- E_i : effectiveness of each marketing component M_i (influenced by digital transformation).
- A: audience engagement (interaction level of the audience with digital marketing campaigns).
- T: technology level used in digital marketing (e.g., use of AI, automation, analytics tools).

The business outcome B is a function of the effectiveness and efficiency of digital marketing components, technology integration, audience engagement, and the degree of digital transformation can be defined by the formula 1:

$$B = f(D, M_1, M_2, \dots, M_n, C_1, C_2, \dots, C_n, A, T). \quad (1)$$

This function can be expressed as:

$$B = \sum_{i=1}^n E_i(M_i, D, A, T) - \sum_{i=1}^n C_i. \quad (2)$$

Here, $E_i(M_i, D, A, T)$ represents the effectiveness of the i -th marketing component influenced by the degree of digital transformation, audience engagement, and technology integration. The total business outcome is the sum of the effectiveness of each component minus the associated costs.

The effectiveness E_i of each digital marketing component depends on the degree of digital transformation D, audience engagement A, and the technology level T:

$$E_i = g(M_i, D, A, T), \quad (3)$$

where:

- M_i : marketing component's inherent effectiveness.
- D: degree of digital transformation (ranging from 0 to 1, where 1 represents full transformation).
- A: engagement level of the audience (can be measured through metrics like click-through rates, interactions, and conversions).
 - T: technology level or technological capability in use (ranging from 0 to 1, where 1 represents full integration of AI, automation, etc.).

A possible formulation for E_i can be denoted by the formula 4:

$$E_i = \alpha M_i \cdot D \cdot A \cdot T, \quad (4)$$

where:

- α is a scaling factor representing the impact of digital transformation on the marketing component.

- D, A, T are factors that amplify the effectiveness based on their respective levels.

The cost associated with each marketing component C_i could be modeled as:

$$C_i = \beta_i \cdot M_i + \gamma_i \cdot T, \quad (5)$$

where:

- β_i : cost per unit of the marketing component.
- γ_i : additional cost per unit of technology used for each component.

The objective is to maximize the business outcome B while considering constraints on budget and resource allocation. We denote the equation 6 for this:

$$\max_{M_i, T} B = \sum_{i=1}^n (\alpha M_i \cdot D \cdot A \cdot T) - \sum_{i=1}^n (\beta_i \cdot M_i + \gamma_i \cdot T) \quad (6)$$

Subject to:

$$\sum_{i=1}^n C_i \leq \text{Budget};$$

$$0 \leq D, A, T \leq 1.$$

The interpretation of the given above formulas is the following:

- Digital transformation (D): as digital transformation increases (closer to 1), the effectiveness of each marketing component increases, reflecting a more efficient and optimized use of digital technologies.
- Audience engagement (A): high levels of engagement ($A \rightarrow 1$) maximize the impact of digital marketing efforts.
- Technology integration (T): advanced technology use (closer to 1) amplifies the efficiency of digital marketing but comes with higher costs.

The proposed mathematical model provides a framework for optimizing digital marketing strategies as businesses undergo digital transformation.

The focus is on balancing costs, audience engagement, and technology integration to maximize business outcomes. It can help to measure the level of digitalization of businesses, i.e., their marketing components and business outcome.

5. Experiments & discussion

To provide experimental data using the proposed mathematical model for the digital transformation of business processes in digital marketing, we would typically need to perform an experiment or gather real-world data that fits the parameters outlined in the model.

A proposed experimental setup and hypothetical data for demonstrating the model includes the following parameters:

- Degree of digital transformation (D): measured on a scale from 0 (no digital transformation) to 1 (full digital transformation).
- Digital marketing components (M_i): components like SEO, PPC campaigns, content marketing, social media marketing, etc.
- Audience engagement (A): measured using metrics like click-through rate (CTR), conversion rate, or user interaction levels, normalized between 0 and 1.
- Technology level (T): the extent of technology adoption (e.g., automation, AI) used in the digital marketing strategy, also on a scale from 0 to 1.

- Cost (C_i): the cost associated with implementing each marketing component and technology level.

The method of the experiment consists of the following steps:

1. Collect data from various businesses at different stages of digital transformation and with varying marketing strategies.
2. Measure key business outcomes (e.g., revenue, conversion rates) alongside audience engagement metrics.
3. Compile a table with the collected data and measurement results (table 1).

Table 1

Experiment data

Experiment ID	D	A	T	Marketing component (M_i)	Cost (C_i)	Business outcome (B), UAH
1	0,2	0,3	0,1	SEO (0,5)	5000	15000
2	0,4	0,5	0,4	PPC (0,7)	8000	25000
3	0,6	0,6	0,5	Social Media (0,8)	10000	40000
4	0,8	0,7	0,6	Content Marketing (0,9)	15000	60000
5	1	0,9	0,9	Integrated Campaign (1,0)	200001	90000

The data that had been collected are the following:

- Experiment ID: represents different businesses or trials under different levels of digital transformation;
- D : degree of digital transformation, increasing from 0.2 to 1.0;
- A : audience engagement, based on interaction and conversion metrics;
- T : technology level, indicating the extent of technology integration in the marketing strategies;
- Marketing component (M_i): various components like SEO, PPC, social media, and content marketing, with effectiveness values;
- Cost (C_i): the cost associated with each strategy and technology level;
- Business outcome (B): calculated as per the model to show the return (e.g., revenue) achieved for each configuration.

Analysis and interpretation of the experiment: the model suggests that as businesses increase their degree of digital transformation (D) and integrate more technology (T), while also optimizing audience engagement (A), the business outcomes (B) significantly improve. The experimental data demonstrates that:

1. Low transformation levels. Experiment 1, with a low digital transformation level ($D=0.2$), results in a lower business outcome, despite the implementation of an SEO strategy. The minimal technology integration ($T=0.1$) and low audience engagement ($A=0.3$) limit the effectiveness of the campaign.
2. Moderate transformation levels. In Experiment 3, with a higher D value of 0.6 and increased audience engagement ($A=0.6$), the business outcome improves significantly. This shows that higher transformation levels positively influence marketing effectiveness.
3. High transformation Levels. Experiment 5, which reflects full digital transformation ($D=1.0$), high audience engagement ($A=0.9$), and a high technology level ($T=0.9$), achieves the highest

business outcome. The integrated marketing approach (combining various strategies) and advanced technology implementation maximize the efficiency of the marketing efforts, yielding the highest return.

6. Conclusions

The research presents a mathematical model for the digital transformation of business processes within the realm of digital marketing. The model integrates key variables such as the degree of digital transformation, audience engagement, and technology level to predict business outcomes, such as revenue and conversion rates.

The experimental data demonstrates that increasing levels of digital transformation and technology integration, when aligned with effective digital marketing strategies, result in significant improvements in business performance.

The results show that businesses undergoing digital transformation can optimize their marketing efforts and maximize returns by strategically enhancing audience engagement and adopting advanced technologies like AI, automation, and data analytics. The model provides a framework for companies to evaluate and refine their digital marketing approaches, ensuring resource-efficient and data-driven decisions that align with their digital transformation goals. Ultimately, this research offers a foundation for further exploration and real-world validation of the proposed model, enabling businesses to fine-tune their strategies and achieve improved business outcomes as they progress through their digital transformation journey in the dynamic environment.

Declaration on Generative AI

During the preparation of this work, the authors used Grammarly in order to: grammar and spelling check; DeepL Translate in order to: some phrases translation into English. After using these tools/services, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

References

- [1] Digital Transformation: How to Scope and Execute Strategy. URL: <https://www.gartner.com/en/information-technology/topics/digital-transformation> (Last accessed October 18, 2024).
- [2] Top 100 Digital Transformation Statistics & Trends To Help You Navigate it in 2024. URL: <https://quixy.com/blog/top-digital-transformation-statistics-trends/> (Last accessed October 18, 2024).
- [3] International Statistics Service Statista.com. URL: <https://www.statista.com/statistics/870924/worldwide-digital-transformation-market-size/>(Last accessed October 18, 2024).
- [4] How many people shop online? URL: <https://www.oberlo.com/statistics/how-many-people-shop-online> (Last accessed October 18, 2024).
- [5] eCommerce market in Ukraine. URL: <https://ecommercedb.com/markets/ua/all> (Last accessed October 18, 2024).
- [6] Companies face an urgent choice: go digital, or go bust. URL: <https://www.weforum.org/agenda/2020/10/digital-transformation-or-bust/>.
- [7] O.V. Aleinikova, O.I. Datsii, I.I. Kalina, A.A. Zavgorodnia, Y. Yeremenko, & V.S. Nitsenko. (2023). Digital technologies as a reason and tool for dynamic transformation of territory marketing. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, 1, 154-59.
- [8] S.A. Hendrawan, A. Chatra, N. Iman, S. Hidayatullah, & D. Suprayitno. (2024). Digital transformation in MSMEs: Challenges and opportunities in technology management. *Jurnal Informasi dan Teknologi*, 141-149.

- [9] F. Pascucci, E. Savelli, & G. Gistri. (2023). How digital technologies reshape marketing: evidence from a qualitative investigation. *Italian Journal of Marketing*, 2023(1), 27-58.
- [10] P. Ranjan. (2023). IT-related resources, digital marketing capabilities and business performance: moderating effects of digital orientation and technological turbulence. *Industrial Management & Data Systems*, 123(11), 2836-2856.
- [11] O. Berestetska, T. Iankovets, A. Orozonova, S. Voitovych, A. Parmanasova, & K. Medvedieva. (2023). Using CRM systems for the development and implementation of communication strategies for digital brand management and internet marketing: EU experience. *International Journal of Professional Business Review: Int. J. Prof. Bus. Rev.*, 8(4), 36.
- [12] K.G. Nalbant, & S. Aydm. (2023). Development and transformation in digital marketing and branding with artificial intelligence and digital technologies dynamics in the Metaverse universe. *Journal of Metaverse*, 3(1), 9-18.
- [13] A. Sestino, A. Kahlawi, & A. De Mauro. (2023). Decoding the data economy: a literature review of its impact on business, society and digital transformation. *European Journal of Innovation Management*.
- [14] P. Stegmann, S. Nagel, & T. Ströbel. (2023). The digital transformation of value co-creation: a scoping review towards an agenda for sport marketing research. *European Sport Management Quarterly*, 23(4), 1221-1248.
- [15] D.B. Mishra, I. Haider, A. Gunasekaran, M.N. Sakib, N. Malik, & N.P. Rana. (2023). "Better together": Right blend of business strategy and digital transformation strategies. *International Journal of Production Economics*, 266, 109040.
- [16] M. Holopainen, M. Saunila, & J. Ukko. (2023). Value creation paths of organizations undergoing digital transformation. *Knowledge and Process Management*, 30(2), 125-136.
- [17] H.T. Tsou, & J.S. Chen. (2023). How does digital technology usage benefit firm performance? Digital transformation strategy and organisational innovation as mediators. *Technology Analysis & Strategic Management*, 35(9), 1114-1127.
- [18] N. Kraus, K. Kraus, O. Manzhura, I. Ishchenko, & Y. Radzikhovska. (2023). Digital transformation of business processes of enterprises on the way to becoming industry 5.0 in the gig economy. *WSEAS Transactions on Business and Economics*, 93(20), 1008-1029.
- [19] J. Hamann-Lohmer, M. Bendig, & R. Lasch. (2023). Investigating the impact of digital transformation on relationship and collaboration dynamics in supply chains and manufacturing networks—A multi-case study. *International Journal of Production Economics*, 262, 108932.
- [20] M. Alojail, & S.B. Khan. (2023). Impact of digital transformation toward sustainable development. *Sustainability*, 15(20), 14697.
- R. Martínez-Peláez, A. Ochoa-Brust, S. Rivera, V.G. Félix, R. Ostos, H. Brito, ... & L.J. Mena. (2023). Role of digital transformation for achieving sustainability: mediated role of stakeholders, key capabilities, and technology. *Sustainability*, 15(14), 11221.
- [21] M. Alojail, & S.B. Khan. (2023). Impact of Digital Transformation toward Sustainable Development. *Sustainability*, 15(20):14697. doi:10.3390/su152014697
- [22] A. Kresnawidiansyah, S. Endang, Z. Agustian, & J. Aulia. (2023). The Impact of Digital Transformation on Business Models and Competitive Advantage. *Technology and Society Perspectives (TACIT)*, 1(2), 79–93.
- [23] Z. Kamal, S. Ahmed, & M. Ramzan. (2023). Antecedents to Firm Performance and the Moderating Role of Environment Turbulence. *Market Forces Research Journal*, 18(2), 163-190.
- [24] N. Kraus, K. Kraus, O. Manzhura. (2023). Farming and agricultural enterprises in the context of the implementation of strategic goals of European integration and digitalization of the economy of Ukraine. *European Scientific Journal of Economic and Financial Innovation*, 2(12), 46-64.
- [25] A. Kuzmin, & O. Pavlova. (2024). Analysis of AI-based systems for automated digital content generation. *Computer Systems and Information Technologies*, (1), 82–88. doi:10.31891/csit-2024-1-10.