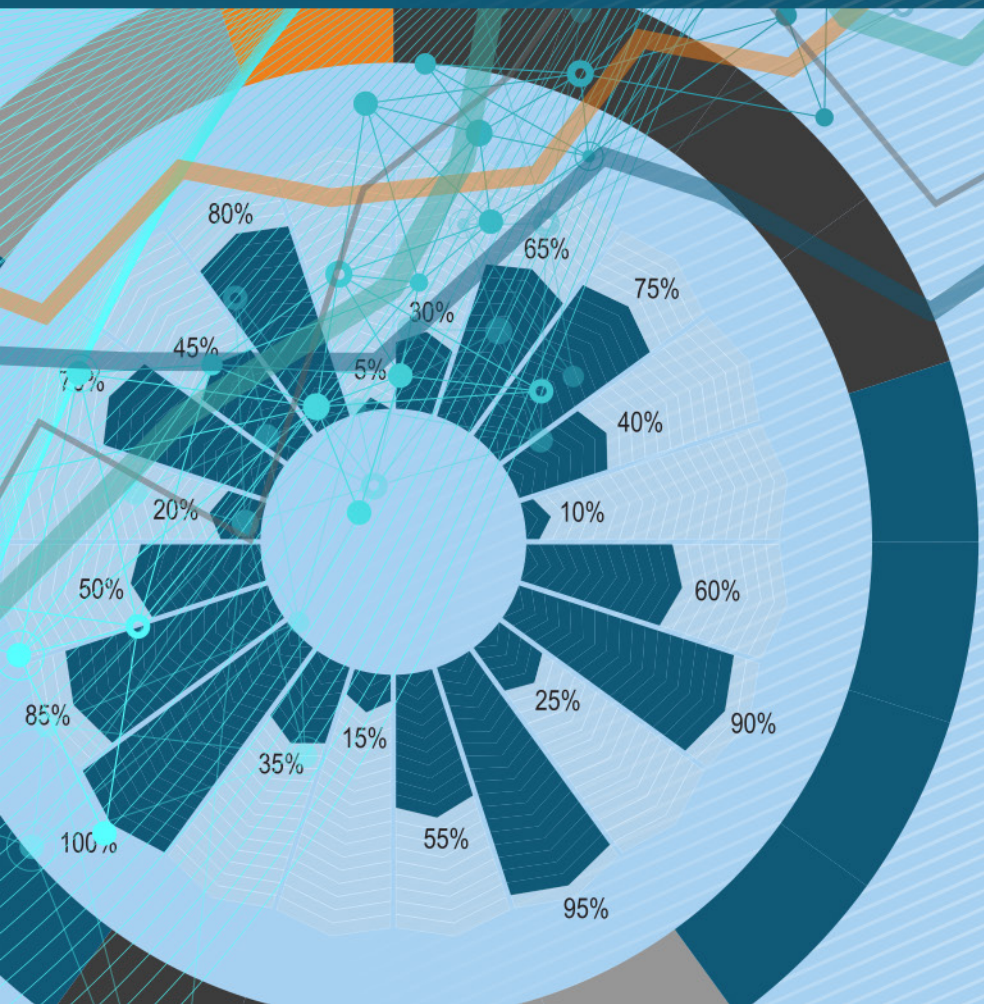
ISSN 2782-1927

JOURNAL OF REGIONAL AND INTERNATIONAL COMPETITIVENESS

JRAIC.COM



Vol. 6 (03) 2025

JOURNAL OF REGIONAL AND INTERNATIONAL COMPETITIVENESS

Scientific and practical peer-reviewed journal

Journal of regional and international competitiveness — theoretical and practical journal dedicated to the issues of international and regional competitiveness.

The **mission** of the journal is to spread modern economic knowledge, publish the most interesting results of scientific research in the field of regional and international competitiveness, and to serve as a helpful forum for professional discussion of a broad spectrum of fundamental problems of socio-economic development, an important tool of communication among science, education, and business.

The Journal accepts for publication: original articles; translations of published articles from foreign journals (with the consent of the right holder for the translation and publication); reviews; essays; reports.

ISSN	2782-1927
Regulator:	Registered by the Federal Service for Supervision in the Sphere of Telecom, Information Technologies and Mass Communication (ROSKOMNADZOR). Date of registration: 31.12.2020. Registration certificate ЭЛ № ФС 77 - 80072
Publication Frequency:	4 issues per year
Language:	English
Founder and Publisher:	Yaroslavl State Technical University, 150023, Russia, Yaroslavl, Moskovsky prospect, 88
Website:	http://www.jraic.com
Postal address:	150023, Russia, Yaroslavl, Moskovsky prospect, 88
E-mail:	jraic.ystu@gmail.com
Phone:	+7 (4852) 44-02-11
Date of issue:	28.09.2025

The journal is included in the list of leading Russian peer-reviewed scientific journals of the Higher Attestation Commission (VAK)

Contents

NATIONAL COMPETITIVENESS

Vietnam's economic growth in the age of digital transformation: opportunities and challenges 4
Nguyen Huu Phu, Dinh Le Hong Giang

Improvement of the cost control system based on quality management audit of military-industrial complex enterprises performing state defence order 16
Vadim A. Fedyukovich

REGIONS COMPETITIVENESS

The portfolio technology as competitive tool of personal branding development 23
Irina V. Popova, Marina B. Abramova, Alexey V. Zorin

INDUSTRY COMPETITIVENESS

Digital twins as a tool to increase the efficiency and sustainability of the agro-industrial complex 31
Alexander P. Berus & Anastasia V. Osadchaya

Vietnam's economic growth in the age of digital transformation: opportunities and challenges

Nguyen Huu Phu

PhD student
Plekhanov Russian University of Economics, Moscow, Russian Federation
E-mail: nguyenhuuphubp@gmail.com

Dinh Le Hong Giang

PhD in Political Science
Vietnamese Academy of Social Sciences, Hanoi, Vietnam
E-mail: giangdinh@yandex.ru

ORIGINAL ARTICLE

Abstract. Vietnam is one of the leading countries in Southeast Asia in the digital transformation process and is among the developing countries that face both opportunities and challenges associated with this change. This research examines Vietnam's digital transformation owing to the country's quick adoption of new technologies and the pressing requirement to solve related structural limitations. Key prospects are examined, including innovation-driven development and global market integration, while facing issues including the digital divide, cybersecurity flaws, and possible economic displacement. This study uses a mixed-method approach, analyzing qualitative information from case studies and policy evaluations in addition to quantitative data from national and international official sources. The results highlight Vietnam's capacity to use digital transformation for sustainable and equitable growth while pointing out important areas that need attention. Creating strong digital regulations, encouraging collaborations between the public and business sectors, and expanding digital literacy initiatives are some examples of practical suggestions.

Keywords: digital transformation; economic development; Vietnam's economic growth; global integration; regulatory reforms; cybersecurity

JEL codes: O10, O14

DOI: 10.52957/2782-1927-2025-6-3-4-15

For citation: Nguyen Huu Phu & Dinh Le Hong Giang. (2025). Vietnam's economic growth in the age of digital transformation: opportunities and challenges. *Journal of regional and international competitiveness*, 6(3), 4.

Introduction

Vietnam's vibrant economy and youthful, tech-savvy population exemplify a developing nation emerging from the challenges of the digital age. The country has purposely taken advantage of both the demographic dividend and its thriving innovation ecosystem, thus becoming a central digital player in Southeast Asia. The ICT sector contributed over 60% of the digital economy in Vietnam and raised around 16.5% of the GDP in 2023[1]. This above-average performance is due to the concentrated efforts of the Vietnamese government in propelling digital transformation, inducing technology-driven policies, and generating technology-related foreign investment. The rapidly growing e-commerce platforms and growing accessibility of mobile internet also add credence to Vietnam's digital economy.

Vietnam's digital economy has been established as the fastest-growing in Southeast Asia for the last two consecutive years, growing at impressive rates of 28% in 2022 and 19% in 2023 – again, three times faster than GDP[2]. This supercharged growth is demonstration of Vietnam's proactive transition into digital transformation and expanding powers in forming the region's technology-centric future. The developments show how quickly digital technology is being adopted.

Nevertheless, Vietnam stands, in all its might, against obstacles that hindering digital transformation: the capability to engage, accommodate those digital changes, and then introduce adjustments during and

[1] *The next wave of Vietnam's digital economy. Source: https://vneconomy.vn/techconnect//lan-song-tiep-theo-cua-kinh-te-so-viet-nam.htm (accessed on 15.03.2025)*

[2] *Digital economy expected to reach 18.6 per cent of Vietnam's GDP. Source: https://vietnamnet.vn/en/digital-economy-expected-to-reach-18-6-per-cent-of-vietnam-s-gdp-2342337 (accessed on 25.03.2025)*

after that. Even if for decades there have been educational reiterations around the expanded ownership of economic abilities and skill sets, these remain basically aligned to today's preponderantly «heavy» realities[3]. Limited capabilities in labor and the national economy create a differentiation for Vietnam in its transition behaviors that can provide varying challenges and constraints.

The aims of the study are to gain an accurate understanding of the relationship between digital transformation and economic growth in Vietnam. It discusses the progress made on the road to the use of digital technologies in the country, highlights impediments levelling growth, and provides some recommendations to overcome these impediments in a successful manner. The research adds to the ground-breaking discussion about the power of digital transformation in achieving sustainable development goals in developing countries, as is the case of Vietnam.

Literature Review

In recent decades, the idea of digital transformation has drawn a lot of interest, especially because of its potential to reshape economies, stimulate innovation, and improve competitiveness globally [12; 1; 17]. Business models and working environment have changed as a result of the COVID-19 pandemic, and digital technologies are essential for facilitating resilience and flexibility [16; 18]. Under these circumstances, in order to continue corporate operations and guarantee sustainable production and consumption practices, institutions should help firms by improving their resources and capacities, allowing them to embrace digital transformation [2]. Additionally, to ensure the successful implementation and long-term sustainability of digital transformation, it is essential to adopt developing techniques and tactics that can effectively guide and manage its complexity [11; 3].

In emerging economies, entrepreneurship and digital transformation, particularly blockchain, can accelerate economic development and promote innovation and expansion [4]. Furthermore, by changing the way capabilities are developed and improving learning opportunities for the workforce, digital transformation has an influence on numerous aspects of life, especially in human resources through higher education [14]. However, although digital transformation is quickly gaining popularity and offers many benefits and opportunities, it also comes with a number of drawbacks, especially for slower and developing nations [8]. Therefore, in developing nations like South Africa, the 4.0 Industrial Revolution will only succeed if governmental, corporate, and social leaders work together [13].

In Vietnam, digital transformation is a crucial driver of socioeconomic growth since it increases productivity, competitiveness, and innovation in a number of economic sectors [6; 5; 15]. Together with green investment and financial development, digital transformation may significantly improve the sustainability of Vietnam's existing high rates of economic growth [10]. For the cultural industry, digital transformation and entrepreneurship present new possibilities, skills, and difficulties that will change how it operates and foster an environment that is conducive to the expansion and advancement of Vietnamese culture [20]. Human capital, digital transformation, and startup success are strongly correlated. In Vietnam, entrepreneurs use human capital development to promote digital transformation, which improves company performance [7].

Although Vietnam is making progress and recognizes the significance of the digital revolution, it still has obstacles that must be overcome if it is to reach its full potential [22]. The differences of preparedness for digital transformation among Vietnamese businesses underscores the necessity of improving labor potential and economic and environmental efficiency to guarantee long-term company success [9]. Major obstacle facing Vietnam in the process of digital transformation, especially in logistics companies, is the lack of knowledge among management, the skills of the workforce, and the high implementation costs [21]. Additionally, the successful adoption and integration of digital technology is hindered by a number of obstacles, including governmental limitations like outdated regulations and inconsistent application [19].

The literature on digital transformation in developing nations, including Vietnam, emphasizes the potential as well as the difficulties that these nations confront. Although Vietnam has made great progress in embracing digital technology, it is stressed that a comprehensive strategy is required to overcome structural

[3] *Challenges and opportunities in Việt Nam's digital transformation process. Source: https://vietnamnews.vn/opinion/1687242/challenges-and-opportunities-in-viet-nam-s-digital-transformation-process.html# (accessed on 28.03.2025)*

obstacles. The foundation for comprehending Vietnam's distinct digital transformation journey is laid out in this review, which also provides insights for building strategies and policies in other developing countries. This study adds to the conversation on how digitalization might support fair and sustainable growth in developing countries by placing Vietnam in a global perspective.

Main Part

The digital transformation process in Vietnam

In the past three decades, Vietnam's economy has transitioned from a centrally planned economy to a vibrant market economy. Country has recorded an average GDP growth of 6.3% from 2000-2024, making Vietnam one of the fastest growing economies globally. Vietnam continued to develop positively during the COVID-19 pandemic where the economy posted a GDP growth of 2.9% in 2020, one of the highest rates worldwide during the pandemic. As per IMF, Vietnam's economy will continue growing rapidly to produce the highest economic growth of any emerging country in Southeast Asia with an acceleration of growth of 6.8% in 2025[4]. This rapid economic growth illustrates the growing economic foundations in Vietnam, as well as its key role in the overall development of the region.

From 2013 to 2023, Vietnam emerged as one of the nations with the quickest rates of growth in the Global Innovation Index (GII). In 2013, Vietnam came in at number 76 on this list. In 2023, ten years later, the country has climbed to 46th rank, securing a spot among the top 50 nations. Out of the 37 lower-middle-income countries, Vietnam's economy is now the second most creative[5]. A strong network of both local and foreign venture capital activity is estimated to boost the valuation of startups in Vietnam to close to $2 billion in 2022. There are over 3,800 startups in the nation, 11 of which are worth more than $100 million. Vietnam also has 100 startup incubators and 200 venture capital companies, which together support the country's expanding entrepreneurial environment[6].

This dynamic innovation landscape has been accompanied by significant digital economic growth, particularly in terms of its contribution to the national GDP (Table 1).

Table 1 – The added value contribution of the digital economy to GDP (2020-2023)

Sector	2020	2021	2022	2023	2024
Total	12.66	12.87	12.83	12.87	13,17
Agriculture, Forestry, and Fisheries	0.05	0.05	0.05	0.06	0.06
Industry and Construction	6.08	6.22	5.90	5.81	5.96
Services	6.53	6.6	6.88	7.00	7.15

Source: General Statistics Office of Vietnam, 2020-2024[7]

It is demonstrated that the services sector led and grew sustainably, reaching from 6.53 to 7.15% in 2024, while the overall contribution of the digital economy reached more than 13% of the national GDP. Over the years, the agricultural, forestry, and fisheries sectors stayed extremely small at 0.05-0.06%. In contrast, the building and industry sectors saw a slight decline, from 6.08% in 2020 to 5.96% in 2023. This trend highlights

[4] *International Monetary Fund. 2025. World Economic Outlook: A Critical Juncture amid Policy Shifts. Washington, DC. April. Source: https://www.imf.org/en/Publications/WEO/Issues/2025/04/22/world-economic-outlook-april-2025 (accessed on 22.03.2025)*

[5] *Global Innovation Index 2023 Innovation in the face of uncertainty 16th Edition. Source: hhttps://www.wipo.int/documents/d/global-innovation-index/docs-en-wipo-pub-2000-2023-en-main-report-global-innovation-index-2023-16th-edition.pdf (accessed on 22.03.2025)*

[6] *Digital economy accounts for over 18% of Viet Nam's GDP. Source: https://en.baochinhphu.vn/digital-economy-accounts-for-over-18-of-viet-nams-gdp-111240719131501058.htm# (accessed on 15.02.2025)*

[7] *General Statistics Office of Vietnam. Source: https://www.gso.gov.vn/tin-tuc-thong-ke/2025/01/thong-cao-bao-chi-ket-qua-bien-soan-chi-tieu-ty-trong-gia-tri-tang-them-cua-kinh-te-so-trong-gdp-grdp-giai-doan-2020-2024/ (accessed on 17.02.2025)*

the services sector's critical role in digital transformation and suggests ways to increase digital adoption across other industries.

Among the key components of the digital economy, e-commerce has emerged as a particularly dynamic and influential driver, reflecting broader changes in consumer behavior and digital business models in Vietnam (Figure 1).

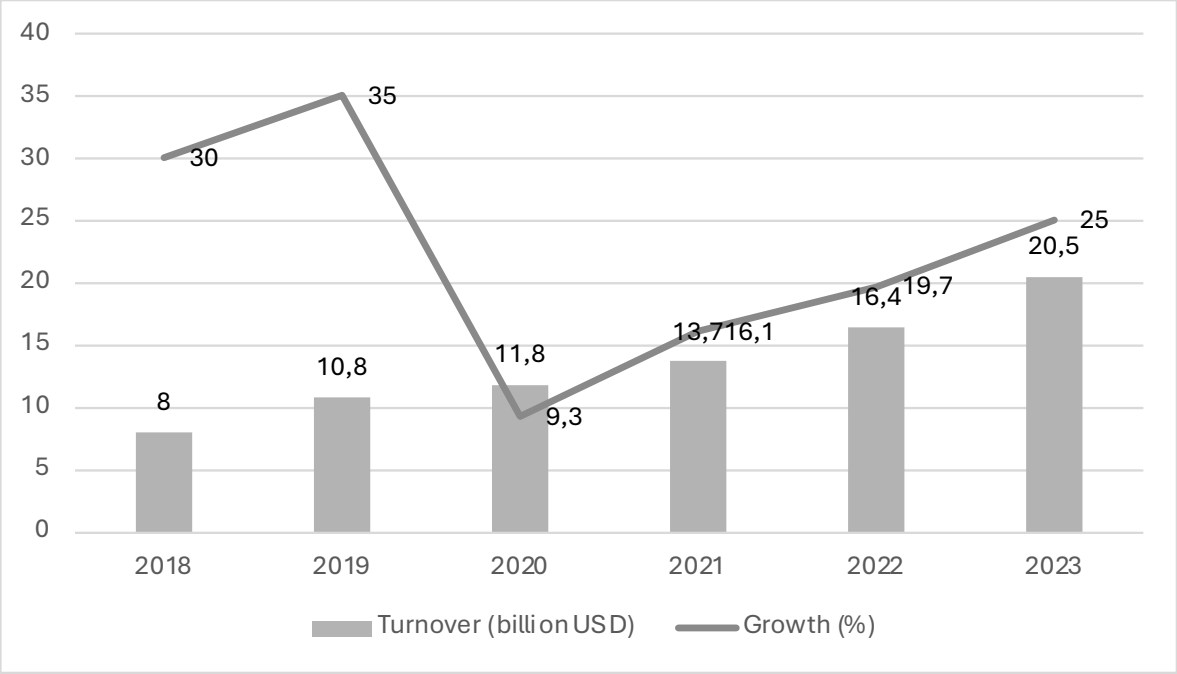


Figure 1. E-commerce retail over the years of Vietnam

Source: E-Commerce and Digital Economy Agency, 2018-2023

The turnover grew from $8 billion in 2018 to $20.5 billion in 2023. This rise in turnover is consistent with a trend of growing consumer use in seeking out online platforms for shopping. However, there is a degree of fluctuation to the rate of increase. The increase in turnover peaked at 35% in 2019 before falling significantly to 9.3% in 2020, potentially as a result of market corrections and disruptions due to the COVID-19 pandemic. The recovery that followed highlights the flexibility and ingenuity of the sector and growth was anticipated to recover to 25% in 2023. The steady growth illustrates the change in e-commerce use in retail environments and consumer behavior, confirming its essential position in today's economy. By 2023 Shopee, Lazada, Tiki, TikTok Shop and Sendo had established themselves as the leaders in e-commerce in Vietnam, delivering 2.2 billion products and achieving turnovers of USD 9.52 billion – which represents a 53.4% increase over the previous year. These players have increased their market share from 31.4% in 2021 to 46.5% in 2023, with expectations set to have revenues of USD 12.72 billion in 2024 – a 35% increase over the previous year[8]. This change illustrates Vietnam's creativity while also representing a culture increasingly depending on digital solutions to enhance connectivity, efficiency, and convenience. This combination of economic and societal digitalization bolsters the country's technology ecology, establishing it as a leader in sustainable growth in the digital age.

Vietnam is increasingly positioning itself as a new technological hub in Southeast Asia, thanks to the country's ongoing digital transformation, a developing startup ecosystem, and substantial venture capital investment (Table 2). This transformation has yielded advances in multiple sectors, establishing Vietnam as a major player in the Southeast Asian technology landscape. Initiatives by the government to promote this growth include forming innovation centers for cooperation and pooling resources, providing strategic support to digital entrepreneurs. These initiatives have also generated an eco-system that encourages business activity, which has attracted significant foreign and local investment.

[8] *Vietnam's E-Commerce Revolution: Telecom Infrastructure Paves the Way. Source: https://www.telecomreviewasia.com/news/featured-articles/4378-vietnam-s-e-commerce-revolution-telecom-infrastructure-paves-the-way/ (accessed on 21.03.2025)*

Table 2 – Overview of digital transformation in Vietnam by sector

Sector	Key digital transformation initiatives
Healthcare	Remote healthcare platforms, universal electronic medical records, telemedicine deployment in all healthcare facilities, creation of a national health database, smart hospitals
Education	Distance learning platforms have digitized curricula, with 100% of educational institutions implementing distance teaching and learning, online assessments, and updating university curricula on digital technologies such as AI and IoT
Finance & Banking	Digital banking services, automated processes, mobile payments, collaborations with FinTech for financial inclusion, and digital credit scoring systems
Agriculture	Smart agriculture, big data in farming, digital supply chain management, and initiatives like «Every farmer is a trader»
Transportation & Logistics	In order to modernize logistics, integrate seaports, rail, and warehousing, intelligent transportation systems concentrate on urban networks, highways, and digital platforms that facilitate digital profiles and efficient administrative procedures while optimizing transport management
Energy	Smart grid automation, digital meters, efficient energy distribution and loss detection systems
Environment	Comprehensive databases on managing resources, land, biodiversity, climate, and disasters, early warning systems, and open national digital maps
Industrial Production	Building smart factories, enabling intelligent operations, developing smart strategies and organizational structures, generating smart goods, and improving workforce digital skills are the main pillars of industrial manufacturing's digital transformation

Source: Authors

Through intentional efforts to implement modern technology across many sectors, Vietnam has made significant progress toward establishing a digital economy. The nation aims to increase accessibility, streamline operations, and improve service delivery by utilizing advances like big data, artificial intelligence (AI), and the Internet of Things (IoT). For example, the use of electronic medical records and telemedicine in the healthcare industry has improved systemic efficiency and lowered treatment obstacles. In the same way, educational programs aim to create a friendly environment, encourage lifelong learning.

Vietnam's comprehensive approach to addressing sector-specific issues and promoting sustainable development is shown in the incorporation of digital technology into industries including energy, transportation, and agriculture. Transparency and operational efficiency in these domains might be enhanced by automation and big data analytics. Also, some of these new features, like e-credit scoring and mobile banking, provide a great deal of financial stability in the banking and finance sector. It is in these technical advances that Vietnam stands a chance to meet the aspirations to become an economy capable of engaging in high-tech and digital processes that responds adequately to the diverse needs of citizens within various geographical locations.

Vietnam's policies and regulations supporting digital transformation

That dedication to digital transformation in Vietnam is becoming an increasingly vital part of the nation's socioeconomic growth. The Vietnamese government has proactively implemented a series of policies, regulatory frameworks, and strategic action plans for it recognizes how impactful digital technologies could be. These measures are intended to promote innovation, reinforce digital infrastructure, and develop an

environment supportive of the growth of the digital economy. In line with the larger socio-economic goals of the nation and strengthening its competitive advantage in the global market, such initiatives show clear vision to build Vietnam into a global lead in digital transformation by 2030 (Table 3).

Table 3 – Key policies and programs for digital transformation in Vietnam

Policy/Regulation	Year	Main Aim
Resolution No. 52-NQ/TW on a number of policies and strategies to proactively participate in the Fourth Industrial Revolution	2019	The objective is to create a strong environment for regional advancement and keep Vietnam in the top three ASEAN nations on the Global Innovation Index (GII). By 2030, more than 30% of GDP will come from the digital economy
National Digital Transformation Program to 2025, vision to 2030	2020	Increase digital economy contribution to 20% of GDP by 2025; rank among top 50 in e-Government
Program to support small and medium enterprises in digital transformation	2021	Support digital adoption in SMEs through subsidies and tax incentives
National Strategy on Green Growth for the 2021-2030 period, with a vision to 2050	2021	Defining that through cutting-edge technology, digital transformation, contemporary governance, and the construction of sustainable infrastructure, green growth propels economic change
Program to Support Digital Transformation of Enterprises in the 2021-2025 Period	2021	By 2025, the program expects 100% of enterprises to be more conscious of digital transformation. Support will be provided to at least 100,000 organizations, including training, consultation, self-assessment tools, and links to digital transformation solutions
Circular No. 06/2022/TT-BKHĐT of the Ministry of Planning and Investment	2022	Regulations offer SMEs technical and advisory assistance, including financial assistance for the purchase or rental of authorized digital transformation solutions. In order to suggest suitable assistance measures, SMEs evaluate their preparedness for digital transformation

Source: Authors

Small and medium-sized enterprises are the building blocks of the Vietnamese economy, while over 98% of the total number of businesses account for this part[9]. These enterprises provide a substantial contribution toward national production and employment, both being a coveted basis for economic stability. Thirteen thousand and eight hundred companies across sixty-three provinces and cities in Vietnam were trained in digital transformation by the end of 2024. Additionally, almost four hundred enterprises were included in developing and implementing fully operational digital transformation roadmaps, and twenty-eight enterprises received tailored on-site training[10]. This variation in business approach and operational scope is indicative of how dynamic the market is and how adaptable businesses are, more so in relation to rapid globalization.

Vietnam's vision for digital transformation goes beyond economic interest to juggle the need for social advancement and sustainable development. Establishing the country as a technological innovation and deployment leader regionally is one of the central goals. Vietnam's attempt to tap the potential of the Fourth Industrial Revolution involves transforming its economy, enhancing governance, and uplifting citizens' well-being. In other words, it involves ensuring the integration of the nation into the global digital economy,

[9] *White Book on Women-Owned Small and Medium Enterprises Released. Source: https://dangcongsan.vn/kinh-te/cong-bo-sach-trang-ve-doanh-nghiep-nho-va-vua-do-phu-nu-lam-chu-658405.html (accessed on 17.03.2025)*

[10] *Policy to support businesses in digital transformation and innovation. Source: https://dangcongsan.vn/kinh-te/cong-bo-sach-trang-ve-doanh-nghiep-nho-va-vua-do-phu-nu-lam-chu-658405.html (accessed on 11.03.2025)*

improving productivity, and enhancing competitiveness.

Key to this idea is the objective of contributing GDP to the digital economy. This means leveraging digital tools and platforms to help foster innovation in the core sectors of manufacturing, agriculture, and services. The internet infrastructure extension projects aim to ensure connectivity across the country, thus providing equal access to digital services and eliminating the digital divide between urban and rural contexts. The policy messages stimulate growth based on the belief the benefits of the digital turn will flow through to all walks of life.

Another key aim is to build a competitive digital ecosystem that gives people and enterprises the tools and resources they need to be competitive in the digital age. Labor upskilling, business support, and technology development are encouraged by the government in order to facilitate innovation and productivity. Data governance and Cybersecurity are equally essential and are highly prioritized to build trust and resilience in the digital economy. Vietnam also aims to plug regulatory gaps and promote responsible behavior online to create a safe, welcoming space for domestic and international investment in the digital sector. Together, this set of initiatives aims to ensure that Vietnam's digital transition provides for growth that is fair, sustainable, and innovative.

Challenges for Vietnam in the Digital Transformation

Vietnam has achieved phenomenal successes in digital transformation, but many obstacles still stand against its longer-term goals. Some of the major challenges include cybersecurity deficiencies, workforce readiness, obsolete or incoherent regulatory frameworks, and limitations in digital infrastructure. These obstacles must be overcome if Vietnam's digital transformation initiatives are to be inclusive, successful, and sustainable. Overcoming these barriers will require cross-sectoral collaboration, giving resilience, creativity, and equitable access to digital resources primacy.

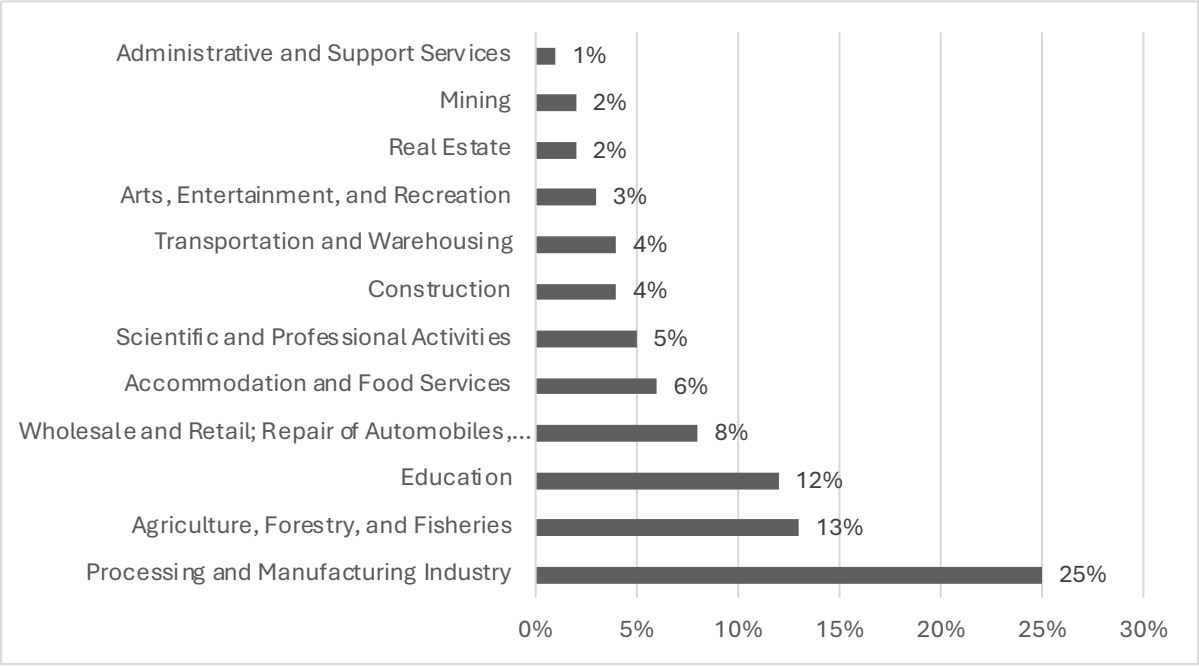


Figure 2. Sectoral Distribution of Digital Transformation Readiness Among Enterprises in Vietnam, 2023
Source: Annual report on digital transformation of Vietnamese enterprises, 2023[11]

Vietnam's businesses encounter a wide range of obstacles in their digital transformation, which reflects different levels of preparedness and ability to adopt new technologies (Figure 2). While some businesses are aggressively using digital solutions to boost productivity and competitiveness, others face major challenges including labor preparedness, insufficient infrastructure, and few resources. These difficulties highlight the

[11] *TAnnual report on digital transformation of Vietnamese enterprises, 2023. Source: https://digital.business.gov.vn/wp-content/uploads/2024/04/Annual-Enterprise-DX-report_final_EN.pdf (accessed on 15.03.2025)*

necessity of sector-specific approaches and encouraging laws in order to close the digital divide, encourage creativity, and guarantee a fair and long-lasting economic transition.

There are significant variations in understanding and resource distribution across industries areas in Vietnam's digital transformation environment. The strategic importance and revolutionary potential of digital technologies are still not completely implemented by many organizations, communities, and businesses. For small and medium-sized businesses (SMEs) in Vietnam, this problem is especially severe (Figure 3).

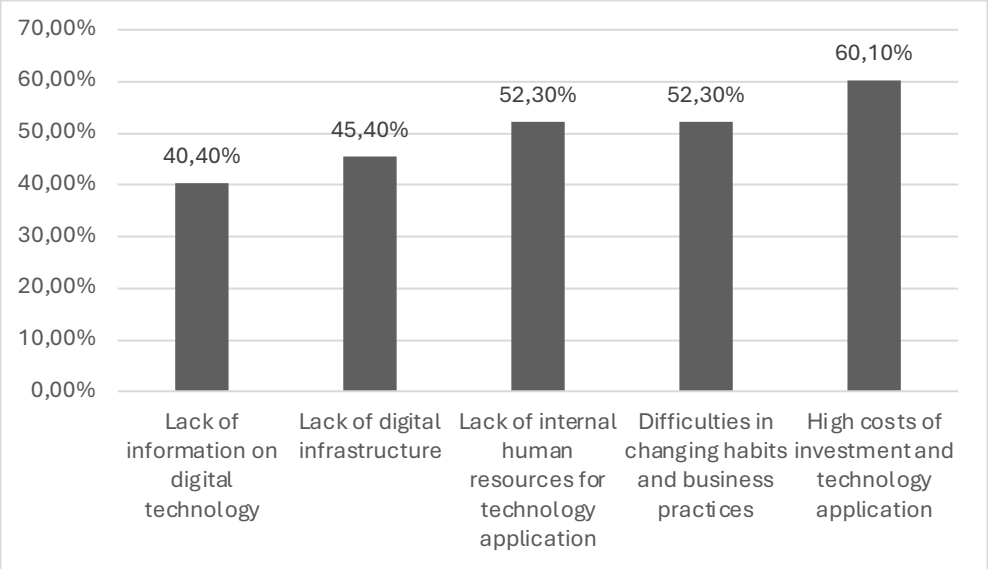


Figure 3. Top 5 barriers that Vietnamese businesses encounter in the process of digital transformation
Source: Barriers and difficulties of businesses when transforming digitally[12]

Moreover, while the community's overall digital literacy has improved, there still are very clear gaps – particularly in remote, border and island areas, as well as areas populated by ethnic minorities[13]. In these places, the more obvious presence of unequal access is compounded by a lack of digital skills and knowledge that leads to less engagement with technology, making the digital gap wider still. More must be done to tackle these discrepancies, through better public-private partnerships, targeted infrastructure investment, and a lot more widespread digital education initiatives to ensure all, equitable and sustainable digital transformation across the country.

Vietnam's quick embrace of digital technologies has made it more vulnerable to various cybersecurity risks. In 2021, Vietnam was one of the top 10 countries most affected by cyberattacks, indicating how vulnerable its digital infrastructure is[14]. The absence of strong cybersecurity frameworks and poor cybersecurity knowledge among individuals and businesses all contribute to this risk. Many businesses lack thorough security procedures, making sensitive information and vital systems vulnerable to hacking, financial fraud, and other crimes. These cybersecurity issues pose a serious obstacle to sustained prosperity as Vietnam continues its digital transition, necessitating immediate government and private sector cooperation to create a robust digital ecosystem.

Digital transformation entails the automation of repetitive tasks and the replacement of traditional jobs. In Vietnam, this could result in sweeping changes in labor markets which could, especially in industry and agriculture, threaten jobs for a significant share of the work force. Estimates suggest that, by 2030, as many as 1.3 million jobs in these sectors could face risk from automation, giving cause for concern about

[12] *Barriers and difficulties of businesses when transforming digitally. Source: https://digital.business.gov.vn/2153-2/ (accessed on 19.03.2025)*
[13] *Identifying challenges in digital transformation. Source: https://www.mof.gov.vn/webcenter/portal/thtk/pages_r/l/chi-tiet-tin-tin-hoc-va-thong-ke?dDocName=MOFUCM270788 (accessed on 08.12.2024)*
[14] *Which Countries are Most Dangerous? Cyber Attack Origin – by Country. Source: https://www.cyberproof.com/blog/which-countries-are-most-dangerous/ (accessed on 08.12.2024)*

rising unemployment and social inequality[15]. High-level digital jobs provide new opportunities but typically demand advanced skills that are often lacking in a large section of the low-skilled labor force, giving rise to an ever-widening skills' gap. Unless the government and other stakeholders embark on strong reskilling programs and planned interventions, the change will endanger the disadvantaged sectors, create a disruption against inclusive economic growth, and further deepen socio-economic fissures.

Another challenge Vietnam faces on its road to digital transformation is that of brain drain, losing some of its best-trained and most employable citizens to greener pastures abroad due to a scarcity of local opportunities or better incentives elsewhere. As the international demand for IT skills grows, keeping Vietnam's top digital talent should be of utmost priority. This will include competitive salaries, improvements in the working conditions, and an increase in domestic career opportunities. The government could further create a more nurturing environment for innovation by backstopping tech firms, research projects, and industry-academia partnerships. It might even be possible to reverse the trend by enticing foreign experts back to Vietnam through tax rebates or the possibility of investment in tech ventures.

These are the challenges that the digital transition now presents for Vietnam. While the government has started to make some headway regarding these concerns, the outcome of discussion of these pressing points will ultimately depend on whether there's collaboration between the private sector and the public. For digital transformation to deliver equal and sustainable benefits in Vietnam, improvements must be made in infrastructure deficit, skills enlargement, proper rating of the existing legal and regulatory environment, and stimulation of resilience against cyber threats. These challenges could be met in a manner that accomplishes its ambitious aspirations and sets an example in the world's thinking about the development course that has similar issues.

Policy Recommendations for Advancing Vietnam's Digital Transformation

A robust, universal, and concerted digital infrastructure is crucial for Vietnam's digital transformation. Though connectivity is increasing, inequalities still lead to differences in harmonic connectivity levels among populations, with significant differences in remote and rural populations. The government should promote public/private partnerships in order to build momentum for population expectations regarding both investments in a 5G network and the investment into high-speed broadband service measuring bandwidth and latency that provides some minimal service standard. Yet, the infrastructure required to reach unserved populations needs to be built by private telecommunications firms, who benefit from financial, investment, and tax incentives, to provide similar and adequate populations access to telecommunication services. Vietnam's second priority should be to ensure proper response to the supply of cloud services and protect data sovereignty where necessary, while at the same time allowing business the means to use digital technology; meaning that needed local data centers for business and industry need to be built in order to make this work.

As Vietnam moves toward a digital economy, it is vital to develop a skilled workforce in digital values. Digital literacy formation cannot work in isolation, this being included at all levels of our national education system is thus a prime requirement. Universities should partner with tech corporations in private industry to provide programs relevant to employment in the field, such as cybersecurity, data science, and artificial intelligence training. After that, on-the-job skills upgrading and technical transition by the national upskilling-reskilling should minimize the risk of redundancy for workers across a wide range of occupations, including those most directly in line with the digital economy. Awareness campaigns within underprivileged and rural communities become paramount in instilling knowledge that leads to a fair share in inputs to the digital economy.

There is an imperative of developing such an ecosystem that, in the digital world, would be safe and reliable for the development of Vietnam in the digital age. A comprehensive national cybersecurity policy should be developed by the government, which would address various vulnerabilities in the system and provide protection for its vital national infrastructure. This policy will include the establishment of Regional Training Centers and fund the training of committed specialists in combating cybercrimes, thereby increasing

[15] *OOOLAB highlights urgent need for upskilling. Source: https://vir.com.vn/ooolab-highlights-urgent-need-for-upskilling-109805.html (accessed on 05.12.2024)*

resilience against them. Public awareness campaigns: people and organizations, including children, should be educated about the threats of the internet and acceptable conduct on digital platforms and often seminars on safety practices; besides, building confidence in the digital sphere.

In the same light, it is vital to ensure that Vietnam's digital transition is inclusive. The government should provide funding for affordable digital devices and internet access for low-income families. Targeted activities such as mentorship and training programs for disadvantaged groups, primarily women and ethnic minorities, may engage them further in the digital economy. Extension of e-governance platforms in rural areas would enable people in the digital age to access basic services such as health and education.

Through these defined approaches, Vietnam can therefore take full advantage of the opportunities consequential to the digital transformation and not escape the consequences. Injecting infrastructure, investing in digital skills, updating its regulatory frameworks, and promoting inclusive prosperity will place Vietnam at the forefront of any developing country in the digital era. The government, companies, and civil society must jointly contribute to fulfilling the vision and ensuring that digital transformation will spur equitable and sustainable growth for all.

Conclusion

This is a manifestation of the interplay of possibilities, hurdles, and opportunities concerning the modernization of the country's economy through digital transformation. Vietnam has become a digital trailblazer in Southeast Asia thanks to the country's advantageous demographic situation, a strong business environment, and a proactive regulatory framework, which have helped Vietnam blossom. Rapidly growing ecommerce and a significant GDP contribution from the ICT industry testify to Vietnam's readiness to transition into the digital economy. All these achievements, buttressed by concerted efforts in infrastructure and research, place Vietnam as an emerging nexus of wealth and growth driven by technology.

However, different challenges are related to the disruption that digitalization can create. The persistent divides represent the disparities among various societal groups in terms of opportunity and access to the new relevant technologies. Security vulnerabilities expose businesses and organizations to data breaches and cyberattacks that bring tremendous financial loss. Also, the closure of traditional businesses, along with the widening skills gap, is likely to aggravate differences among the working class and even threaten progress. These challenges indicate a need for targeted efforts to ensure as many members of society reap benefits from the digital revolution.

In dealing with these problems and maintaining development, Vietnam is required to put more commitment into its digital transformation. Top of the agenda will be investment in new technologies such as artificial intelligence and big data, alongside the construction of solid and high-speed internet infrastructure. Bridging the skills gap and propelling digital literacy, especially in disenfranchised groups, will be key in ensuring broad participation in the digital economy. Building further on this, policies that promote public-private partnerships can combine resources and ideas to address problems more effectively.

There are many lessons Vietnam can indicate to those other developing countries engaged in their own digital transformation. The focus on innovation management, proactive rule, and incorporation of sustainable goals into the digital projects illustrates how indispensable flexibility and inclusivity are in this digital age. This frame of thinking augurs the need to strike a balance pertinent to the digital transformation-namely, ensuring that it is a strong enabler of holistic and equitable growth-driven by technical innovation and social equity plus welfare commitment.

FUNDING

The work was done on a personal initiative.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR'S CONTRIBUTIONS

Dinh Le Hong Giang – conceptualization; supervision.
Nguyen Huu Phu – writing – original draft.

References

1. Adama, N. H. E., & Okeke, N. C. D. (2024). Digital transformation as a catalyst for business model innovation: A critical review of impact and implementation strategies. Magna Scientia Advanced Research and Reviews, 10(2), 256–264. https://doi.org/10.30574/msarr.2024.10.2.0066

2. Bai, C., Quayson, M., & Sarkis, J. (2021). COVID-19 pandemic digitization lessons for sustainable development of micro-and small- enterprises. Sustainable Production and Consumption, 27, 1989–2001. https://doi.org/10.1016/j.spc.2021.04.035

3. Bartsch, S., Weber, E., Büttgen, M., & Huber, A. (2020). Leadership matters in crisis-induced digital transformation: how to lead service employees effectively during the COVID-19 pandemic. Journal of Service Management, 32(1), 71–85. https://doi.org/10.1108/josm-05-2020-0160

4. Bhuiyan, M. R. I. (2024). Examining the Digital Transformation and Digital Entrepreneurship: A PRISMA Based Systematic Review. Pakistan Journal of Life and Social Sciences (PJLSS), 22(1). https://doi.org/10.57239/pjlss-2024-22.1.0077

5. Chuc, N. D., & Anh, D. T. (2023). Digital Transformation in Vietnam: Policies, Results and Recommendations. Southeast Asian Economies, 40(1), 127–144. https://doi.org/10.1355/ae40-1f

6. Doan, T., DO, Pham, H. a. T., Thalassinos, E. I., & Le, H. A. (2022). The Impact of Digital Transformation on Performance: Evidence from Vietnamese Commercial Banks. Journal of Risk and Financial Management, 15(1), 21. https://doi.org/10.3390/jrfm15010021

7. Ghi, T., Thu, N., Huan, N., & Trung, N. (2022). Human capital, digital transformation, and firm performance of startups in Vietnam. Management, 26(1), 1–18. https://doi.org/10.2478/manment-2019-0081

8. Hai, T. N., Van, Q. N., & Tuyet, M. N. T. (2021). Digital Transformation: Opportunities and Challenges for Leaders in the Emerging Countries in Response to Covid-19 Pandemic. Emerging Science Journal, 5, 21–36. https://doi.org/10.28991/esj-2021-sper-03

9. Hoa, N. N. T. X., & Tuyen, N. T. (2021). A model for assessing the digital transformation readiness for Vietnamese SMEs. Journal of Eastern European and Central Asian Research (JEECAR), 8(4), 541–555. https://doi.org/10.15549/jeecar.v8i4.848

10. Hung, N. T. (2022). Green investment, financial development, digitalization and economic sustainability in Vietnam: Evidence from a quantile-on-quantile regression and wavelet coherence. Technological Forecasting and Social Change, 186, 122185. https://doi.org/10.1016/j.techfore.2022.122185

11. Li, F. (2020). Leading digital transformation: three emerging approaches for managing the transition. International Journal of Operations & Production Management, 40(6), 809–817. https://doi.org/10.1108/ijopm-04-2020-0202

12. Lobejko, S. (2020). Digital transformation and innovativeness of enterprises. Optimum Economic Studies, 2(100), 36–46. https://doi.org/10.15290/oes.2020.02.100.03

13. Manda, M. I., & Dhaou, S. B. (2019). Responding to the challenges and opportunities in the 4th Industrial revolution in developing countries. ICEGOV2019. https://doi.org/10.1145/3326365.3326398

14. Marks, A., & Al-Ali, M. (2020). Digital Transformation in Higher Education: A Framework for Maturity Assessment. International Journal of Advanced Computer Science and Applications, 11(12). https://doi.org/10.14569/ijacsa.2020.0111261

15. Nguyen, T. H. (2024). Digital Transformation in Vietnam - Trends and Solutions in the Coming Time. International Journal of Advanced Multidisciplinary Research and Studies, 4(3), 407–415. https://doi.org/10.62225/2583049x.2024.4.3.2801

16. Priyono, A., Moin, A., & Putri, V. N. a. O. (2020). Identifying Digital Transformation Paths in the Business Model of SMEs during the COVID-19 Pandemic. Journal of Open Innovation Technology Market and Complexity, 6(4), 104. https://doi.org/10.3390/joitmc6040104

17. Raji, N. M. A., Olodo, N. H. B., Oke, N. T. T., Addy, N. W. A., Ofodile, N. O. C., & Oyewole, N. a. T. (2024). THE DIGITAL TRANSFORMATION OF SMES: A COMPARATIVE REVIEW BETWEEN THE USA AND AFRICA. International Journal of Management & Entrepreneurship Research, 6(3), 737–751. https://doi.org/10.51594/ijmer.v6i3.884

18. Sein, M. K. (2020). The serendipitous impact of COVID-19 pandemic: A rare opportunity for research and practice. International Journal of Information Management, 55, 102164. https://doi.org/10.1016/j.ijinfomgt.2020.102164

19. Thao, N.C. (2024). E-Logistic Development in the Context of Digital Transformation in Vietnam. International Journal of Advanced Multidisciplinary Research and Studies

20. Trung, N. S., & Van, V. H. (2020). Vietnamese Cultural Identity in the Process of International Integration. Journal of Advances in Education and Philosophy, 04(05), 220–225. https://doi.org/10.36348/jaep.2020.v04i05.006

21. Viet, H. L., & Quoc, H. D. (2023). The Factors Affecting Digital Transformation in Vietnam Logistics Enterprises. Electronics, 12(8), 1825. https://doi.org/10.3390/electronics12081825

22. Zulianto, M. (2024). ASEAN Digital Economy Framework Agreement (DEFA): Opportunities and Challenges for Vietnam. Asia-Pacific Journal of Public Policy, 10(1), 53–62. https://doi.org/10.52137/apjpp.v10i1.214

Received 23.05.2025
Revised 26.06.2025
Accepted 10.09.2025

Improvement of the cost control system based on quality management audit of military-industrial complex enterprises performing state defence order

Vadim A. Fedyukovich

ORIGINAL ARTICLE

Postgraduate student
Center of Aerospace Defence Almaz-Antey, Moscow, Russian Federation
E-mail: f.vadim@bk.ru

Abstract. The article is devoted to the improvement of the cost control system at enterprises of the Defence Industrial Complex (DIC) performing the State Defence Order (SDO). The relevance of the study is determined by the growing requirements for transparency, efficiency, and rational use of financial resources within the framework of public procurement in the defence sector. Traditional cost control systems, based mainly on accounting and self-inspection methods, do not fully meet modern needs, as they fail to ensure a sufficient level of responsiveness to risks, deviations, and inefficiencies in contract execution. The paper proposes a new conceptual and methodological approach that integrates accounting, budgetary, and financial control into a unified system oriented toward compliance with legislation, reliability of financial information, and efficiency of resource allocation. Special attention is paid to the classification of costs incurred in SDO execution, their eligibility for inclusion in fixed contract prices, and their verification in accordance with legal and contractual requirements. The developed methodology introduces intermediate checks of actual expenditures, comparative analysis with planned indicators, and the use of adapted earned value methods for forecasting and decision-making. Practical application of the approach increases the accuracy of price formation, reduces unaccepted costs, and enhances financial sustainability. The results contribute to improving management efficiency and competitiveness of defence enterprises in fulfilling state contracts.

Keywords: State Defence Order; cost control system; separate accounting; price formation; audit of military-industrial complex

JEL codes: M41, H57, L64

DOI: 10.52957/2782-1927-2025-6-3-16-22

For citation: Vadim A. Fedyukovich. (2025). Improvement of the cost control system based on quality management audit of military-industrial complex enterprises performing state defence order. *Journal of regional and international competitiveness*, 6(3), 16.

Introduction

Traditional cost control systems used quality control auditing of enterprise management [1]. Based on cost control systems, accounting and control include separate accounting for contracts SDO, and state regulatory methods [3, 4]. At the same time, audits included the self-inspection methods [2]. However, the concepts of audit and self-inspection do not show the price formation in terms of the cost-effective methods. Moreover, increasing the efficiency of enterprises economic activities in terms of SDO performing concerns with the theoretical and methodological base for cost control process. We introduce new approaches to the cost control system and propose new methods for assessment of cost control system effectiveness.

The research suggests the author's definition of the concept of costs and highlights the difference from the concepts of expenses and costs. The following concept based on the difference of the cost requirements set for pricing SDO contracts. Moreover, the classification has been supplemented with the statement: "The costs incurred in the execution of SDO are the company's resources used in their execution. These costs are subject to verification for compliance with the norms of legislation for SDO[1] and the terms of the contract to consider

[1] *On the State Defence Order: Federal Law No. 278-FZ on December 29, 2012 (as amended on 22.04.2024); Decree of the Government of the Russian Federation No. 1465 on 02.12.2017 (as amended on 12.08.2023) "On State Regulation of Prices for Products Supplied under the State Defence Order, and on Amendments and Invalidation of Certain Acts of the Government of the Russian Federation" (with the "Provision on State Regulation of Prices for Products Supplied under the State Defence Order"); Order of the Ministry*

their complying to a fixed price." The paper also considers the factors of influence and industry-specific features of cost control at enterprises of the military-industrial complex in the execution of SDO. These factors determine the prospects for further research of cost control systems, development of their scientifically based methodology in terms of the specifics of defence industry enterprises. Moreover, they construct mathematical models providing data analysis and interpretation and form approaches to determine the effectiveness of these systems and models.

Main part

Indeed, the clarification of cost control systems conceptual framework, their classification, and efficiency assessment, in terms of the specifics of defence industry enterprises executing SDO provided development of a methodology for controlling costs. This methodology is focused on the operational analysis of incurred costs in terms of their eligibility for inclusion in the fixed price under the SDO, development of management decisions aimed at reducing costs. Additionally, it substantiates a mechanism for forecasting the results of financial and economic activities based on the cost control methodology applied during the execution of the SDO, distinguished by the combined use of an adapted earned value method and production.

The developed methodology based on a systematic approach and contains the author's classification and the purpose of control and methods of its implementation. The author's proposal of a three-pronged cost control system allows defence industry to perform public procurement to increase management efficiency (Figure 1).

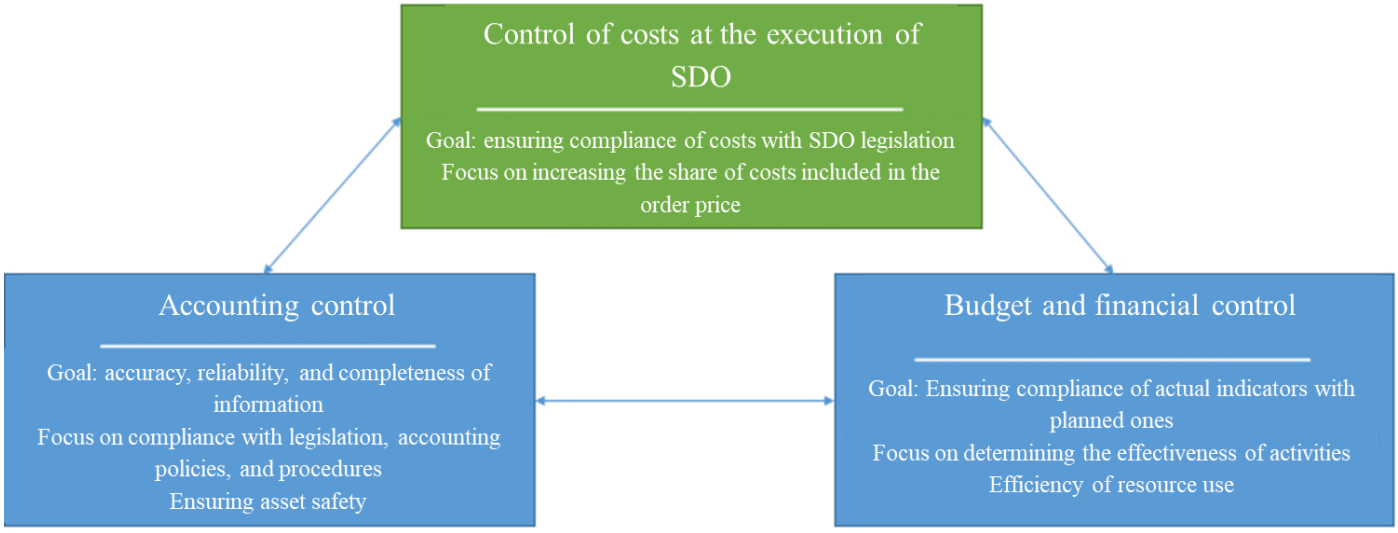


Figure 1. The general scheme of the tripartite cost control system

Source: Author

The Methodology for intermediate checking of costs during the execution of SDO (Figure 2).

The practical significance of our proposals includes more precise accountant activity to make decisions on the reflection of estimated values[2]. For instance, to charge a reserve for the impairment of inventories (work in progress). The constant assessment of contract costs in terms of determining a fixed price provides a reliably estimation of the real fair value of assets such as the cost of work-in-progress orders. It also allows ones to charge an impairment reserve to more reliably reflect the financial condition of the enterprise.

of Industry and Trade of the Russian Federation on February 8, 2019 No. 334 "On Approval of the Procedure for Determining the Composition of Costs Included in the Price of Products Dupplied under the State Defence Order"

[2] *On Accounting: Federal Law No. 402-FZ of December 03, 2011 (amended 12.12.2023)*

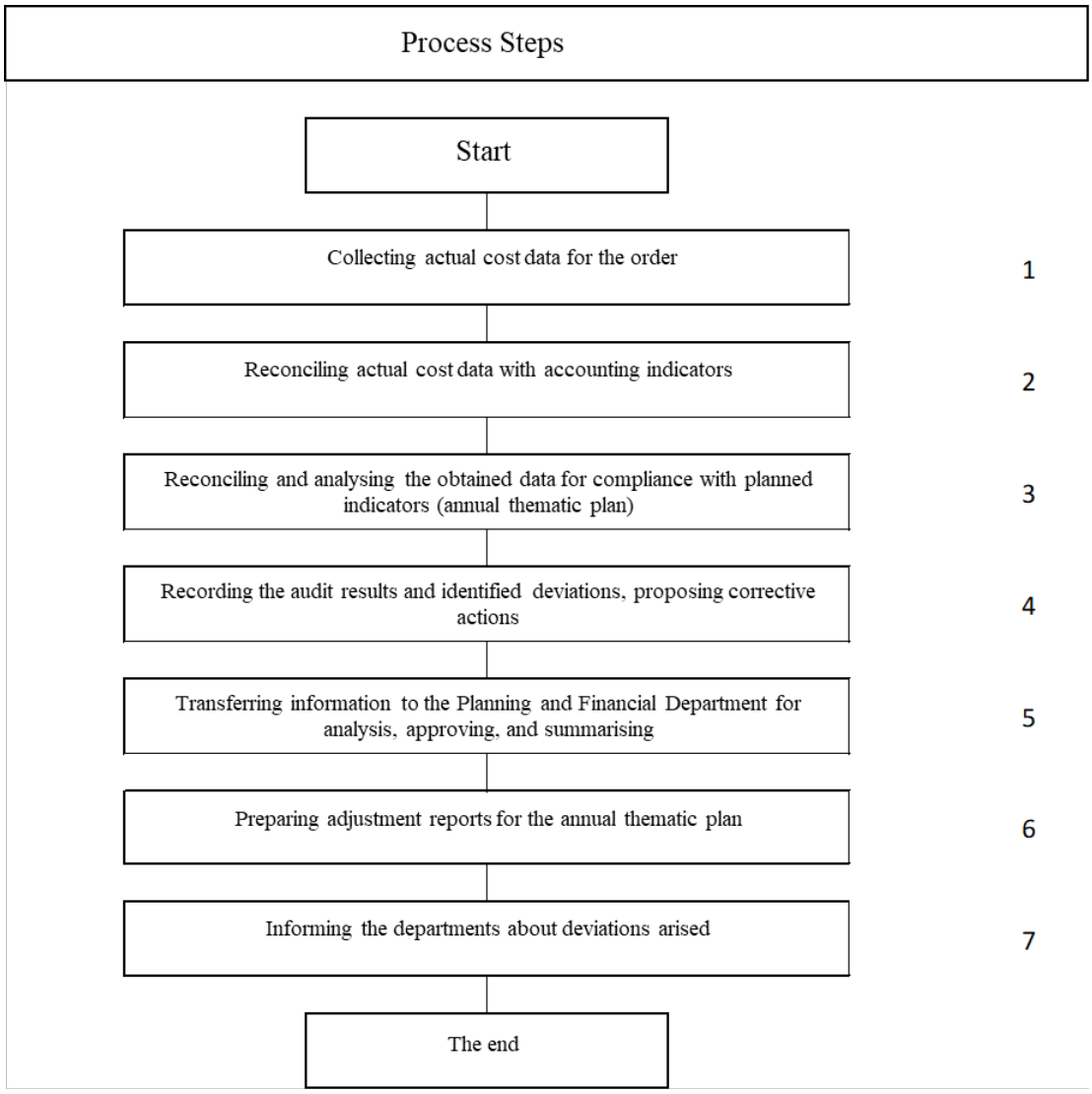


Figure 2. The methodology for intermediate checking of costs during the execution of SDO
Source: Author

The author's cost classification scheme is shown in Figure 3.

Figure 3. Classification of costs for intermediate checking of costs during the execution of SDO
Source: Author

Table 1 shows the indicators (based on [8]) for calculating the adapted mechanism of the production function.

Table 1 – Indicators for calculating the adapted mechanism of the production function. Developed by the author on the basis of the production function model by G.B. Kleiner [9] and earned value method[3]

Indicator	Name	Source	Value
Planned Value	(PV)	Planned Budget Data	Planned Value of Work Done at the Date
Earned Value	(EV)	Planned Budget Data	Planned Cost of Actual Work Done at the Date
Actual Cost	(AC)	Accounting Data	Actual Costs at the Date
Budget at Completion	(BC)	Planned Budget Data	Total Planned Budget
Current Cost Deviation	(CCD)	CCD = EV - AC	A negative value indicates resource overruns.
Cost Performance Index	(CPI)	CPI = EV /AC	A value of more than 1 indicates high efficiency; a value of less than 1 indicates low efficiency.
Forecast at Completion	(FAC)	FAC = BC / CPI	Cost forecast without eliminating of the current deviations
Forecast to Completion	(FTC)	FTC = FAC-AC	Forecast of the remaining costs considering continuing trend towards deviations
Rejection Upon Completion	(RUC)	RUC = BC - FAC	The predicted value of the deviation of actual costs from the planned ones

Source: Author

To determine the current cost of an order, it necessary to:

Based on the data on actual expenditures, and pursuant to the conducted analysis and classification of costs, determine the proportion of costs accounted for in the pricing of products within the framework of the SDO for each item of the cost estimate i:

$$\%CC_i = CC_i / AC_i,$$

where CC_i is the cost of the calculation item in terms of the purpose of SDO pricing; AC_i is the actual cost of the calculation item.

Therefore, the current (as well as the planned, forecast) cost of the order is equal to:

$$C = AC_1 * \%CC_1 * CP_1 + AC_2 * \%CC_2 * CP_2 + ... + AC_i * \%CC_i * CP_i ,$$

where CP_i is the coefficient of profitability according to the calculation method agreed with the customer.

We developed a methodology to determine the effectiveness of measures taken within the framework of the cost control system methodology.

Since the proposed cost control measures are the intermediate stages in the preparation of calculation and costing materials and do not require additional expenses, reporting calculations, price approval, the effectiveness of the control system shall be understood as the coefficient:

$$Ce = (CAC / ACA) \rightarrow 1,$$

where CAC is the cost agreed upon by the customer when forming a fixed price, ACA is the actual cost according to accounting data.

Conclusion

[3] *Minkevich, A. What is the earned value method? Source: https://ampm.by/blog/earned-value-management (accessed on 10.05.2025).*

The efficiency of applying the methodology for intermediate cost control incurred during the execution of SDO has been calculated (see Figure 4).

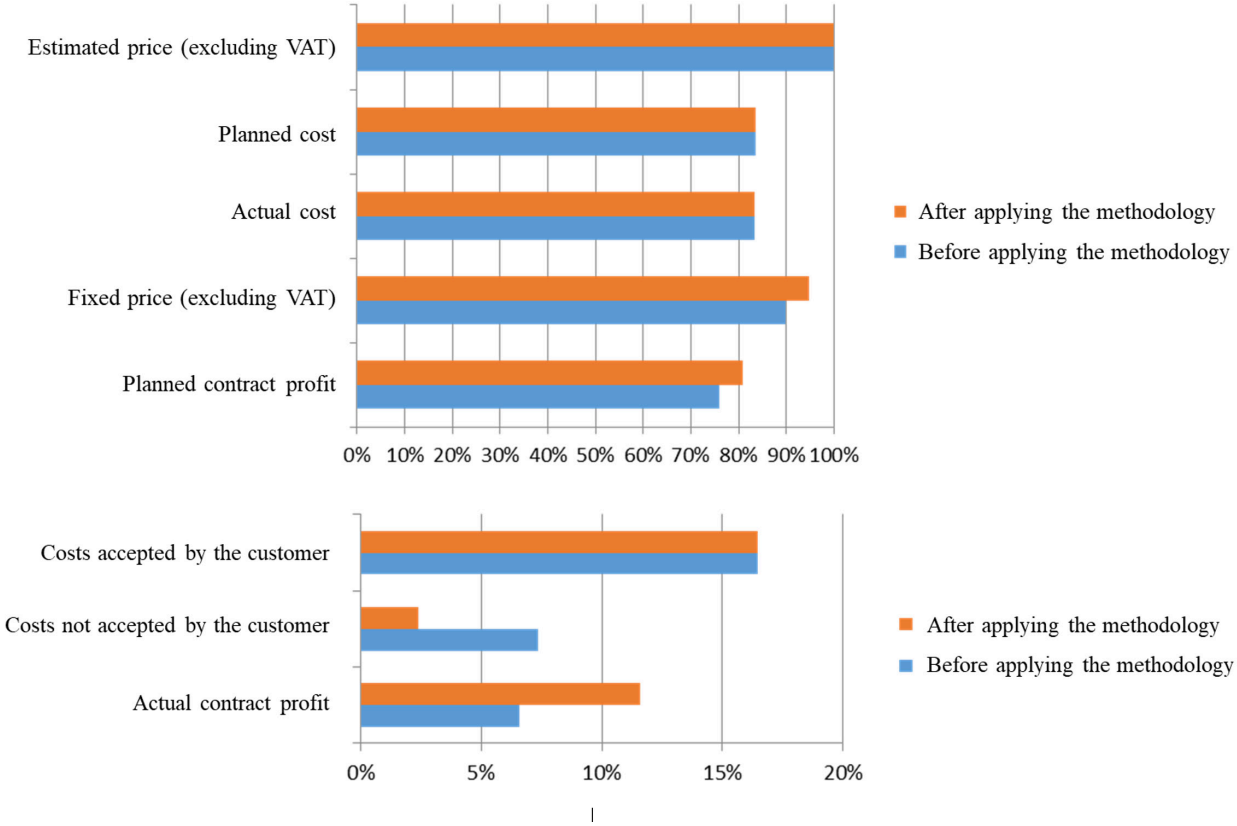


Figure 4. The effectiveness of the Methodology for intermediate checking of costs during the execution of SDO

Source: Author

Ce = 76% / 83% = 0.91 (before applying)
Ce = 81% / 83% = 0.97 (after applying)

As a result, we determine the methods of practical application of author's models for not only SDO industries.

FUNDING

The work was done on a personal initiative.

CONFLICT OF INTEREST

The author declares no conflict of interest.

References

1. Anokhova, E. V. (2016). The audit of the enterprises performing the state defence order. *In The synergy of accounting, analysis, and auditing to ensure the economic security of business and the state: Proceedings of the II International scientific and practical conference dedicated to the memory of Prof. Petrova V. I. and Prof. Bakanova M. I. (pp. 5–10)*. Moscow: Auditor Publishing House. (in Russian)

2. Klychova, G. S., Zakirova, A. R., & Nigmatullina, N. N. (2021). Control supply of the cost management system of enterprises. *Bulletin of Kazan State Agrarian University*, 16(4[64]), 115–121. https://doi.org/10.12737/2073-0462-2022-115-121 (in Russian)

3. Semenova, Yu. E., Voronkova, O. V., & Ostrovskaya, E. N. (2022). Improving the mechanism of enterprise cost management and controlling based on big data. *Science and Business: Ways of Development*, 1(127), 146–149. (in Russian)

4. Mikhalenok, N. O. (2006). *Institutionalization of economic management in Russia: Contents, forms, possibilities of systemic changes (V. A. Noskova, Ed.)*. Samara: SNC RAS, SamGAPS. (in Russian)

5. Orekhov, A. M. (2009). Methods of economic research. Moscow: Infra-M. (in Russian)

6. Skornyakov, L. A. (1982). *Elements of the theory of structures (2nd ed.).* Moscow: Nauka. (in Russian)

7. Klyuchko, N. V. (2002). *The consistency of cooperative processes. System research. Methodological problems. Yearbook*. Moscow: Unified URSS. (in Russian)

8. Kuchkarov, Z. A., Nikanorov, S. P., Solntsev, G. V., & Shabarov, V. N. (2007). *Research of socio-economic systems: Methodology. Theory. The consequences*. Moscow: Kontsept. (in Russian)

9. Kleiner, G. B. (1986). *Production functions: Theory, methods, application*. Moscow: Finance and Statistics. (in Russian)

Received 04.06.2025
Revised 07.07.2025
Accepted 11.09.2025

Jraic.com
JOURNAL OF REGIONAL AND INTERNATIONAL COMPETITIVENESS 2025; 6(3):23-30

The portfolio technology as competitive tool of personal branding development

Irina V. Popova

Doctor of Sociology, Associate Professor
Yaroslavl State Technical University, Yaroslavl, Russian Federation
E-mail: pivik@list.ru

Marina B. Abramova

Candidate of Chemical Sciences, Associate Professor
Yaroslavl State Technical University, Yaroslavl, Russian Federation
E-mail: abramovamb@ystu.ru

Alexey V. Zorin

Candidate of Economic Sciences, Associate Professor
Kostroma State Agricultural Academy, Kostroma, Russian Federation
E-mail: zav104@yandex.ru

ORIGINAL ARTICLE

Abstract. The increasing competition in the labour market emerged the problem of graduates' adaptation. The education system helps to live and work effectively in a rapidly changing world. Nowadays, the major purpose of education is personal, social, and professional competences. Indeed, the ability of the graduates to analyse and effectively use information is one of the most demanded. Therefore, an independent work of the students takes a significant place in the curricula of higher education institutions. However, to be competitive in the labour market is the one urgent task of the modern education. The purpose of this study is to determine empirically the effectiveness of portfolio technology for personal branding development in terms of competitiveness. Indeed, the process of personal branding development is relevant since the employment of graduates is included in the university's accreditation indicators. Despite the portfolio technology has been introduced into the higher education system, according to our research, it does not achieve its goals. The reason is the formal and unjustified attitude of the education system towards the technology. However, our research shows a high ranking of motivation to master self-presentation skills, professional career, etc. Therefore, there is a need to address this contradiction through the effective management. The sociological survey method allows us to describe the process under study and identify the difference between educational institutions. Indeed, the skill of personal portfolio development depends on the objectives of the educational process at the university. Moreover, many students are not informed about the portfolio technology. We possess it a result of insufficient management in terms of personal brand development. In general, according to research results, mastering of portfolio technology as a tool for personal branding and competitiveness is quite poor.

Keywords: portfolio technology; personal competition; personal branding; self-presentation; professional community

JEL codes: A14

DOI: 10.52957/2782-1927-2025-6-3-23-30

For citation: Irina V. Popova, Marina B. Abramova, Alexey V. Zorin. (2025). The portfolio technology as competitive tool of personal branding development. *Journal of regional and international competitiveness*, 6(3), 23.

Introduction

Indeed, two trends in the labour market define the studying of personal branding and portfolio as a competitive tool.

- firstly, the growing competition for jobs and demands of employers;
- secondly, the development of digital technologies for self-presentation and business contacts.

Modern digitalisation increases the level of competition within professional community. Indeed, social media provides new opportunities for employees. Nowadays, they can choose the mode of work: on-line or off-line. Therefore, the competitiveness within the professional communities increased. Moreover, some professional communities capitalise their professionalism. For example, doctors of narrow specialisation having developed a personal brand usually involved into the pais health care; teachers became popular tutors;

design engineers establish personal design bureaus, etc. All mentioned above form the competitiveness requiring the skills of self-presentation.

Therefore, it is necessary to determine the concept of brand. The term was borrowed from marketing and business industry and its main definitions are related to the concepts of a trademark. According to Mazilkina E.I., brand is a promoted trademark or image resulting from various marketing efforts [9, p. 11]. O.G. Vazhnova suggests two types of definitions of brand concept. Firstly, there are individual attributes: the name, logo, and other visual elements (fonts, design, colour schemes, and symbols) to distinguish a company or product from competitors. Secondly, it is the image and reputation of a company, product, or service for the customers and partners [3, p. 8]. Knyazeva M.A. possesses brand as a trademark characterised by a certain perception on the part of the target audience [8, p. 67]. According to the educational literature, brand can be understood as the reputation, image, and recognition of a trademark to distinguish from competitors for the consumers of goods and services. It is relevant to the production of goods or the provision of services by legal entities. Therefore, many people percept the term brand as corporate brand or company brand. However, development of opportunities for individuals allows them to capitalise their professional achievements throught their skills, image, and reputation. It provides the introduction of personal brand concept. The concept of a personal brand is developing. According to Zeynelova A.E., a personal brand is the perception of a person by the others [6, p. 18]. The personal brand is becoming widespread within professional communities. It concerns with the desire of publicity, provided by expanding personal presentation through the social networks. A personal brand is a public image of a person in a particular niche, i.e. medicine, education, beauty, business, art, etc. Nevertheless, it is not necessary to be a certified specialist; it is more important to have an experience and charisma. Today, consumers critically consider any advertising activity and mostly focused on a specific person. It provides the prevalence of the personal brand over the company one because of competition. Teamwork and personal characteristics are a priority to select specialists in any field. The crisis economy requires businesses to reduce costs. As a result of optimisation, only highly competitive specialists having the ability to attract attention to themselves remain in the staff. Along with this, they attract attention to the company and increase the value of company product or service. Personality becomes primary one [4, p. 50].

The modern interpretation of personal brand concept is the image and reputation of a particular person and consumer expectations on the service provided. Moreover, a personal brand is closely related to its personal socially significant qualities, the service provided or the product itself [11, p. 91]. The brand's reputation itself allows consumers of services to wait for the quality and professionalism [5, p. 50].

Therefore, in modern competitive economic conditions, the demand of employers is growing and changing towards assessing the applicant's level of competence rather than basic education. Hence, the issue of professional personal positioning is becoming particularly relevant.

Methods

One of the most effective tools to compete and show ones' competence is a portfolio. It is an opportunity to demonstrate achievements in a particular field of activity and impress a potential employer. The formation of a new trend trough the presentation of personality in various fields of professional activity acquires portfolio management skills. With the transition to the Bologna process, Russian universities introduced the requirement to keep a portfolio for each student. Working with a portfolio in a practical, professional, and socio-educational environment contributes to the development and assessment of students' competencies. It allows graduates to develop their professional qualities, and effectively present their achievements to future employers [13, p. 138].

Many Russian scientists studied a professional portfolio and its role in the development of personal competitiveness. A.G. Asmolov researched issues of personal and professional development related to the portfolio as a tool of self-presentation [1]; V.A. Bolotov developed the methodological basis of the portfolio as a tool for evaluating professional achievements [2]; I.A. Zimnaya studied issues of professional competence and its reflection in the portfolio [7]; N.F. Radionova investigated the role of the portfolio in the system of professional development of a teacher [14].

The concept of a portfolio, as a business card of an individual or an organisation, has gained importance with increasing of competition in the labour market. To attract the attention of employers or clients, employees collected samples of completed works or certificates of achievements in the profession. Initially, it was a kind of dossier.

The idea of using a portfolio in education is widespread and to be actively applied in Russia with the transition to the Bologna process. It began to develop the technology of graduate competitiveness as a result of a student's activity after completing a certain educational stage and preparing for future professional activity. In this regard, the development of the concept began within the framework of pedagogical science.

The Russian specialists have different approaches to the definition of the concept of portfolio. For instance, Stefanovskaya T.A. considers the technology of portfolio as the organisation of the pedagogical process, a set of actions improving the relationships between the components of the pedagogical process in accordance with a certain theoretical paradigm [15].

Selevko G.K. defines portfolio technology as a system of constituent components of the pedagogical process, based on a scientific basis and contributing to the achievement of the intended results [16].

D. Meyer considers portfolio technology as a purposeful product and a collection of students' works, demonstrating their efforts, progress, achievements [10].

Subsequently, the concept was transferred to the higher professional education. Nevertheless, the term portfolio is widely used in many areas of human activity and has a large number of definitions and characteristics. However, there is no generally accepted interpretation of this concept yet. Nowadays, the Russian educational system understands this term as a folder of individual achievements.

Nevertheless, portfolio technology allows student to accumulate and competently evaluate the personal educational results for special periods of studying. It includes diplomas and other papers on specific results achieved by students in various events, contests, etc. According to this particular approach, portfolio motivates the student’s activity, develops productive learning skills, encourages students' activity and independence, expands educational opportunities and self-education, etc.

Therefore, economic situation requires changing of the labour market. It provides qualitatively reconsideration of graduates professional activity. The priority moral and psychological qualities of a successful employee are initiative and independence, creativity, the ability to cooperate, high motivation for professional development and career growth. It provides the mobility and competitiveness of the employee. Hence, the portfolio technology is an effective tool for assessment a person in terms of his or her professional or educational activity. However, it is necessary to study the issue of the portfolio technology empirically in the higher professional education system.

Results

This research is a continuation of the analysis results. The purpose of the research was to determine the structure of university students' competitiveness, empirical substantiation of ways to improve the quality of personal competition skills, willingness to build a professional activity strategy in accordance with the objectives of the university's educational process. The beginning of the research was published in a Journal "The structure of students' personal competitiveness as a determinant of the formation of educational process objectives of an educational institution" [12].

The study was conducted using a Google form survey; a total sample size was 600 people. The object of research is students of Yaroslavl State Technical University (YSTU) (1-4 year of Bachelor's degree; 1-2 year of Master's degree; all the institutes); Kostroma State Agrarian Academy (KSAA) (1-4 year of Bachelor's degree; Economics faculty).

The sociological survey method allows us to determine the proportion of respondents with the different skills to form a personal portfolio. The results obtained show the difference in students' preparation for using portfolio as a personal competitiveness tool.

Table 1 – Proportion of YSTU and KSAA students with personal portfolio management skills (% of respondents)

Privacy Strength	YSTU	KSAA
Yes, I am always careful about its content	5.5	5.1
Yes, I am not always careful about its content	27.5	59.0
No, I am not careful about its content	45.3	28.2
I do not know what it is	27.5	7.7

Source: Authors

Indeed, the research results are as follows:

- the development of personal portfolio management skills depends on the objectives of the university's educational process;
- the proportion of the students interested in developing personal brand skills is quite low for both universities;
- there is a significant difference in the number of the students considering personal brand skills unnecessary (the share of those in both university is quite high); it confirms the role of the educational institution;
- many students are not informed about the portfolio technology. We possess it a result of insufficient management in terms of personal brand formation and development;
- in general, according to research results, mastering of portfolio technology as a tool for personal branding and competitiveness is poor.

The trends of rapid production renewal in modern conditions determine the high demands on the new generation of specialists. It requires the students' activity, independence, flexibility, non-standard thinking, general and professional culture. Indeed, earlier, the purpose of education was the formation of the knowledge, skills, and qualities of a person necessary for work. Nowadays, specialist training involves the development of personality qualities relevant to achieving success in any professional activity.

However, an employment of the university graduates requires the development of the job selection criteria.

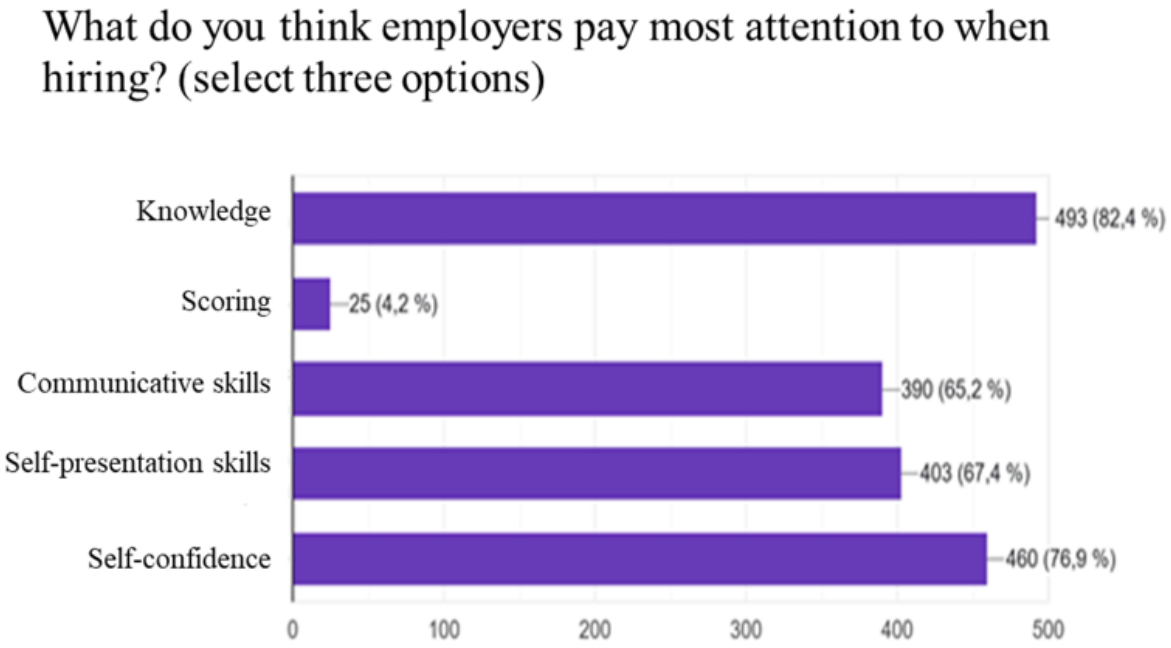


Figure 1. YSTU students' views on the job selection criteria (% of the respondents)

Source: Authors

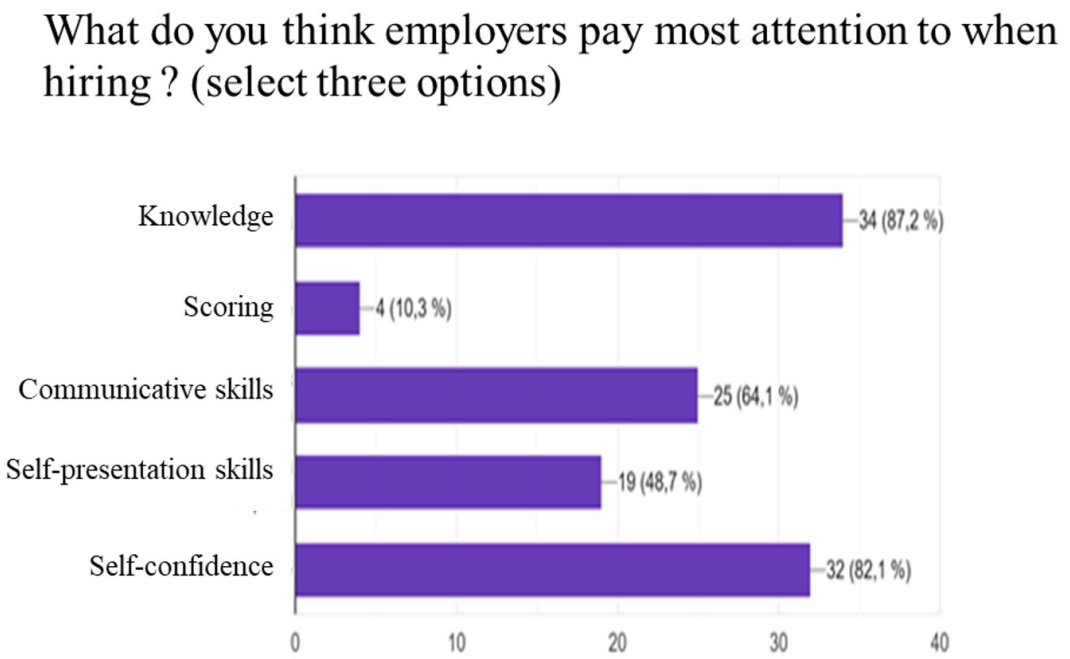


Figure 2. KSAA students' views on the job selection criteria (% of the respondents)
Source: Authors

According to the comparative analysis, there is a difference in the assessment of criteria such as "diploma grades": 4.2% versus 10.3% and "self-presentation skills" 67.4% versus 48.7%. It may indirectly indicate differences in local labour markets. However, to contradict knowledge, skills, and abilities to the personality qualities requires the achievement of success in the professional activity. To address the problem, the following question was asked:

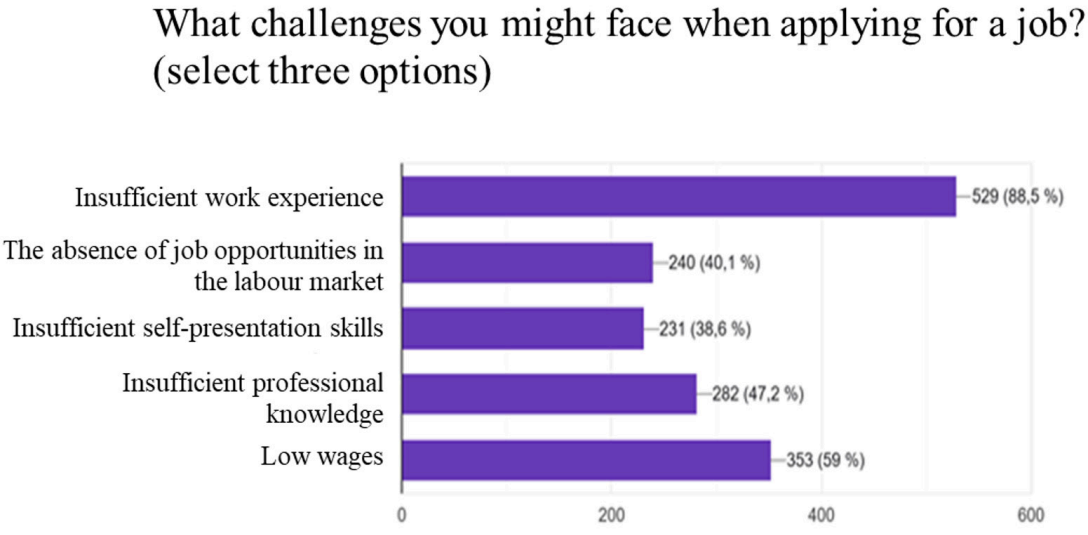


Figure 3. YSTU students' assessment of difficulties in employment (% of the number of respondents)
Source: Authors

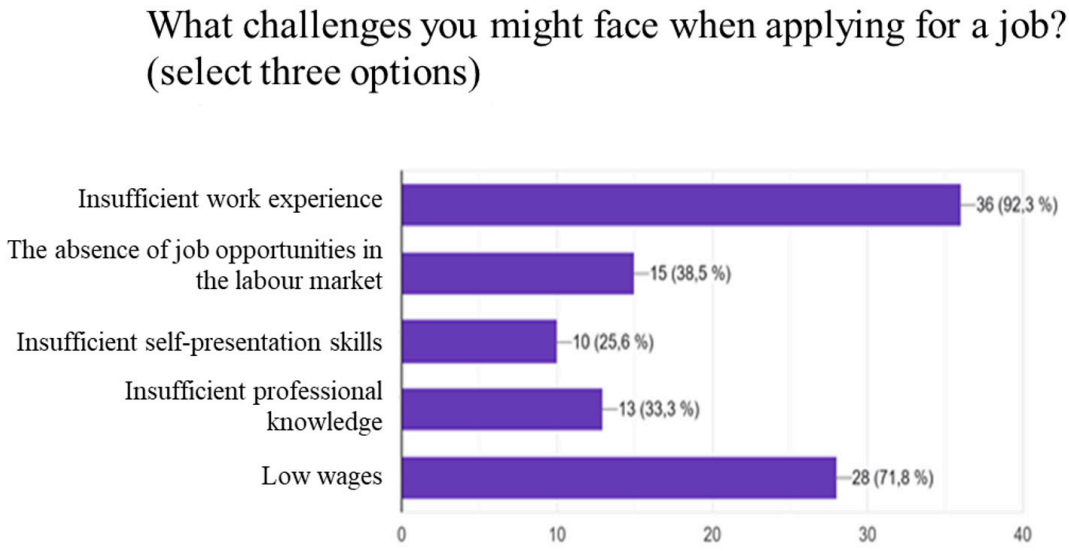


Figure 4. KSAA students' assessment of difficulties in employment (% of the number of respondents)
Source: Authors

To the question: "How do you assess the level of competition for young professionals in the labour market in your city?":

Table 2 – Respondents' assessment of the level of competition in the local labour market (% of the number of respondents)

Assessment	YSTU	KSAA
The competition is high, it is difficult to get a job in the specialty	52.2	47.8
The competition is not very high, it is not difficult to get a job in the specialty	48.7	51.3

Source: Authors

The results of the study revealed a significant contradiction since the higher education system ignores the possibility of using the portfolio methodology as a tool for personal competitiveness. According to the study, 94.3% of YSTU students and 86.8% of KSAA students consider important the professional and career growth. To the question: "Which of these personal qualities would you like to develop for yourself, since you are not good enough at it yet?"

The ability to show oneself needs to be developed chose 73.5% of YSTU and 55.2% of KSAA students.

Conclusion

Nowadays, on the competitive labour market, having a portfolio is of particular importance to increase one's competitiveness. A portfolio is a collection of works, achievements, and projects demonstrating a specialist's professional skills, experience, and personal qualities.

One of the key advantages of a portfolio is the opportunity to demonstrate real examples of the achievements and competencies to potential employers or clients. The portfolio as convincing evidence of the candidate's competence and reliability in the conditions of high competition in the labour market.

In addition, the portfolio promotes personal and professional development. Regularly updating of a portfolio helps to track professional growth, analyse achievements, and set new goals. It allows the specialist to be competitive in the labour market and ready for new challenges.

In the education, the portfolio also establishes the competitiveness of future specialists. In universities, a portfolio in a special professional, and socio-educational practice for development and assessment of students' competencies. This allows graduates to develop professional qualities, and effectively present their

achievements to future employers.

The effectiveness of a portfolio as a competitive tool is determined by following factors: firstly, it is the relevance of portfolio materials; secondly, it has a clear structure and logical presentation of information; thirdly, the portfolio shows the professional growth and development. A portfolio is a fashion trend, and a necessary tool of a modern professional. It ensures a career development, establishes business contacts, and increases graduates' personal value in the labour market.

However, an empirical study conducted at two universities revealed the ineffective use of this tool for building a personal brand and competitiveness. Despite of motivation to develop self-presentation skills, and a desire to pursue a career in the profession, practice of using portfolio technology does not achieve its goals.

FUNDING

The work was done on a personal initiative.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTION

Irina V. Popova – writing – original draft.
Marina B. Abramova – data curation, formal analysis, validation.
Alexey V. Zorin – conceptualization, project administration, writing – review & editing.

References

1. Asmolov, A. G., & Pasternak, N. A. (2020). *The child in adult culture*. Moscow: Yurait. (in Russian)
2. Bolotov, V. A. (2010). Scientific and pedagogical support for the assessment of the quality of education. *Problems of Modern Education*, (1), 9–13. (in Russian)
3. Vazhnova, O. G. (2015). Formation of the comprehensive school brand. *Yaroslavl Pedagogical Bulletin*, 2(2), 7–12. (in Russian)
4. Volochaeva, O. F. (n.d.). The personal brand of a journalist as a factor of professional success in the new conditions. *Scientific Papers of RANEPA*, 14(1[58]), 50–53. (in Russian)
5. Donina, E. E. (2023). The content of the concept of "personal professional brand of a teacher." In E. Yu. Ignatieva, S. M. Elkina, & M. V. Zvyaglov (Eds.), *Collection of scientific articles of the All-Russian Scientific and Practical Conference (pp. 47–52)*. Veliky Novgorod. (in Russian)
6. Zeynelova, A. E. (2017). The image and personal brand of a teacher. In *Human Studies: Proceedings of the 13th International Scientific Conference. (pp. 18–22)*. Kemerovo: Pluto Publishing House. (in Russian)
7. Zimnyaya, I. A. (2010). *Educational psychology*. Moscow: MPSI. (in Russian)
8. Knyazeva, M. A. (2020). Discourse analysis as a method of teaching the discipline "Brand Management" (on the example of a university brand). *Education and Problems of Society Development, 1(10)*, 67–71. (in Russian)
9. Mazilkina, E. I. (2008). *Branding: Study and practice (Textbook)*. Moscow: Dashkov and Co. (in Russian)
10. International Conference "Portfolio in Modern Education." (2020). Moscow.
11. Pitko, O. A. (2022). The role of social networks in promoting a teacher's personal brand. *Actual Problems of Modern Science, Technology and Education, 13(1)*, 91–94. (in Russian)
12. Popova, I. V., Abramova, M. B., & Zorin, A. V. (2024). The structure of students' personal competitiveness as a determinant of target setting formation in academic educational process. *Journal of Regional and International Competitiveness, 5(4)*, 46.
13. *Problems and prospects of education development (IV): Proceedings of the International Scientific Conference, Perm, July 2013.* (2013). Perm: Mercury. (in Russian)
14. Radionova, N. F. (2019). The realisation of competency approach in the process of studying of the

master course "Pedagogical design of educational process at the University." *The Emissia. Offline Letters: An Electronic Scientific Journal, (12)*, ART 2795. http://emissia.org/offline/2019/2795.htm (accessed June 24, 2025).

15. Stefanovskaya, T. A. (1988). *Pedagogy: Science and art. A course of lectures. A textbook for students, teachers, and graduate students*. Moscow: Svershenstvo. (in Russian)

16. Selevko, G. K. (1998). *Modern pedagogical technologies (Textbook)*. Moscow: Narodnoe obrazovaniye. (in Russian)

Received 22.06.2025
Revised 12.08.2025
Accepted 12.09.2025

Jraic.com
JOURNAL OF REGIONAL AND INTERNATIONAL COMPETITIVENESS 2025; 6(3):31-37

Digital twins as a tool to increase the efficiency and sustainability of the agro-industrial complex

Alexander P. Berus

ORIGINAL ARTICLE

Kuban State Agrarian University named after I.T. Trublin, Krasnodar, Russian Federation
E-mail: berusaleksandr@mail.ru

Anastasia V. Osadchaya *SPIN-код: 2176-7134, AuthorID: 1265597*

Assistant Lecturer
Kuban State Agrarian University named after I.T. Trublin, Krasnodar, Russian Federation
E-mail: osadchaj.a@edu.kubsau.ru

Abstract. This article examines the applicability and impact of digital twin technologies across the agri-food sector, from field operations to postharvest logistics. Building on a structured review of recent literature and industry cases, we synthesize how physics-based and data-driven twins integrate sensing, IoT, and AI to enable real-time monitoring, scenario analysis, and decision support. We classify agricultural digital twins into four functional groups – crop and livestock production, machinery and maintenance, postharvest handling, and supply-chain coordination – and map them to key performance indicators such as yield stability, resource efficiency, quality preservation, and risk reduction. The analysis identifies consistent benefits, including improved input use, earlier anomaly detection, and more resilient planning under weather and market uncertainty. However, adoption is constrained by data quality and interoperability issues, high initial costs, skills gaps, and unresolved concerns around cybersecurity and governance. We propose a staged implementation framework that prioritizes high-value use cases, lightweight edge analytics, and open data standards, accompanied by a governance model for data sharing. The article contributes a practical roadmap and a set of evaluation metrics that link digital-twin capabilities to farm-level and supply-chain decisions. Limitations relate to heterogeneous evidence and context specificity. Future work should explore integration with generative AI, privacy-preserving learning, and cross-farm platforms.

Keywords: digital twins; agrotechnology; digitalisation of agriculture; precision agriculture; virtual farm models

JEL codes: Q16, Q55, O33

DOI: 10.52957/2782-1927-2025-6-3-31-37

For citation: Alexander P. Berus & Anastasia V. Osadchaya. (2025). Digital twins as a tool to increase the efficiency and sustainability of the agro-industrial complex. *Journal of regional and international competitiveness*, 6(3), 31.

Introduction

Agriculture is one of the key sectors of the global economy. Nowadays, population growth, climate change, soil degradation, lack of water resources and qualified personnel are the threats to the sustainable development of the industry. According to the Food and Agriculture Organization of the United Nations (FAO), by 2050 the world's population will increase to almost 10 bn people[1]. In a scenario with moderate economic growth, such population growth rates will cause an increase in global demand for agricultural products by 50-60% compared to current level. It will degrade the natural resources. Moreover, already every 11 people in the world are hungry; according to an average estimate there are more than 735 mln of people. Therefore, the digital transformation of agriculture is becoming a prerequisite for ensuring food security and sustainable development.

Digital twins are innovative technologies of Industry 4.0. They allow us to optimise the agricultural processes, increase yields, conserve water, fertilizers, and energy, etc. [2]. However, the issue is understudied, especially for the developing countries.

The purpose of this work is to assess the opportunities and risks of digital twins in agriculture. Moreover, we emphasise on increasing of available resources efficiency and sustainability of agro-industrial production

[1] *Food and Agriculture Organization of the United Nations. (2018). The future of food and agriculture – Alternative pathways to 2050. FAO. Source: https://openknowledge.fao.org/server/api/core/bitstreams/e51e0cf0-4ece-428c-8227-ff6c51b06b16/content (accessed on 01.04.2025)*

through optimising processes, reducing costs, and minimising environmental threats. Our research focuses on the economic component of digital twins' implementation. The article focuses on the main areas of digital twins' application, provides practical examples, and discusses their key issues.

Many domestic and foreign scientists considered the development and implementation of digital twins in terms of productivity, sustainability, and transformation of agriculture. They are as follows: G.A. Getz [2], A.S. Dorokhov [1], L.O. Velikanova [12], A.V. Zharinov [15], I.A. Panteleev [7], S. Kim [4], W.J. Knibbe [5], X. Han [3], Y. Yin [14], D. Onwude [6], C. Pylianidis [8], etc.

Indeed, scientific literature consider a digital twin as a tool to increase the efficiency and sustainability of agricultural production. W.J. Knibbe [5] and X. Han [3] highlight successful applications of digital twins for optimising greenhouse microclimate and animal health monitoring. S. Kim [4] and Y. Yin [14] examines the possibilities of individualised agricultural management and predictive machine maintenance. D. Onwude [6] and C. Pylianidis [8] focuses on its environmental aspects and sustainable development issues.

The methodological basis of the study was a systematic approach, a method of comparative analysis, modelling, and forecasting. During the research we analyse statistical data, analytical materials, FAO reports, reports on the development of digital technologies, case studies in peer-reviewed international journals, etc.

Main part

Characteristics and concept ofthe digital twin

Digital twins are digital models of a physical objects or systems providing a connection between a physical object in reality and its virtual model. This technology is a part of Industry 4.0 based on the collection and analysis of data from sensors and other sources to simulate various processes and scenarios, forecast, and make optimal decisions [1]. It allows ones to simulate activity of the physical object and help to save time, money, avoid many risks associated with the implementation of various changes in the environment [15].

Digital twins can be classified in term of their purpose and level of complexity. The first type is a prototype (Digital Twin Prototype, DTP); it is used at the design and development stage and contains all the information to create a physical object, including geometric, structural, and technological models. DTP allows ones to optimise and test a product before its physical implementation, reduce risks and production costs. For example, in agriculture, DTP can be used to design new models of agricultural machinery or plan farm infrastructure.

The second type is a Digital Twin Instance (DTI); it is developed for a specific physical object and accompanies it throughout its life cycle. DTI collects data on the condition of the facility, its operation, repairs, and replacements. It allows it to monitor its performance and make decisions about necessary activity. In agriculture, those monitor the condition of agricultural machinery, animals, and plants.

The third type is an aggregated twin (Digital Twin Aggregate, DTA); it combines data from multiple digital twins for managing the objects and systems. In agriculture, those manage several fields or farms through analysis of soil, yields, and climatic conditions to optimise resources and development of various strategies.

The main components of a digital twin include three key elements: data collection, modelling, and application. Digital twins use four key technologies ensuring real-time data collection, storage, analysis, and design of physical objects digital representations.

Internet of Things (IoT) forms an extensive network connecting objects, people, or their combinations. Indeed, various types of wireless sensor networks are used to collect data from physical objects. It allows ones to design digital copies for analysis, manipulation, and optimisation.

Cloud computing provides digital twins with the necessary computing resources and storage capabilities. This technology helps digital twins to store extensive data in the cloud and access the necessary information. It effectively reduces the computing time of complex systems and solves the problems associated with storing large amounts of data.

Artificial Intelligence (AI) helps to analyse data, formulate recommendations, forecast system behaviour, and propose strategies to prevent potential problems. Key areas of AI include machine learning, computer

vision, natural language processing, etc.

Augmented Reality (AR/VR/MR) combines physical and virtual reality. Virtual (VR), augmented (AR), and mixed reality (MR) are subdomains included in the broad term of augmented reality. AR imposes digital information on real objects; VR and MR designs virtualised or hybrid environments for interacting with a model object.

The development of technology provides digital twins to be more complex and multifunctional. Modern digital twins can integrate data from a wide variety of sources, such as satellite imagery, meteorological data, and IoT devices. It provides modelling of various complex systems. In addition, with the development of machine learning and artificial intelligence technologies, digital twins can analyse current data, independently offer solutions to optimise processes, etc. [7].

Therefore, digital twins are increasingly being used in agriculture and forestry, animal husbandry, energy, construction, manufacturing, transport, logistics, healthcare, etc. According to MarketsandMarkets forecast, the global digital twin market will grow from 10.1 bn USD in 2023 to 110.1 bn USD by 2028, with an average annual growth rate of 61.3% over the forecast period[2].

The use of digital twins in agriculture

In agriculture, different types of digital twins are widely used. They optimise work processes and increase the efficiency of enterprises. Moreover, they design dynamic real time virtual models of physical agricultural objects, plants, animals, fields, or ecosystems. Using data from various sources such as sensors and IoT devices, satellites, drones, and weather stations, digital twins provide a deep understanding of current processes and help accurately manage agricultural operations. These models show the real state of objects, forecast their development by modelling of various scenarios using advanced algorithms, including machine learning technologies.

Precision farming is one of the key applications of digital twins. They allow farmers to simulate different crop scenarios, taking into account the soil type, climatic conditions, humidity levels, and nutrient availability to make efficient decisions for planting, watering, harvesting, management, etc.

For example, the practical application of digital twins in the tangerine orchards on Jeju Island, South Korea. According to Nature Communications Journal, scientists have developed and implemented a digital twin covering more than 185,000 hectares of tangerine plantations across the island. The system combines data from IoT sensors, satellites, open weather sources, and other digital platforms. The digital twin made it possible to track changes in the microclimate and plants, forecast yields with high accuracy.

The digital model achieved 89.6% accuracy in crop forecasts. It reduces crop losses and water consumption by 17% and 23%, respectively. Indeed, it optimises logistics and storage costs and decreases the associated costs by an average of 12% [4].

Therefore, digital twin is a tool for individualised agricultural management in terms of the specifics of zones. It ensures productivity and more sustainable resource management.

The resource management is an important aspect of digital twins' application. These technologies provide more efficient use of water, fertilizers, and various chemicals by monitoring soil and plant conditions. It significantly reduces waste, costs, and increases the sustainability of agriculture.

Willem Jan Knibbe described the use of a digital twin in greenhouse crop production in the Netherlands. The study presents a digital twin integrating data from sensors, climate models, and parameters of plants to optimise the management of microclimates in greenhouses. As a result, producers managed to reduce water consumption by 20-25%; increasing fertilizer efficiency by 18%. Moreover, modelling plant growth and automatically controlling environmental parameters (lighting, temperature, oxygen levels, etc.) increase tomato yields by 11% without increasing energy and chemical costs. It reduces the burden on the environment and provides the sustainable development of agriculture [5].

In animal husbandry, digital twins are used to monitor animal health in real time. Sensors installed on

[2] *Markets and Markets. Digital Twin Market Size, Share & Industry Trends Growth Analysis Report by Application, Industry, Enterprise and Geography – Global Growth Driver and Industry Forecast to 2028. Source: https://www.marketsandmarkets.com/Market-Reports/digital-twin-market-225269522.html (accessed on 12.03.2025)*

animals collect data on their movement, behaviour, body temperature, and other physiological parameters. These data are transferred to a digital model analysing and identifying deviations from the norm to explore the health problems at an early stage.

For example, China has developed a digital twin model for cattle monitoring. The study used IoT sensors installed on animals to collect data on their body temperature, activity level, behaviour, and other parameters. These data were transferred into a digital model based on deep learning algorithms. The model analysed animal behaviour and detected deviations from the norm in real time. The system achieved an accuracy of 94.97% in classifying animal behaviour. It increases significantly the timeliness of disease detection and reduces losses. The model was successfully used to monitor 120 heads of cattle for 30 days, demonstrating high reliability and scalability [3].

In addition, digital twins are used in the management of agricultural machinery. The analysis of data from tractors and other machines provides predictive maintenance. It prevents breakdowns, reduces downtime, and increases the service life [11].

For example, the development of a digital twin for the Lovol GM100 combine harvester. The study implemented a lightweight digital twin system simulating both the structure of the machine and the complex kinematic relationships between its key components. One of the key elements of the system was an intelligent fuel consumption forecasting model based on the LightGBM gradient boosting algorithm based on data received from sensors in real harvest conditions.

The system covered a variety of parameters, including driving speed, transmission load, and current fuel consumption. Special attention was paid to maintaining the correct transmission of the physical behaviour of the combine units in real-time conditions. According to the field tests, the fuel consumption of forecasting system under full load conditions reaches an average error is 0.24 l/h; a maximum error is 0.84 l/h; an average relative error is 1.09% [14].

It provides the reduction of maintenance and fuel costs. Moreover, the implementation of predictive analytics helps to make technical and managerial decisions based on machine behaviour.

Moreover, the transportation, drying, cooling, and storage of agricultural products can also be optimised through using digital twins. The technologies enable real-time monitoring of the supply chain. It increases its reliability and sustainability.

Monitoring of data on temperature and humidity in the warehouse prevents a spoilage and increases a duration of products by using digital twins. Indeed, a digital warehouse twin can analyse temperature and humidity data to make timely adjustments and prevent losses.

To analyse and optimise the storage and transportation conditions of fresh cucumbers, eggplants, strawberries, and raspberries the scientists of Swiss Empa laboratory designed a digital twin. The programme organised the temperature and associate it with a loss of product quality based on measuring air temperature data. The study analysed 95 shipments in the cold chain from Spain to Switzerland. According to the results, reducing the storage time at the distribution centre by just one day increased the quality of the fruit quality index by 18% for cucumbers and eggplants and by 60% for berries. Reducing the temperature during shipment by 5°C extended duration of strawberries by an average of 36%, and raspberries by 73%. In addition, a 10% increase in relative humidity during transportation and storage reduced weight loss for all fruits studied by 20% [9].

Therefore, use of digital twins can significantly improve the efficiency of post-harvest processes, reduce product losses, and increase the quality of fruits supplied.

Generally, digital twins help model market demand and supply in accordance with the market needs. It reduces the excess production and associated costs and increases the profitability of agricultural enterprises [12].

Moreover, the technology is also used for environmental monitoring and compliance with regulatory requirements and standards. Digital models (twins) help to model and monitor parameters of greenhouse gas emissions, chemicals, soil, water, etc. It ensures quickly responding to deviations from the norm and developing measures to reduce the negative impact of agricultural activities on the environment.

One of the most significant domestic examples of digital twin technologies is Russia's largest agricultural holding Rusagro Group of Companies, Russia. The company actively uses digital twins in various segments of business, including logistics, processing of agricultural products, and crop production.

The latter uses digital field containing information about the electronic boundaries of passive zones, the history of crop cultivation, soil indicators, and the results of technological operations. It optimises the use of machinery, forecasts and monitors harvesting, etc. To plan farming rotation, Rusagro designed a digital product. It analyses more than a million scenarios for each field with a planning horizon of up to 10 years, considering chemical composition of the soil, potential yields, and market conditions.

In the fat and oil business, Rusagro designed digital twins of its oil extraction plants and raw material management models based on the Digital Farmer platform. It optimises logistics, reduces transportation costs, and improves raw material management. Based on LLamasoft Supply Chain Guru, the company has developed a tactical model for 1 year, focusing on the sunflower harvest season, and designed an operational model with a next day planning horizon. These models efficiently distribute the volume of raw materials, increase the capacity utilisation of factories and elevators, and adapt to the current conditions. As a result, the average unloading time decreased by 15%; the cost of hired transport decreased by almost 10%; the total savings on transportation costs per crop amounted to 6.2 mln RUB.

In addition, Rusagro implemented the Russian MES-class production management platform – IndaSoft at its enterprises, including elevators, the oil extraction plant in Balakovo, Saratov region, Russia and the fat plant in Saratov, Russia. It optimises the company's management processes, minimises the risks of disruptions of the production process, and ensures the import substitution.

Finally, Rusagro introduces an integrated approach to the digital transformation of the agro-industrial complex, successfully implementing digital twins to increase efficiency, reduce costs, and ensure sustainable development.

These examples of practical applications of digital twins in agriculture demonstrate their potential in optimising various processes, increasing the efficiency and sustainability of the agro-industrial complex.

Challenges of digital twin implementing

One of the main barriers to the adoption of digital twins is the high cost of their development and implementation. Digital twin function requires the development or purchasing software, stable Internet connection, cloud services for data storage and processing to integrate them into existing enterprise management systems. According to analysts, the cost of implementing a digital twin in agricultural production may exceed 50,000-100,000 USD per medium-sized enterprise, depending on its scale and complexity of the technological infrastructure[3].

The large agricultural holdings, especially in highly competitive conditions, could implement these technologies. However, such investments are unaffordable for small and medium-sized farms, especially in countries with a low level of digitalisation. According to the EU farmers survey, only 27% of small and medium-sized businesses are ready to invest in digital twins in the next 5 years. However, they note insufficient free capital and government support [8].

Additionally, digital twins require investments for start-ups, regular maintenance, software updates, and equipment calibration, increasing overall costs.

Moreover, the effective use of digital twins requires specialists with serious interdisciplinary knowledge in IT, engineering, data management, modelling, and artificial intelligence (AI). Nowadays, there is a serious shortage of such personnel, especially in developing countries [8].

Therefore, farmers and qualified employees of agricultural holdings often have difficulty interpreting the results generated by digital models. It reduces the effectiveness of digital twins using, requiring additional investments in training and retraining of personnel.

The introduction of digital twins often requires significant changes to existing processes and

[3] *Markets and Markets. Digital Twin Market Size, Share & Industry Trends Growth Analysis Report by Application, Industry, Enterprise and Geography – Global Growth Driver and Industry Forecast to 2028. Source: https://www.marketsandmarkets.com/Market-Reports/digital-twin-market-225269522.html (accessed on 12.03.2025)*

infrastructure. It is difficult and costly, especially for businesses using the outdated technologies. Nevertheless, the integration of digital twins with other systems such as IoT and Big Data requires careful configuration and testing.

The effectiveness of digital doubles directly depends on the quality and volume of data, including sensors, satellite images, and weather forecasts. Insufficient data accuracy or lack cause the incorrect forecasts and decisions negatively affecting the management of agricultural processes.

The main issue is the heterogeneity of data from different sensors and devices. As a result, digital twins might have difficulties in integrating data from various sources, decreasing the accuracy of models and forecasts. Therefore, they require constant monitoring and calibration of equipment.

The quality of data can be directly affected by physical factors, such as failure of certain sensors, sensor drift, or power failures. Journal of Building Performance Simulation examines the issues of using streaming data in predictive digital twins [13].

Moreover, in agriculture digital twins process big data, confidential information on fields, yields, various business processes, etc. It makes them a potential target for cyber-attacks by intruders and competitors. Therefore, it is very important to ensure reliable data protection and compliance with regulatory requirements.

According to the report by Spain's national institute for Cybersecurity, INCIBE-CERT (Spain), digital twins are the critical vulnerability points as their security breach can lead to serious consequences for the operation of all industrial equipment and the safety of workers.

The study by IEEE highlights constant data synchronisation for physical and virtual environments as the relevant security risk in terms of digital twins. The most typical threats are attacks on data transmission channels, malicious interference in decision-making algorithms, and denial-of-service (DoS) attacks. Therefore, minimising risks requires spending on implementing secure communication protocols, encrypting data, creating role-based access, regularly updating software monitoring, and anomaly monitoring [10].

Hence, cybersecurity is an essential element in the implementation of digital twins. Its ignoring or being negligent can cause economic losses and endanger the sustainability of agricultural production.

Conclusion

According to the research results, digital twins are widely used in various fields of the agro-industrial complex, i.e. precision farming, greenhouse crop production, animal husbandry, logistics, agricultural machinery management, and post-harvest processes. Digital twins' implementation in Jeju Island, South Korea, the Netherlands, China, and Russia show the ability of the technology to increase yields, reduce resource costs, and optimise production processes. These examples show the high potential of digital twins as a key tool for improving the sustainability and efficiency of agriculture in limited resources and climate change.

However, the research revealed a number of serious barriers for the widespread adoption of digital twins. They are the high cost of development and implementation, the lack of qualified personnel capable of working with digital counterparts, necessary data quality and security, etc. It is particularly difficult to adapt the technology for small and medium-sized farms – a significant part of the agricultural sector worldwide.

Therefore, digital twins have sufficient potential to become a key tool for the transition to the agriculture of the future. It will provide more productive, sustainable, and adaptive agriculture. It requires coordinated efforts of the scientific community, business, and the government. However, the prospects justify the investments and risks.

FUNDING

The work was done on a personal initiative.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR'S CONTRIBUTIONS

Anastasia V. Osadchaya – conceptualization; supervision.
Alexander P. Berus – writing – original draft.

References

1. Dorokhov, S., Pavkin, D. Y., & Yurochka, S. S. (2023). Digital twin technology in agriculture: Prospects for use. *Agroingeniriya [Agroengineering]*, 25(4), 14–25. https://doi.org/10.26897/2687-1149-2023-4-14-25 (In Russian).

2. Getz, G. A., & Yefremov, A. A. (2022). The effectiveness of digital twins in agriculture. In *Novye informacionnye tekhnologii i sistemy (NITiS-2022)* (pp. 317–320). Penza State University.

3. Han, X., Lin, Z., Cameron, C., Vucetic, B., & Lomax, S. (2022). AI-based digital twin model for cattle caring. *Sensors*, 22(19), 7118. https://doi.org/10.3390/s22197118.

4. Kim, S., & Heo, S. (2024). An agricultural digital twin for mandarins demonstrates the potential for individualized agriculture. *Nature Communications*, 15. https://doi.org/10.1038/s41467-024-45725-x.

5. Knibbe, W. J., Afman, L., Boersma, S., Bogaardt, M.-J., van Evert, F., van der Heide, J., … de Wit, A. (2022). Digital twins in the green life sciences. NJAS: Impact in Agricultural and Life Sciences, 94(1), 249–279. https://doi.org/10.1080/27685241.2022.2150571.

6. Onwude, D., Bahrami, F., Shrivastava, C., Berry, T., Cronje, P., North, J., … Defraeye, T. (2022). Physics-driven digital twins to quantify the impact of pre- and postharvest variability on the end quality evolution of orange fruit. Resources, Conservation and Recycling, 186, 106585. https://doi.org/10.1016/j.resconrec.2022.106585.

7. Panteleev, I. A. (2024). Digital twins in the food industry: A new frontier of optimization and sustainable development. Finansovye rynki i banki [Financial Markets and Banks], (8), 201–203.

8. Pylianidis, C., Osinga, S., & Athanasiadis, I. N. (2021). Introducing digital twins to agriculture. Computers and Electronics in Agriculture, 184, 105942. https://doi.org/10.1016/j.compag.2020.105942.

9. Shoji, K., Schudel, S., Shrivastava, C., Onwude, D., & Defraeye, T. (2022). Optimizing the postharvest supply chain of imported fresh produce with physics-based digital twins. Journal of Food Engineering, 329, 111077. https://doi.org/10.1016/j.jfoodeng.2022.111077.

10. Siddique, S., Haque, M. A., Rifat, R. H., George, R., Shujaee, K., & Gupta, K. D. (2023). Cyber security issues in the industrial applications of digital twins. In 2023 IEEE Symposium Series on Computational Intelligence (SSCI) (pp. 873–878). https://doi.org/10.1109/SSCI52147.2023.10371850.

11. Ulezko, A. V., & Reimer, V. V. (2023). Priority tasks of modernizing the information support system for agriculture in the context of digitalization. Bulletin of the Moscow University of Finance and Law (MFUA), (2), 37–50.

12. Velikanova, L. O., & Maximenko, A. A. (2023). Digital transformation of agriculture: Modern development technologies. Vestnik Akademii znanij [Bulletin of the Academy of Knowledge], 6(59), 113–118.

13. Ward, R., Choudary, R., Jans Singh, M., Roumpani, F., Lazauskas, T., Yong, M., Barlow, N., & Hauru, M. (2023). The challenges of using live-streamed data in a predictive digital twin. Journal of Building Performance Simulation, 16(5), 609–630. https://doi.org/10.1080/19401493.2023.2187463.

14. Yin, Y., Ma, B., Meng, Z., Chen, L., Liu, M., Zhang, Y., Zhang, B., & Wen, C. (2024). Construction method and case study of digital twin system for combine harvester. Computers and Electronics in Agriculture, 226, 109395. https://doi.org/10.1016/j.compag.2024.109395.

15. Zharinov, A. V., & Zotov, B. V. (2023). Digital twins: Problems and prospects. In State audit in ensuring high quality of life of the population and national security: Proceedings of the international scientific and practical conference, Astana, April 1, 2023 (pp. 280–284). L. N. Gumilyov Eurasian National University.

Received 06.05.2025
Revised 16.07.2025
Accepted 10.08.2025

JOURNAL
OF REGIONAL
AND INTERNATIONAL
COMPETITIVENESS

JRAIC.COM