ДИАЛОГ КУЛЬТУР

МАТЕРИАЛЫ XIX МЕЖДУНАРОДНОЙ НАУЧНО-ПРАКТИЧЕСКОЙ КОНФЕРЕНЦИИ НА АНГЛИЙСКОМ ЯЗЫКЕ

Научное издание

Часть I

Санкт-Петербург
2026

Министерство науки и высшего образования Российской Федерации
ФЕДЕРАЛЬНОЕ ГОСУДАРСТВЕННОЕ БЮДЖЕТНОЕ ОБРАЗОВАТЕЛЬНОЕ УЧРЕЖДЕНИЕ ВЫСШЕГО ОБРАЗОВАНИЯ
«Санкт-Петербургский государственный университет промышленных технологий и дизайна»
Высшая школа технологии и энергетики

МАТЕРИАЛЫ

XIX Международной научно-практической конференции на английском языке «ДИАЛОГ КУЛЬТУР»

20–21 мая 2026 года

Научное издание
2026 ● Часть I

Под общей редакцией заведующего кафедрой иностранных языков, кандидата филологических наук, доцента
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Санкт-Петербург
2026

УДК 62+54+502.001
ББК 31+35+20.1
Д 44

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Д 44 Материалы XIX Международной научно-практической конференции на английском языке «Диалог культур» (20–21 мая 2026 г.). В 2 ч. / Минобрнауки РФ; ФГБОУ ВО «С.-Петерб. гос. ун-т промышленных технологий и дизайна»; ответ. ред. и сост. Т. С. Шарапа, М. С. Липатов; под общ. ред. В. В. Кирилловой. — СПб.: ВШТЭ СПбГУПТД, 2026. — Ч. I. — 414 с.

ISBN 978-5-91646-486-3

В настоящем сборнике представлены материалы XIX Международной научно-практической конференции на английском языке «Диалог культур», состоявшейся 20-21 мая 2026 года в Санкт-Петербурге.

Сборник адресован широкому кругу читателей, заинтересованных в научных открытиях и исследованиях, написанных учеными, докторами наук, профессорами, доцентами, преподавателями, аспирантами, магистрантами и студентами различных высших учебных заведений, а также всем, кто интересуется данной тематикой с целью применения в научной деятельности и образовательном процессе.

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Материалы конференции размещены в научной электронной библиотеке elibrary.ru и зарегистрированы в наукометрической базе РИНЦ (Российский индекс научного цитирования).

УДК 62+54+502.001
ББК 31+35+20.1

ISBN 978-5-91646-486-3

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Ministry of Science and Higher Education of the Russian Federation

FEDERAL STATE BUDGETARY EDUCATIONAL INSTITUTION OF HIGHER EDUCATION

“Saint Petersburg State University of Industrial Technologies and Design”
Higher School of Technology and Energy

PROCEEDINGS

of the XIX International Scientific and Practical Conference in English “DIALOGUE OF CULTURES”

Scientific publication
2026 ● Part I

Under the general editorship of Head of the Department of Foreign Languages, PhD in Philology, Associate Professor
V. V. Kirillova

Saint Petersburg
2026

UDC 62+54+502.001
BBK 31+35+20.1
D 44

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D 44 Proceedings of the XIX International Scientific and Practical Conference in English “Dialogue of cultures” (20–21 May 2026). In 2 parts / Ministry of Education and Science of the Russian Federation; FSBEI HE “Saint Petersburg State University of Industrial Technologies and Design”; responsible editors and compilers T. S. Sharapa, M. S. Lipatov; under the general editorship of V. V. Kirillova. SPb.: HSTE SPbGUITD, 2026. Part I, 414 p.

ISBN 978-5-91646-486-3

This collection presents the materials of the XIX International Scientific and Practical Conference in English "Dialogue of Cultures", held on 20-21 May 2026 in St. Petersburg.

The collection is addressed to a wide range of readers interested in scientific discoveries and research written by scientists, doctors of sciences, professors, associate professors, teachers, postgraduates, master's students and students of various higher educational institutions, as well as to all those who are interested in this subject in order to apply it in scientific activities and educational process.

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UDC 62+54+502.001
BBK 31+35+20.1

ISBN 978-5-91646-486-3

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SECTION 1. ECONOMICS AND SOCIAL DEVELOPMENT TRENDS

УДК 339.138

ARTIFICIAL INTELLIGENCE IN MARKETING

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Abstract. The study examines the role of artificial intelligence technologies in the marketing activities of modern enterprises. It highlights that the effective implementation of these technologies requires the ongoing development of employees' digital and information technology competencies. At the same time, the introduction of artificial intelligence does not necessarily lead to a decrease in employment opportunities within the labor market. In addition, the research identifies the principal directions in which artificial intelligence can be applied in marketing practice.

Keywords: artificial intelligence, digital marketing, marketing strategy, consumer behavior, data analytics.

ИСКУССТВЕННЫЙ ИНТЕЛЛЕКТ В МАРКЕТИНГЕ

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Аннотация. В исследовании рассматривается роль технологий искусственного интеллекта в маркетинговой деятельности современных предприятий. Подчеркивается, что эффективное внедрение этих технологий требует постоянного развития цифровых и информационно-технологических компетенций сотрудников. В то же время внедрение искусственного интеллекта не обязательно приводит к сокращению возможностей занятости на рынке труда. Кроме того, в работе определены основные направления применения искусственного интеллекта в маркетинговой практике.

Ключевые слова: искусственный интеллект, цифровой маркетинг, маркетинговая стратегия, анализ данных, поведение потребителей, цифровые технологии, маркетинговая аналитика.

The accelerated development of digital technologies and their active integration into numerous areas of human activity are reshaping the modern socio-economic landscape. The growing availability of digital goods and services, the emergence of virtual environments for communication, and the expansion of online interaction platforms are influencing the behavioral patterns of consumers, transforming their

values, motivations, and everyday lifestyles. At the same time, the influence of opinion leaders in the digital environment is increasing, communities within social networks are actively developing, the market of specialized digital applications is expanding, and systems for managing relationships with consumers are becoming more sophisticated.

In this context, the further evolution of marketing is increasingly determined by the ability to achieve a deep and holistic understanding of consumer needs and behavioral patterns across multiple platforms, devices, and product segments. An essential function in this regard is performed by the analysis, prediction, and modeling of customer behavior through the use of advanced digital solutions. Such solutions include artificial intelligence, intelligent automation, deep learning methods, predictive analytics, and cognitive computing technologies. Among them, artificial intelligence occupies a particularly prominent position because of its strong capacity to enhance both the productivity and the overall effectiveness of marketing activity.

Over the past few years, artificial intelligence has emerged as one of the most dynamic and widely debated technological fields, exerting a substantial influence on numerous dimensions of contemporary society. In the sphere of marketing, its relevance is steadily increasing due to the growth of computing power, the reduction in data-processing costs, the acceleration of information analysis, and the improvement of managerial decision-making quality.

At the same time, the expanding implementation of artificial intelligence technologies contributes to rising demand for highly skilled specialists in information technology, data analysis, and software engineering. These professional competencies are crucial for the effective incorporation of intelligent systems into marketing practice and for the successful application of data-driven approaches in organizational operations.

In the context of the ongoing digital transformation of the economy, scholarly interest in the application of artificial intelligence technologies within marketing systems has grown considerably. Contemporary research increasingly highlights the role of intelligent digital tools in enhancing the analytical capabilities of organizations, optimizing marketing processes, and supporting the development of innovative approaches to market interaction. As companies accumulate large volumes of data about consumer behavior, the ability to effectively process and interpret this information becomes a critical factor in maintaining competitiveness.

A number of academic works examine the broader technological foundations that enable the development of intelligent systems within modern digital environments. For instance, A. Germanchuk studies the functioning of digital educational environments and emphasizes the importance of personalization technologies supported by advanced data-processing tools. The author notes that intelligent systems make it possible to adapt digital platforms to the individual characteristics and needs of users, thereby improving the effectiveness of interaction and communication processes within digital ecosystems [1, p. 15].

Another important area of research concerns the analytical potential of artificial intelligence in marketing activities. E. Biryuchenko explores the role of intelligent technologies in marketing analytics and highlights their ability to process extensive datasets, detect hidden relationships within consumer information, and support more

accurate market forecasting. According to the author, the implementation of artificial intelligence tools significantly expands the possibilities of analytical work in marketing and contributes to more informed managerial decision-making based on data-driven insights [2, p. 20].

The rapid expansion of digital commerce has also attracted the attention of researchers studying the transformation of marketing practices in online environments. In this regard, E. Korshunova analyzes current trends in the development of the e-commerce sector and identifies key factors shaping the evolution of digital trade. The author points out that the growth of online marketplaces and electronic sales channels stimulates the adoption of innovative technologies for managing customer interactions, analyzing demand patterns, and organizing marketing activities in digital markets [3, p. 78].

Taken together, these studies demonstrate that artificial intelligence technologies are gradually becoming an integral element of modern marketing infrastructure. Their use enables companies to automate the collection and processing of information, improve the accuracy of consumer behavior analysis, and create more personalized marketing communications. As a result, organizations gain new opportunities to strengthen long-term relationships with customers, enhance the effectiveness of their marketing strategies, and successfully adapt to the rapidly changing conditions of the digital economy.

Even though intelligent technological solutions applied in marketing have been extensively examined in academic discourse, their accelerating diffusion within corporate practice continues to create both promising opportunities and new professional difficulties. According to N. O. Mizyaeva, contemporary digital space functions as a key environment in which brand identity is shaped and promoted, fundamentally altering the ways organizations communicate with audiences and construct their market presence [4, p. 47].

Under these circumstances, the introduction of advanced computational tools can substantially increase the effectiveness of promotional activities and streamline many organizational procedures. This improvement is largely connected with the delegation of routine, regularly repeated functions to automated systems that previously depended on manual effort. Consequently, marketing practitioners obtain greater freedom to concentrate on initiatives requiring imagination, analytical vision, and long-term planning related to brand advancement in online environments. At the same time, the expanding influence of technological innovations makes continuous professional development essential, as specialists must acquire new competencies and remain capable of adjusting to the constantly changing digital infrastructure that defines modern marketing practice. Furthermore, the growing reliance on artificial intelligence technologies highlights the importance of issues related to data security and responsible data management. In this regard, it is important to conduct a balanced assessment of both the potential benefits and the possible risks that accompany the implementation of artificial intelligence technologies. Particular attention should also be given to the preparation and training of specialists who possess the necessary competencies to effectively work with such digital tools. A comprehensive analysis of these aspects allows organizations to use the advantages of artificial intelligence more efficiently

while reducing the likelihood of negative consequences for the development of marketing activities.

The main objective of this study is to analyze the opportunities provided by artificial intelligence technologies as well as the potential challenges that may arise during their integration into the marketing processes of modern enterprises.

Over the past few years, artificial intelligence has achieved notable progress, especially in areas associated with complex analytical and cognitive tasks that were traditionally performed by managers and highly skilled professionals. Individuals occupying such positions typically depend on abilities such as inductive reasoning, social awareness, creative thinking, and the capacity for innovation. Despite the rapid advancement of digital technologies, these human capabilities still remain difficult to fully replicate through artificial intelligence systems at the current stage of technological development.

At the same time, some experts predict that in the near future many employees may face the risk of job displacement or may need to acquire new professional skills due to the automation of certain work functions. Several studies examining changes in workforce composition and work processes resulting from investments in artificial intelligence provide valuable insights into the transformative potential of these technologies in marketing activities.

The potential risk of job displacement encourages professionals to constantly expand their knowledge and skills, develop interdisciplinary competencies, and actively participate in professional training programs, seminars, and educational initiatives focused on emerging digital technologies. In this context, the development of artificial intelligence technologies should be viewed not only as a challenge but also as an opportunity for professional growth and workforce development.

The adoption of intelligent digital systems in business practice raises a range of challenges connected with the handling of information and the protection of confidential materials. AI-based solutions process the data that organizations supply to them without independently evaluating its reliability, sensitivity, or level of confidentiality. As a result, there is a possibility that strategically important corporate information, employee records, or private client details may be unintentionally exposed. Incidents of this nature can negatively affect a company’s reputation, lead to economic losses, and in some cases provoke legal disputes or regulatory sanctions.

These factors demonstrate that the integration of advanced algorithmic technologies into organizational activities requires a particularly careful and responsible approach. In the context of communication between firms and their audiences, concerns about the safety of personal information often become a source of tension. When individuals doubt that their private data is adequately protected, their perception of a company may deteriorate. Such uncertainty may alter consumer trust and provoke unpredictable responses to the decisions and initiatives of particular organizations [5].

Another challenge lies in the reliability of the results generated by neural network–based artificial intelligence systems. These systems may occasionally produce inaccurate or misleading information as a result of incorrect interpretation of input data or distortions during the processing stage. Moreover, the quality of artificial

intelligence outputs cannot be considered constant, as it may vary depending on external factors and the characteristics of the training data.

It should also be noted that the creation, preparation, and widespread application of intelligent algorithmic systems in business and production settings usually demand considerable capital expenditures and substantial technological capacity.

Therefore, despite the numerous advantages offered by artificial intelligence technologies, they should primarily be viewed as tools designed to support human decision-making rather than replace it entirely. Even though intelligent algorithmic systems possess substantial capacity to optimize promotional activities and increase the overall performance of marketing strategies, their effective use still depends on human participation. Strategic planning, coordination, and control carried out by specialists remain essential for achieving balanced and reliable outcomes.

Although such digital solutions are gradually spreading across numerous branches of the economy, only a limited number of marketing professionals currently employ them for complex technical operations such as software development. In everyday professional practice, these systems are more frequently utilized for examining large datasets, detecting inconsistencies within existing platforms, and supporting the refinement of marketing approaches.

At the same time, some practitioners avoid openly acknowledging their reliance on automated analytical tools, fearing that colleagues may react critically to this practice. Others question the ethical aspects of using such technologies or doubt their stability and dependability. Nevertheless, among independent specialists and experts who actively experiment with modern digital instruments, interest in intelligent technologies continues to grow. This tendency demonstrates both the increasing importance of advanced analytical systems and the necessity for further academic investigation aimed at ensuring their effective incorporation into professional marketing activities.

A key prerequisite for the effective use of artificial intelligence technologies is the continuous training and professional development of organizational staff in the field of digital technologies and data analytics. The continued expansion of intelligent digital systems within marketing activities may eventually enable organizations to allocate greater attention to long-term planning and the growth of business initiatives. At the same time, automated solutions can significantly decrease the human effort and time traditionally spent on repetitive and routine operational functions.

Further academic investigation in this field should therefore concentrate on the applied dimension of adopting intelligent technologies. Particular emphasis should be placed on formulating practical frameworks and detailed methodological guidance that support their effective utilization in the planning, development, and implementation of marketing strategies.

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УДК 339.138

CURRENT TRENDS AND MARKET DYNAMICS IN ELECTRONIC COMMERCE

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Abstract. The paper analyzes the advantages of electronic commerce for both business entities engaged in entrepreneurial activity and consumers purchasing goods and services online. A steady increase in the number of users of the global Internet network is observed. Furthermore, the study identifies and characterizes the key trends and patterns that determine the further development of the online sales sector.

Keywords: electronic commerce, internet users, social media, internet marketing, data analytics.

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АКТУАЛЬНЫЕ ТРЕНДЫ И ДИНАМИКА РЫНКА ЭЛЕКТРОННОЙ ТОРГОВЛИ

Аннотация. В работе анализируются положительные стороны электронной коммерции как для организаций, осуществляющих предпринимательскую деятельность, так и для потребителей, приобретающих товары и услуги в сети. Отмечается устойчивая тенденция роста численности пользователей глобальной сети Интернет. Кроме того, в исследовании выявлены и охарактеризованы основные направления и закономерности, определяющие дальнейшее развитие сегмента онлайн-продаж.

Ключевые слова: интернет-торговля, интернет-пользователи, социальные сети, интернет-маркетинг, анализ данных.

In the context of the ongoing digitalization of the economy, the importance of online product sales continues to increase. The use of Internet-based technologies has become an effective mechanism for distributing goods, as it enables companies to establish sales channels within a relatively short period of time and with lower financial costs. Under challenging economic conditions, this form of commercial activity supports the sustainability of domestic producers while also creating opportunities for their further growth and strengthening of their market positions.

The expansion of digital communication technologies has contributed to the emergence of electronic commerce as an integral component of the contemporary trade system. Owing to the development of the global network, this form of commercial interaction has acquired an international dimension and continues to involve a steadily growing number of participants, including firms, intermediaries, and end consumers.

Within the modern business environment, e-commerce provides numerous advantages both for companies offering goods and services and for customers purchasing them. For organizations, it creates additional opportunities to expand market reach and optimize business processes, while consumers benefit from more convenient conditions for searching, selecting, and acquiring products. A key factor in the effectiveness of online sales is the ability to address individual consumer needs and preferences. Implementing such an approach allows enterprises to achieve sustainable competitive advantages and improve the overall performance of their economic activities.

One of the most significant advantages of online commerce is the opportunity for consumers to search for, evaluate, and purchase products at any time of the day regardless of their geographical location. This format of interaction makes the purchasing process highly convenient and accessible to a broad range of users.

An important factor contributing to the effectiveness of electronic commerce is the formation and maintenance of a positive brand image within the digital environment. In highly competitive markets, consumer perceptions of a brand largely determine their willingness to make online purchases and continue interacting with a company. A strong brand enhances customer trust, increases brand recognition, and encourages repeat purchasing behavior.

Communication content distributed through digital channels, including social media platforms, online marketplaces, and corporate websites, plays a particularly significant role in this process. A well-structured communication strategy enables companies to shape a stable brand perception and establish long-term relationships with their customers. As noted by A. N. Germanchuk and N. O. Mizyaeva, the structure of brand image is significantly influenced by the nature of communication content, which affects how the target audience perceives the company and contributes to the formation of its reputation within the information space [1, p. 296].

Another important benefit of electronic commerce is that customers can obtain up-to-date and reliable information about products directly from manufacturers. This enables consumers to examine product characteristics in detail and compare them with similar offerings provided by competing companies. For businesses, the digital environment facilitates faster communication with potential customers regarding the introduction of new products and reduces the costs associated with testing and developing product prototypes.

The application of Internet technologies also allows firms to broaden their market reach and enter new sales territories that were previously difficult to access. At the same time, companies gain the ability to analyze customer preferences more effectively, which contributes to better satisfaction of consumer demands and the

establishment of long-term mutually beneficial relationships.

Furthermore, electronic trading platforms enable buyers to complete transactions using a wide range of digital payment systems. Modern Internet-based telecommunications technologies also provide continuous customer support and allow orders for goods to be placed at any time and from virtually any location worldwide [2, p. 33]

One of the defining characteristics of the contemporary global economic system is the increasing emphasis on the personalization of sales processes. Under such conditions, companies are required to deliver specific goods or services to individual consumers while maintaining an optimal cost structure. In this context, electronic commerce serves as an effective mechanism for achieving these objectives, as it facilitates interaction between producers, suppliers, and customers through digital communication channels characterized by flexibility and high speed.

The rapid development of online trade has also been significantly influenced by the COVID-19 pandemic, which affected economic systems and everyday activities across the world. Although the crisis created considerable challenges for traditional retail formats, it simultaneously acted as a catalyst for the expansion of e-commerce. During the period of restrictions and lockdown measures, many companies redirected their efforts toward strengthening their online distribution channels.

Businesses that had already specialized in digital retailing experienced particularly strong growth during this period. Among the most prominent international online platforms are Amazon, eBay, AliExpress, Taobao, Tmall, JD.com, Wish, Newegg, and Lazada. Within the Russian market, significant growth was demonstrated by companies such as Ozon, Wildberries, DNS, Citilink, M.Video, and Samokat.

Table. Largest E-Commerce Platforms in Russia

Platform	**Segment**	**Sales Indicator**
Wildberries	marketplace	approximately $50 billion GMV (2024); about 47 % of the Russian market
Ozon	marketplace	around 1.4 trillion rubles in online sales turnover
DNS	electronics retail	approximately $2.68 billion in online sales
Citilink	electronics retail	major online retailer of consumer electronics
M.Video	electronics retail	actively developing e-commerce operations
Samokat	rapid delivery service	operates in the quick-commerce segment

The analysis of the data presented in Table indicates that the Russian e-commerce market is characterized by a high level of concentration around major online

marketplaces. Platforms such as Wildberries and Ozon occupy leading positions and account for a significant share of total online retail turnover, acting as key drivers of the national digital commerce sector. At the same time, specialized retailers focusing on specific product categories, particularly consumer electronics, also play an important role, including companies such as DNS, Citilink, and M.Video. Another emerging direction in the development of e-commerce is the quick-commerce segment, represented by services such as Samokat, which are focused on meeting consumer demand through rapid delivery. Overall, the data suggest an increasing diversification of the market structure and growing competition among different formats of online retail.

Consequently, the restrictive measures introduced during the pandemic significantly accelerated the digital transformation of retail activities, prompting many companies to shift toward online business models. Another notable trend is the increasing role of social networking platforms, which are gradually evolving into independent sales channels and functioning as full-fledged components of the modern e-commerce infrastructure.

One of the most prominent trends in the development of the digital economy in recent years has been the rapid expansion of the functional capabilities of social networking platforms, which are gradually transforming into independent channels of electronic commerce. Social media platforms are no longer limited to communication purposes; they have evolved into effective tools for the distribution of goods and services, enabling direct interaction between businesses and consumers.

An illustrative example of this transformation can be observed in the initiative implemented by the Spanish retail banking institution CaixaBank, which introduced a technological solution that enables retailers to conduct sales through social media platforms and messaging applications. During the period of pandemic-related restrictions, many small businesses were forced to suspend the operation of their physical outlets, which encouraged them to shift toward online commercial activities. In order to support entrepreneurs, the bank launched the Social Commerce service, allowing retailers to manage digital sales directly through their accounts on platforms such as Facebook, Twitter, Instagram, WhatsApp, and Telegram [3, p. 449].

It should also be emphasized that the effectiveness of such digital sales models largely depends on the quality and personalization of communication content distributed through online channels. As noted by N. O. Mizyaeva, personalized content plays a significant role in shaping brand identity and strengthening its perception among target audiences, thereby increasing the effectiveness of marketing communication strategies in the digital environment [4, p. 213].

As emphasized by E. A. Korshunova, the formation of sustainable customer loyalty largely depends on the quality of interaction between companies and their audiences, as well as on the level of consumer satisfaction with the goods and services provided [5, p. 256]. In this context, digital communication channels play an increasingly important role, enabling firms to establish effective relationships with customers and maintain long-term engagement.

Within the contemporary digital environment, social media platforms function not only as channels for product distribution but also as powerful tools for brand promotion. Companies actively employ various content formats, including video materials, textual publications, visual posts, advertising campaigns, and collaborative projects with well-known online influencers. Moreover, social networks provide favorable conditions for the development of small businesses by offering additional opportunities to promote their products. For instance, the platforms Facebook and Instagram introduced the “Share a Business” feature, which allows users to recommend their preferred brands and stores to a wider audience.

According to E. A. Korshunova, effective engagement with consumers requires the implementation of modern marketing instruments aimed at increasing customer involvement and satisfaction levels [5, p. 256]. As the e-commerce sector continues to expand rapidly, companies increasingly rely on various forms of Internet marketing to attract potential buyers. These include promotion through video-hosting platforms, the creation of specialized digital platforms containing information about producers and distributors, as well as the use of viral marketing strategies, email marketing, and search-engine optimization techniques.

Marketing analytics also plays a crucial role in this process, as it enables organizations to enhance awareness of their products and services among potential customers, generate initial interest in purchases, and encourage further cooperation between consumers and businesses.

Within the framework of ongoing digital transformation, the Internet of Things has become another important technological factor influencing the development of online trade. These technologies allow companies to collect and process real-time data, conduct online customer surveys, analyze large datasets, and implement technological solutions such as QR codes to accelerate customer service processes.

At present, electronic commerce represents one of the most rapidly developing and economically promising areas of entrepreneurial activity. Experts suggest that the key trends shaping the future of this sector will include the growth of mobile commerce, the expansion of free delivery services, the development of digital shopping formats, and the increasing use of personalized databases designed to simplify and accelerate consumer decision- making processes.

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УДК 339.924

THE TRANSFORMATION OF CHINA'S ROLE IN THE SCO: FROM DEMOGRAPHIC GIANT TO ASYMMETRIC TRADE DOMINANCE

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Abstract. This paper examines China's evolving role in the Shanghai Cooperation Organisation (SCO) through the lens of macroeconomic indicators and trade flows over the 2015–2024 period. The study reveals a marked shift: while China's demographic weight within the SCO is gradually declining relative to India's, its share of intra-SCO trade has grown.

Keywords: Shanghai Cooperation Organisation, China, trade asymmetry, economic integration, intra-SCO trade, sanctions, de-dollarisation, Belt and Road Initiative, macroeconomic analysis.

ТРАНСФОРМАЦИЯ РОЛИ КИТАЯ В ШОС: ОТ ДЕМОГРАФИЧЕСКОГО ГИГАНТА К АСИММЕТРИЧНОМУ ТОРГОВОМУ ДОМИНИРОВАНИЮ

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Аннотация. В данной статье рассматривается эволюция роли Китая в Шанхайской организации сотрудничества (ШОС) через призму макроэкономических показателей и торговых потоков за период 2015–2024 годов. Исследование выявляет заметный сдвиг: хотя демографический вес Китая в рамках ШОС постепенно снижается по сравнению с Индией, его доля во внутриинтеграционной торговле выросла.

Ключевые слова: Шанхайская организация сотрудничества, Китай, торговая асимметрия, экономическая интеграция, торговля внутри ШОС, санкции, дедолларизация, инициатива «Один пояс, один путь», макроэкономический анализ.

The Shanghai Cooperation Organisation (SCO) stands today as one of the most

consequential regional groupings in the world, uniting more than 40 percent of the global population and roughly a quarter of world GDP. Within this space, China occupies a role that is at once indispensable and contested. It is the largest economy, the principal trading partner of virtually every member state, and the primary architect of the organisation's infrastructure agenda through the Belt and Road Initiative. Yet its dominance is neither uniform nor unchallenged: India's demographic trajectory is overtaking China's, Russia's geopolitical weight remains substantial, and the smaller Central Asian republics are quietly growing more assertive in calibrating their dependence on Beijing.

This paper traces the transformation of China's position in the SCO across the decade 2015–2024, using World Bank macroeconomic data and International Trade Centre bilateral trade statistics. The analysis proceeds from demographic and macroeconomic fundamentals, through the commodity and geographic structure of intra-SCO trade, to a forward-looking PEST and SWOT assessment of integration prospects. A particular focus is placed on the Russia–China bilateral axis, which has shifted dramatically since the 2022 sanctions package imposed by Western governments.

The SCO emerged from the "Shanghai Five" process of the 1990s, initially designed to settle Soviet-era border disputes between China and the newly independent Central Asian states. Formally established in 2001, the organisation acquired permanent institutions – a Secretariat in Beijing and the Regional Anti-Terrorist Structure in Tashkent – and expanded its mandate well beyond security into trade, transport, and technology. The most consequential moment of enlargement came in 2017, when India and Pakistan joined as full members, pushing the combined population of the bloc past 3.2 billion. Iran joined in 2023 and Belarus followed in 2024, each adding distinct strategic weight [1, p. 55].

The SCO Charter commits the organisation to principles of mutual respect for sovereignty, non-interference, and consensus-based decision-making. These norms suit China's preference for bilateral economic ties rather than supranational rules, but they also mean that the organisation lacks the binding trade liberalisation mechanisms of, say, the EU or ASEAN [2, p. 4]. Economic integration proceeds through project-by-project deals and framework agreements rather than common tariffs or a single market.

By any aggregate measure, China towers over the SCO economically. Its GDP accounted for roughly 71 percent of the organisation's combined output in 2015 and remained above 71 percent in 2024 despite a brief dip in the intervening years. In absolute terms, Chinese GDP grew from approximately $11.3 trillion to $18.7 trillion over this period, while the entire rest of the SCO moved from roughly $4.5 trillion to $7.4 trillion combined (Table 1) [3]. India grew faster in relative terms – its share of SCO GDP climbed from 13.3 to nearly 15 percent – but the gap in absolute scale remains enormous (Table 2) [3].

Table 1. GDP of the SCO countries, 2015–2024 (US$ billion)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
China (1)	11280,81	11456,02	12537,56	14147,77	14560,17	14996,41	18201,70	18316,77	18270,36	18743,80
India (2)	2103,59	2294,80	2651,47	2702,93	2835,61	2674,85	3167,27	3346,11	3638,49	3912,69
Russia (3)	1363,48	1276,79	1574,20	1657,33	1693,12	1493,08	1829,19	2291,61	2071,51	2173,84
Belarus (8)	56,45	47,72	54,73	60,03	64,41	61,37	69,67	73,78	72,48	75,96
Kyrgyzstan (9)	6,68	6,81	7,70	8,27	9,37	8,27	9,25	12,13	15,18	17,48
Tajikistan (10)	8,27	6,99	7,54	7,76	8,30	8,13	8,94	10,71	12,24	14,20
SCO	15799,03	16085,23	17898,08	19577,14	20074,36	20042,26	24292,42	25135,95	25187,25	26151,32

Table 2. Share of SCO countries in GDP, 2014–2023 (% of SCO GDP)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
China (1)	71,40	71,22	70,05	72,27	72,53	74,82	74,93	72,87	72,54	71,67
India (2)	13,31	14,27	14,81	13,81	14,13	13,35	13,04	13,31	14,45	14,96
Russia (3)	8,63	7,94	8,80	8,47	8,43	7,45	7,53	9,12	8,22	8,31
Belarus (8)	0,36	0,30	0,31	0,31	0,32	0,31	0,29	0,29	0,29	0,29
Kyrgyzstan (9)	0,04	0,04	0,04	0,04	0,05	0,04	0,04	0,05	0,06	0,07
Tajikistan (10)	0,05	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,05	0,05
SCO	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

The demographic picture, by contrast, is one of relative decline for China. Its population peaked around 2021–2022 and has since contracted, while India's has grown steadily. By 2024, India's 1.45 billion people slightly outnumbered China's 1.41 billion, and the gap is widening (Table 3) [3]. China's share of total SCO population slipped from 42.8 percent in 2015 to 41.1 percent in 2024, while India's rose from 41.2 to 42.3 percent (Table 4) [3]. This demographic crossing-of-curves does not immediately translate into economic rivalry – China's per-capita productivity remains far higher than India's – but it signals a long-run challenge to China's claim to demographic centrality within the bloc.

Table 3. Population of the SCO countries, 2015–2024 (million people)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
India (1)	1328,02	1343,94	1359,66	1374,66	1389,03	1402,62	1414,20	1425,42	1438,07	1450,94
China (2)	1379,86	1387,79	1396,22	1402,76	1407,75	1411,10	1412,36	1412,18	1410,71	1408,98
Pakistan (3)	217,29	220,14	223,27	226,93	230,80	235,00	239,48	243,70	247,50	251,27
Tajikistan (8)	8,64	8,87	9,09	9,31	9,53	9,75	9,97	10,18	10,39	10,59
Belarus (9)	9,46	9,47	9,46	9,44	9,42	9,38	9,30	9,23	9,18	9,13
Kyrgyzstan (10)	6,04	6,18	6,31	6,44	6,59	6,73	6,85	6,98	7,10	7,22
SCO	3225,41	3254,86	3284,79	3312,36	3337,80	3360,61	3379,35	3396,42	3413,37	3430,19

Table 4. Share of countries in the population of the SCO, 2014–2023 (% of the population of the SCO)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
India (1)	41,17	41,29	41,39	41,50	41,62	41,74	41,85	41,97	42,13	42,30
China (2)	42,78	42,64	42,51	42,35	42,18	41,99	41,79	41,58	41,33	41,08
Pakistan (3)	6,74	6,76	6,80	6,85	6,91	6,99	7,09	7,18	7,25	7,33
Tajikistan (8)	0,27	0,27	0,28	0,28	0,29	0,29	0,29	0,30	0,30	0,31
Belarus (9)	0,29	0,29	0,29	0,28	0,28	0,28	0,28	0,27	0,27	0,27
Kyrgyzstan (10)	0,19	0,19	0,19	0,19	0,20	0,20	0,20	0,21	0,21	0,21
SCO	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

A more immediately paradoxical finding concerns per-capita GDP. Despite its aggregate dominance, China ranked only third in the SCO on this measure in 2024, behind Russia ($14,890) and Kazakhstan ($14,010). China's own figure of $13,300 is respectable, but the gap illustrates that its economic leadership rests on scale rather than the highest living standards in the region (Table 5) [3]. For China to consolidate qualitative as well as quantitative leadership, it will need sustained growth in household income.

Table 5. GDP per capita of the SCO countries, 2015–2024 (US$,000)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Russia (1)	9,28	8,66	10,66	11,21	11,45	10,11	12,43	15,62	14,16	14,89
Kazakhstan (2)	10,20	7,48	8,94	9,47	9,46	8,78	9,98	11,26	12,88	14,01
China (3)	8,18	8,25	8,98	10,09	10,34	10,63	12,89	12,97	12,95	13,30
Kyrgyzstan (8)	1,11	1,10	1,22	1,28	1,42	1,23	1,35	1,74	2,14	2,42
Pakistan (9)	1,38	1,42	1,52	1,57	1,39	1,28	1,46	1,54	1,37	1,48
Tajikistan (10)	0,96	0,79	0,83	0,83	0,87	0,83	0,90	1,05	1,18	1,34
SCO	46,40	42,69	47,83	49,23	49,68	46,28	55,32	61,50	62,44	66,39

On macroeconomic stability, however, China's position is essentially unrivalled within the SCO. Inflation in China stood at just 0.22 percent in 2024 – a figure that contrasts sharply with Pakistan's 12.6 percent, Iran's 32.5 percent, and Uzbekistan's 9.6 percent (Table 6) [3]. This pricing stability provides Chinese exporters with a competitive edge and supports Beijing's ambition to promote the renminbi as a regional settlement currency. The structural composition of Chinese GDP has also shifted: industry fell from 40 to 36 percent of output between 2015 and 2024, while services rose from 52 to 57 percent, reflecting a genuine, if incomplete, transition toward a more mature economic model (Figure 1) [3].

Table 6. Inflation rate in the SCO countries, 2015-2024 (%)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
China (1)	1,44	2,00	1,59	2,07	2,90	2,42	0,98	1,97	0,23	0,22
India (2)	4,91	4,95	3,33	3,94	3,73	6,62	5,13	6,70	5,65	4,95
Belarus (3)	13,53	11,84	6,03	4,87	5,60	5,55	9,46	15,21	5,00	5,79
Uzbekistan (8)	8,75	8,13	13,88	17,52	14,53	12,87	10,85	11,45	9,96	9,63
Pakistan (9)	2,53	3,77	4,09	5,08	10,58	9,74	9,50	19,87	30,77	12,63
Iran (10)	12,48	7,25	8,04	18,01	39,91	30,59	43,39	43,49	44,58	32,46
SCO	7,81	6,57	5,70	6,90	9,80	9,36	11,77	15,96	15,21	10,64

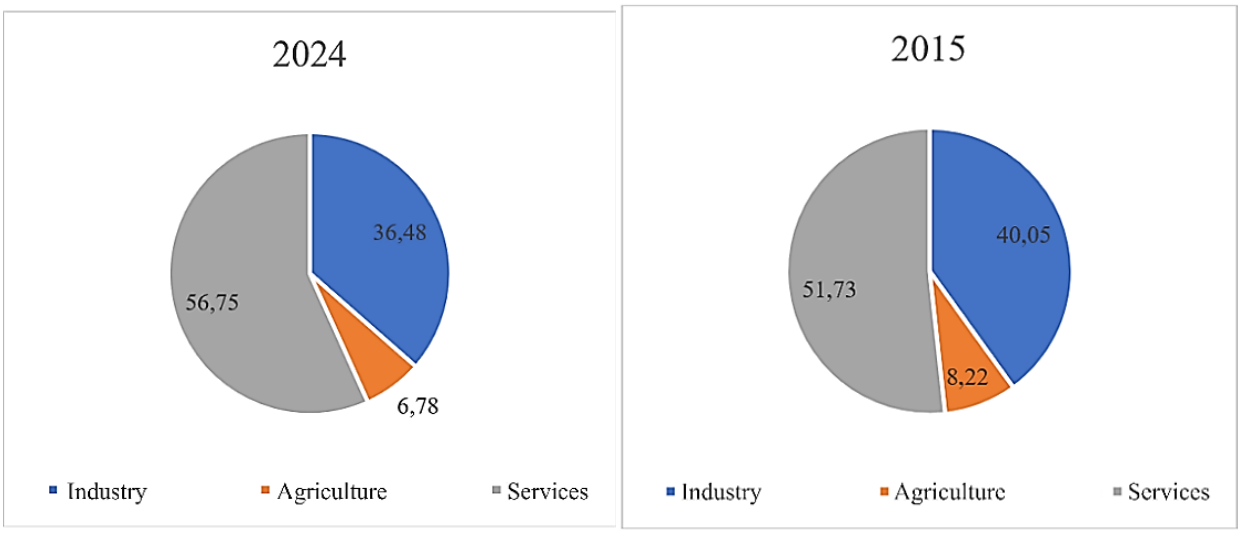


Figure 1. Sectoral structure of China's GDP, 2015 and 2024 (%)

The most striking finding of this study is the acceleration of China's trade dominance within the SCO. China's share of intra-SCO merchandise exports rose from 54.8 percent in 2015 to 83.5 percent in 2024. In dollar terms, Chinese internal exports to SCO partners grew from $144.9 billion to $335.1 billion – more than doubling (Table 7) [4]. By contrast, Kazakhstan, the second-largest intra-SCO exporter, shipped only $30.3 billion in 2024, roughly 9 percent of the Chinese figure. India, despite its size, contributed just 5.8 percent of intra-SCO exports (Table 8) [4].

Table 7. Domestic merchandise exports of SCO countries, 2015–2024 (US$ billion)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
China (1)	144,88	149,19	170,05	179,25	177,76	163,91	229,31	271,93	322,64	335,10
Kazakhstan (2)	12,75	10,39	13,82	15,71	18,64	19,50	23,12	25,36	30,32	30,28
India (3)	16,61	15,04	19,38	24,48	25,69	24,72	28,77	21,34	22,74	23,43
Pakistan (8)	2,46	2,15	2,08	2,51	2,37	2,10	3,47	2,90	3,09	2,85
Kyrgyzstan (9)	0,76	0,66	0,85	0,86	0,92	0,78	1,08	1,82	1,71	1,87
Tajikistan (10)	0,37	0,41	0,51	0,63	0,53	0,35	0,78	1,26	0,96	0,98
SCO	264,56	265,18	321,34	362,95	374,25	335,40	461,93	362,22	423,90	401,38

Table 8. Share of domestic merchandise exports of SCO countries, 2015-2024
(% of SCO merchandise exports)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	
China (1)	54,76	56,26	52,92	49,39	47,50	48,87	49,64	75,07	76,11	83,49
Kazakhstan (2)	4,82	3,92	4,30	4,33	4,98	5,81	5,01	7,00	7,15	7,54
India (3)	6,28	5,67	6,03	6,74	6,86	7,37	6,23	5,89	5,36	5,84
Pakistan (8)	0,93	0,81	0,65	0,69	0,63	0,63	0,75	0,80	0,73	0,71
Kyrgyzstan (9)	0,29	0,25	0,26	0,24	0,25	0,23	0,23	0,50	0,40	0,47
Tajikistan (10)	0,14	0,15	0,16	0,17	0,14	0,10	0,17	0,35	0,23	0,24
SCO	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

The import side is more balanced. China absorbed 39.9 percent of intra-SCO imports in 2024, practically matching India's 39.2 percent. Together, the two giants accounted for roughly 79 percent of all intra-SCO import demand. This bilateral concentration – China and India as the two great internal markets – is a defining structural feature of the organisation's trade architecture. For smaller members like Kyrgyzstan or Tajikistan, access to these two markets represents a dominant share of their external revenue (Table 9, 10) [4].

Table 9. Volume of domestic merchandise imports of the SCO countries, 2015–2024
(US$ billion)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
China (1)	73,35	67,68	86,53	112,57	104,47	97,14	129,35	160,76	175,96	177,23
India (2)	73,42	74,50	92,83	97,10	79,97	66,56	97,57	143,94	160,97	173,89
Kazakhstan (3)	17,53	14,41	18,29	20,13	22,78	21,93	28,98	23,81	36,62	36,90
Pakistan (8)	13,16	15,97	17,83	17,34	14,23	13,78	22,44	18,16	13,93	18,20
Kyrgyzstan (9)	3,00	3,12	3,57	3,96	4,02	2,85	4,48	7,85	9,15	9,22
Tajikistan (10)	2,64	2,50	2,23	2,44	2,71	2,55	3,39	4,14	4,39	5,43
SCO	266,90	265,44	336,70	378,74	360,47	329,44	434,16	397,22	447,44	443,95

Table 10. Share of domestic merchandise imports of SCO countries, 2015–2024
(% of SCO merchandise imports)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
China (1)	27,48	25,50	25,70	29,72	28,98	29,49	29,79	40,47	39,33	39,92
India (2)	27,51	28,07	27,57	25,64	22,18	20,20	22,47	36,24	35,98	39,17
Kazakhstan (3)	6,57	5,43	5,43	5,31	6,32	6,66	6,67	5,99	8,18	8,31
Pakistan (8)	4,93	6,02	5,30	4,58	3,95	4,18	5,17	4,57	3,11	4,10
Kyrgyzstan (9)	1,12	1,18	1,06	1,05	1,12	0,87	1,03	1,98	2,04	2,08
Tajikistan (10)	0,99	0,94	0,66	0,64	0,75	0,77	0,78	1,04	0,98	1,22
SCO	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

China’s overall share of intra-SCO trade turnover climbed from 41 percent in 2015 to over 60 percent in 2024. This concentration means that economic conditions inside China – its growth rate, demand for raw materials, monetary policy – function effectively as a systemic driver for the entire organisation. When Chinese growth slowed in 2022–2023, SCO-wide turnover growth decelerated accordingly (Table 11, 12) [4].

Table 11. Volume of internal trade turnover of the countries of the integration group, 2015-2024 (billion US dollars)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
China (1)	218,23	216,87	256,58	291,82	282,23	261,05	358,65	432,69	498,60	512,33
India (2)	90,03	89,53	112,21	121,58	105,66	91,28	126,34	165,29	183,71	197,32
Kazakhstan (3)	30,28	24,80	32,11	35,83	41,42	41,42	52,10	49,17	66,94	67,18
Pakistan (8)	15,62	18,12	19,91	19,85	16,60	15,88	25,91	21,06	17,02	21,05
Kyrgyzstan (9)	3,77	3,77	4,42	4,81	4,94	3,63	5,56	9,67	10,86	11,10
Tajikistan (10)	3,00	2,91	2,74	3,07	3,24	2,89	4,17	5,40	5,36	6,41
SCO	531,46	530,62	658,03	741,69	734,72	664,83	896,09	759,44	871,34	845,33

Table 12. Share of domestic trade turnover of the integration grouping countries, 2015-2024 (% of the trade turnover of the SCO)

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
China (1)	41,06	40,87	38,99	39,35	38,41	39,27	40,02	56,97	57,22	60,61
India (2)	16,94	16,87	17,05	16,39	14,38	13,73	14,10	21,76	21,08	23,34
Kazakhstan (3)	5,70	4,67	4,88	4,83	5,64	6,23	5,81	6,47	7,68	7,95
Pakistan (8)	2,94	3,41	3,03	2,68	2,26	2,39	2,89	2,77	1,95	2,49
Kyrgyzstan (9)	0,71	0,71	0,67	0,65	0,67	0,55	0,62	1,27	1,25	1,31
Tajikistan (10)	0,56	0,55	0,42	0,41	0,44	0,43	0,47	0,71	0,62	0,76
SCO	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

The commodity composition of China’s intra-SCO trade reveals a textbook centre-periphery pattern. On the export side, electrical machinery and equipment accounted for 21.9 percent of Chinese exports to SCO partners in 2024 (up from 17.6 percent in 2015), and mechanical equipment added another 19.8 percent. The most dramatic shift, however, was in vehicles: their share surged from 2.5 to 11.7 percent over the decade, reflecting the rapid internationalisation of Chinese automotive manufacturers. Together, machines and vehicles represented 41.7 percent of Chinese intra-SCO exports by 2024, compared to 33.8 percent in 2015 (Figure 2) [4].

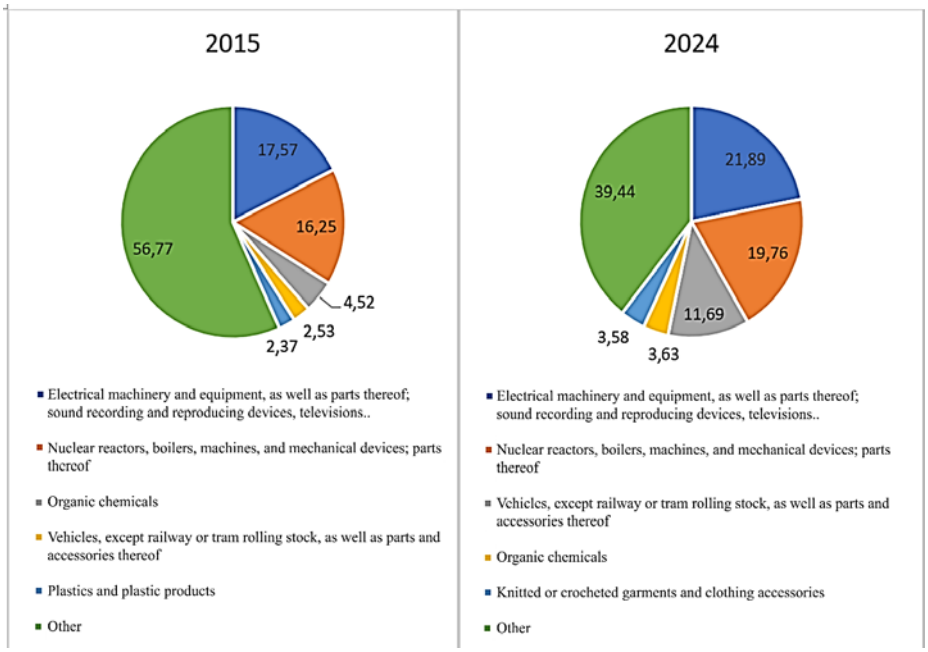


Figure 2. Commodity structure of China's domestic exports, 2015 and 2024 (%)

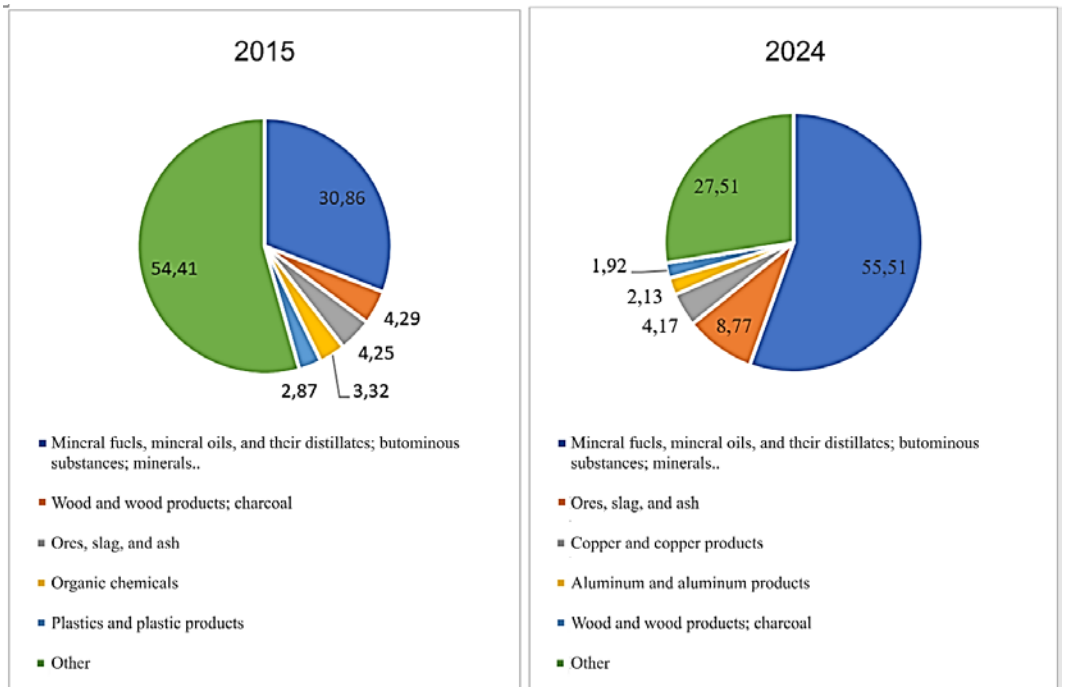


Figure 3. Commodity structure of China's domestic exports, 2015 and 2024 (%)

On the import side, mineral fuels dominated China's purchases from SCO partners with 55.5 percent of the total in 2024, up sharply from 30.9 percent in 2015. Ores, slag and ash added 8.8 percent (Figure 3) [4]. The surge in energy and raw materials is directly tied to the reorientation of Russian exports after 2022: Russia now supplies nearly two-thirds of all China's intra-SCO imports, overwhelmingly in oil, gas and other commodities. Comparing internal and external import structures reinforces the picture: China's imports from outside the SCO are dominated by electronics,

semiconductors and complex machinery – technology-intensive goods it cannot yet fully substitute domestically. The SCO, by contrast, is primarily a resource supplier.

Geographically, China's intra-SCO exports remain concentrated on two partners: India absorbed 36.0 percent of the total in 2024 (down from 40.2 percent in 2015), while Russia's share climbed dramatically from 24.0 to 34.5 percent. Russia's rise as a destination for Chinese goods reflects the substitution of Western consumer and industrial goods following sanctions, particularly after February 2022. Iran, once third-largest destination at 12.3 percent of Chinese intra-SCO exports, has dropped out of the top five – likely a consequence of compliance pressures on Chinese firms operating near the boundaries of secondary sanctions (Figure 4) [4].

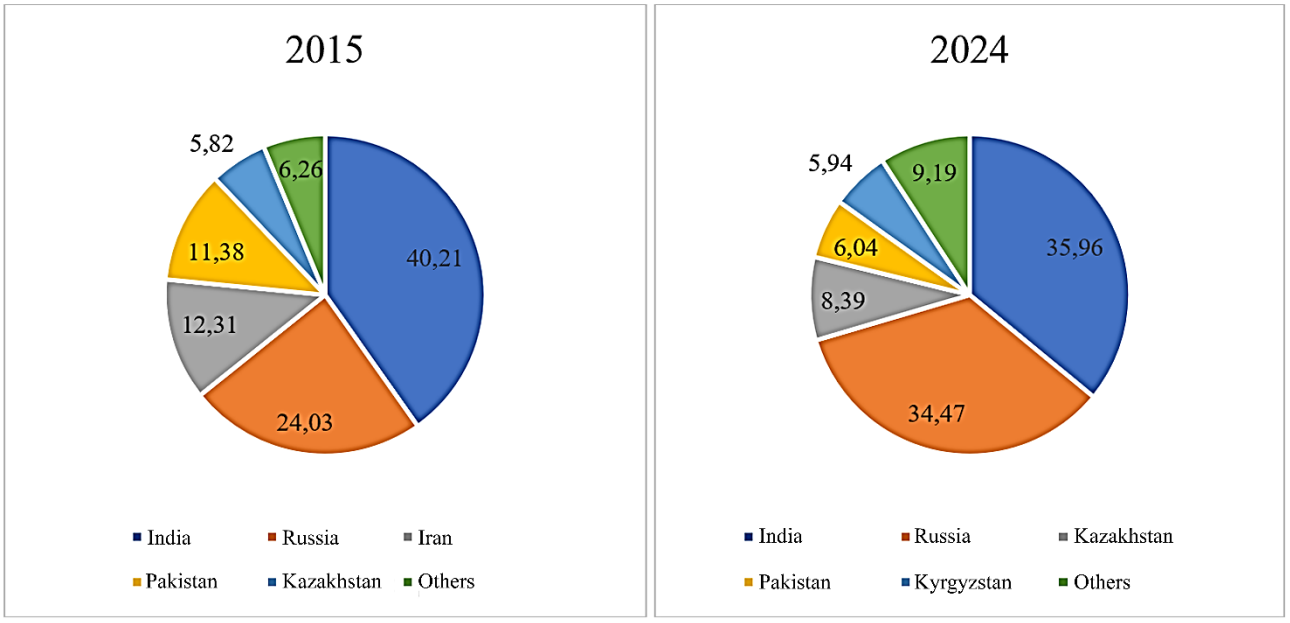


Figure 4. Geographical structure of China's domestic merchandise exports, 2015 and 2024 (%)

On the import side, the shift is even more pronounced. Russia supplied 45.3 percent of China's intra-SCO imports in 2015 but fully 64.2 percent in 2024. Uzbekistan, once the third-largest supplier, has essentially disappeared from the top five. Kazakhstan still supplies 11.1 percent, largely hydrocarbons and metals, while India has risen to second place with 13.8 percent, reflecting growing agricultural and pharmaceutical trade (Figure 5) [4]. This concentration of Chinese import dependence on a single partner creates both a strategic advantage – a geographically proximate, pipeline-connected energy source – and a structural vulnerability should the bilateral relationship face disruption.

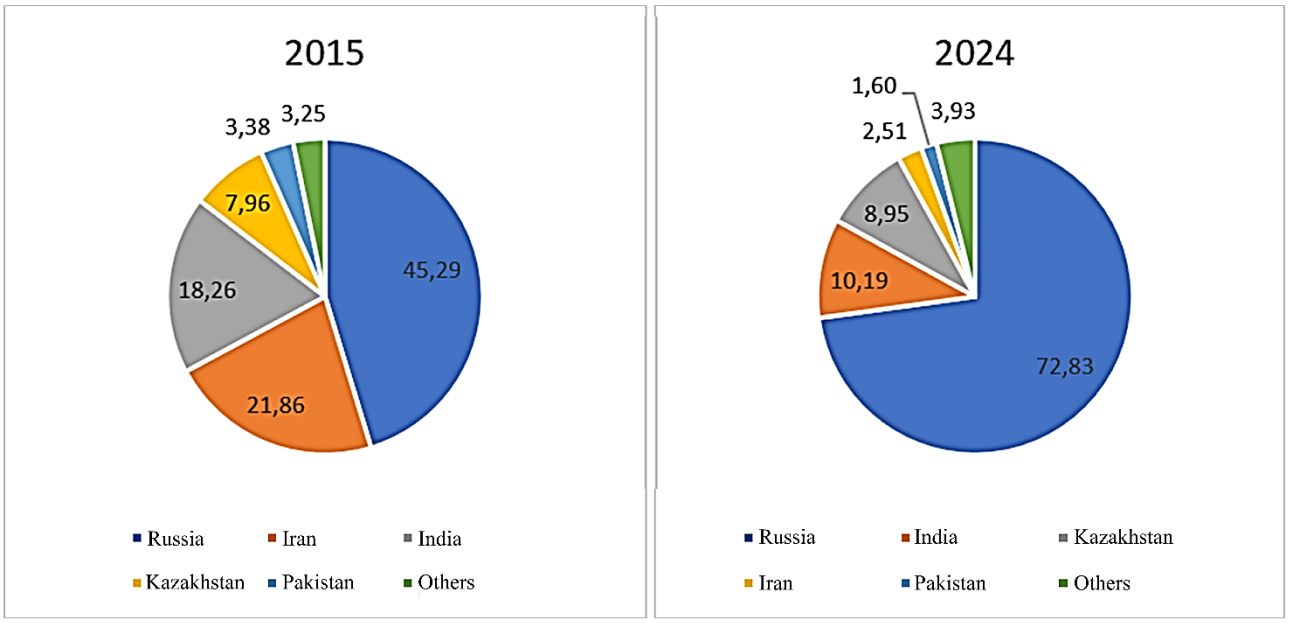


Figure 5. Geographical structure of China's domestic merchandise imports, 2015 and 2024 (%)

The bilateral China–Russia trading relationship deserves separate attention because it has reshaped the entire SCO trade architecture over a very short period. Chinese exports to Russia grew from $76.1 billion in 2022 to $115.5 billion in 2024, an increase of over 50 percent in two years. Chinese imports from Russia expanded from $114.2 to $129.1 billion over the same period (Table 13) [4]. The result is that Russia now runs a trade deficit with China, importing consumer goods, vehicles and electronics at prices and in volumes that partially compensate for the withdrawal of Western suppliers.

Table 13. China's Trade with Russia, 2022-2024 (US$ billion)

	2022	**2023**	**2024**
Export	76,12	111,06	115,50
Import	114,15	128,48	129,07

China's approach to this relationship has been carefully calibrated. Beijing has not joined Western sanctions and has publicly committed to maintaining normal trade and economic relations with Moscow [5, c. 4]. At the same time, major Chinese banks and state enterprises have been cautious about transactions that might trigger secondary sanctions from the United States. The practical outcome has been a shift toward alternative payment systems – renminbi-rouble settlement has grown substantially – and the development of logistics corridors that bypass traditional Western-controlled financial infrastructure. The "Power of Siberia" gas pipeline project, already operational, and planned expansions of Siberian gas routes into China exemplify the deepening energy entanglement.

China's integration trajectory within the SCO yields a nuanced picture. Politically, the paradox of sanctions pressure is that it simultaneously creates obstacles for Chinese firms operating in Russia and accelerates the development of alternative financial and logistical infrastructure. The appointment of a Kazakh national as SCO

Secretary-General from January 2025 signals that smaller members are gaining procedural visibility, even if economic weight remains lopsided. Economically, the steady growth of intra-SCO trade turnover (despite external headwinds), combined with active de-dollarisation, points toward a deepening of financial interdependence. However, the wide disparity in development levels – from China's $13,300 per-capita income to Tajikistan's $1,340 – makes uniform integration frameworks impractical.

Socially, the SCO's demographic mass – exceeding 40 percent of the world's population – represents an enormous consumer market in the making. Chinese universities are absorbing growing numbers of students from SCO partners, creating a cadre of professionals who share technical vocabulary and professional networks with Chinese institutions. Language barriers and differences in legal tradition, however, continue to limit business-level integration, especially among small and medium enterprises. Technologically, China's role as the organisation's principal source of digital infrastructure – e-commerce platforms, telecommunications equipment, renewable energy hardware – is expanding. The renewable energy dimension is particularly significant: China is the world's leading manufacturer of solar panels and wind turbines, and several SCO member states are at early stages of energy transition with strong demand for cost-competitive clean-energy technology.

All reinforces these findings. The principal strengths are China's economic scale, its established manufacturing base and its Belt and Road infrastructure investments [6, p. 1]. Key weaknesses include the growing structural asymmetry that may strain the organisation's cohesion, incomplete financial integration mechanisms, and the technology dependence of China itself on external suppliers for advanced semiconductors and precision instruments. Opportunities centre on the de-dollarisation agenda, digitalisation and the green energy transition. Threats include escalating Western sanctions that complicate Chinese firms' participation in SCO-related transactions, geopolitical volatility along the India-Pakistan and Afghanistan borders, and the risk that internal economic imbalances generate political friction.

China's role in the SCO has undergone a meaningful transformation over the past decade. What began as demographic and economic leadership grounded in sheer population size has evolved into something more precisely defined: asymmetric trade dominance. China's share of intra-SCO trade has grown faster than its share of the population or even aggregate GDP, driven by the combination of its industrial export capacity and its partners' growing demand for capital goods, vehicles and technology.

This dominance has a structural logic: China imports raw materials and energy (mostly from Russia and Kazakhstan) and exports finished goods, occupying the role of industrial hub in a classic centre-periphery arrangement. The post-2022 geopolitical realignment has reinforced and accelerated this pattern, with Russia redirecting energy flows eastward and import demand toward China [7, p. 7]. The resulting model is one of deepening interdependence, but interdependence on distinctly unequal terms.

Whether this model is sustainable over the long run depends on whether smaller SCO members are able to climb the value chain rather than remain locked into commodity exports, and whether India's growing economic weight translates into a genuine counterbalancing force within the organisation's governance. The SCO's consensus-based norms provide little mechanism for rebalancing; that will have to

come through market forces and bilateral negotiations. For China, maintaining its leadership position will require more than economic scale. It will require offering terms of cooperation that its partners perceive as mutually beneficial rather than merely acquiesced to.

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УДК 339.138

CUSTOMER ORIENTATION IN THE DEVELOPMENT OF AN ENTERPRISE MARKETING STRATEGY

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Abstract. The article explores customer orientation as a strategic basis for shaping enterprise marketing strategy. Particular attention is paid to its role under growing competition and changing consumer behavior. The paper systematizes the instruments and strategic forms of customer-oriented marketing and characterizes the indicators used to evaluate its effect on customer satisfaction, loyalty, retention, and long-term business stability.

Keywords: customer orientation, marketing strategy, customer loyalty, customer experience, customer relationship management, customer satisfaction, relationship marketing, customer retention, customer value, competitive advantage.

КЛИЕНТООРИЕНТИРОВАННЫЙ ПОДХОД К РАЗРАБОТКЕ МАРКЕТИНГОВОЙ СТРАТЕГИИ ПРЕДПРИЯТИЯ

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Аннотация. В статье раскрывается значение клиентоориентированного подхода в разработке маркетинговой стратегии предприятия. Показано, что в условиях усиливающейся конкуренции и изменений в потребительском поведении ориентация на клиента становится важным фактором устойчивого развития. Систематизированы инструменты и стратегии клиентоориентированного маркетинга, а также охарактеризованы показатели, применяемые для оценки удовлетворенности, лояльности и удержания клиентов.

Ключевые слова: клиентоориентированность, маркетинговая стратегия, лояльность потребителей, клиентский опыт, управление взаимоотношениями с клиентами, удовлетворенность потребителей, маркетинг взаимоотношений, удержание клиентов, ценность для клиента, конкурентные преимущества.

Changes in the market environment compel enterprises to reconsider the principles on which their marketing strategies are built. Under conditions of stronger competition and unstable external influences, strategic success increasingly depends not only on product promotion but also on the ability to develop durable relationships with customers. For this reason, customer orientation is becoming one of the defining

priorities of modern enterprise development.

A detailed understanding of customer needs allows firms to design products and services that are more relevant to market demand and less vulnerable to substitution. This contributes to stronger customer loyalty, improves retention, and creates additional opportunities for attracting new consumer groups, which ultimately supports the economic performance of the enterprise.

The relevance of this study is linked to the growing role of customer-oriented marketing in helping organizations respond to shifts in consumer behavior. Today, customer value is formed not only through the act of purchase itself but also through the quality of interaction, the degree of personalization, and the firm's ability to adapt its offer to specific expectations.

In such conditions, customer orientation should be considered not as a separate marketing technique but as an important element of enterprise management. The effectiveness of strategic decisions increasingly depends on how accurately the organization identifies customer expectations and transforms them into practical marketing solutions. As a result, customer orientation influences both the content of business goals and the methods used to achieve them.

This approach reflects a shift away from short-term sales stimulation based mainly on price incentives and toward mechanisms aimed at attracting, retaining, and understanding customers. Enterprises that integrate customer interests into managerial decision-making gain stronger opportunities to build stable interaction with buyers and to improve the long-term effectiveness of their market activity.

Customer orientation began to attract sustained attention in international academic literature in the second half of the twentieth century. The first scholarly approaches to the study of company-customer interaction appeared in the 1950s, while by the 1980s interest in this issue had expanded considerably.

Since the 1990s, relationship marketing has occupied an important place in marketing theory. Within this perspective, the focus shifts from a single transaction to the maintenance of long-term interaction between the company and the customer. L. Berry made a substantial contribution to this line of research by interpreting marketing as a process of creating, supporting, and strengthening lasting customer relationships [1, p. 236].

The logic of relationship marketing is based on recognizing the customer as the central reference point of market activity. In parallel with this approach, R. Saxe and B. Weitz examined customer orientation at the level of individual selling behavior, paying particular attention to how sales personnel adapt their actions to customer needs and expectations [2, p. 343-344].

In the 1990s, research on customer orientation expanded considerably and moved beyond the analysis of sales behavior alone. A. Kohli and B. Jaworski [3, p. 2-3], J. Narver and S. Slater [4, p. 334], and R. Deshpandé [5, p. 24] approached this issue from different perspectives, but all emphasized that customer orientation should be treated as a strategically significant characteristic of market-oriented organizations.

In Russian economic practice, interest in customer orientation increased markedly during the formation of market mechanisms and later became associated with the search for sustainable sources of competitiveness. Domestic researchers, including

S. N. Apenko [6, p. 50], O. V. Gulakova, V. A. Rebyazina, V. M. Panin [7, p. 88], I. V. Semenov [8, p. 361], and O. A. Tretyak [9, p. 130], have examined this issue in relation to personnel behavior, market orientation, and the evaluation of customer focus.

Despite the broad scope of research, no single definition of customer orientation has become universally accepted. Its meaning varies depending on the analytical framework: in some studies it is treated as a managerial principle, in others as a cultural value, an organizational process, or a factor that influences business performance.

The behavioral approach focuses on the way employees interact with customers in the course of direct market contact. From the standpoint of R. Saxe and B. Weitz, customer orientation is expressed in the salesperson's effort to assist the buyer in choosing the option that best corresponds to actual needs and expectations [2, p. 343].

Within the process approach, customer orientation is understood as a sequence of managerial actions linked to information and adaptation. In the interpretation proposed by A. Kohli and B. Jaworski, it includes generating knowledge about customer needs, distributing this knowledge throughout the organization, and using it to adjust products and services to market expectations [3, p. 2-3].

R. Deshpandé, J. Farley, and F. Webster Jr. consider customer orientation primarily in the context of corporate values [5, p. 24]. In this case, it is associated with a system of beliefs according to which customer interests occupy a central place in managerial and organizational priorities.

Since values shape the internal logic of organizational behavior, many researchers interpret customer orientation as part of corporate culture. In particular, J. Narver and S. Slater regard it as one of the central components of a culture directed toward the satisfaction of customer needs [4, p. 335]. At the same time, within strategic management this concept extends beyond adaptation to current demand and includes the anticipation of future expectations, which gives it a proactive character in the development of market offerings [4, p. 336].

Within this approach, customers and partners are actively involved in the development of new products, services, and business processes. Therefore, customer orientation should be regarded as a long-term strategy of enterprise development. A similar position is advanced by N. S. Komleva and N. A. Pachin, who define customer orientation as a relationship-management strategy aimed at establishing long-term cooperation with consumers [10, p. 208].

J.-J. Lambin associates customer orientation with an in-depth study of customer needs and the creation of additional value for buyers [11, p. 35-36]. K. Kharsky interprets this concept as a strategy for increasing enterprise profitability through the creation of conditions that stimulate repeat purchases [12, p. 18]. Therefore, customer orientation can be interpreted as a long-term strategic approach through which an enterprise builds stable interaction with customers, strengthens its market position, and creates conditions for sustainable economic results.

A customer-oriented marketing strategy is effective only when value for the consumer is formed throughout the entire process of interaction with the company. This requires continuous analysis of customer needs, behavior, and response to the firm's actions. Whereas traditional marketing is usually focused on promotion and sales

stimulation, customer-oriented marketing places greater emphasis on customer experience, interaction quality, and long-term relationship development. The differences between these two approaches are summarized in Table 1.

Table 1. Comparative characteristics of traditional marketing and customer-oriented marketing

Comparison criterion	**Traditional marketing**	**Customer-oriented marketing**
Main goal	Increase in sales volume	Building long-term customer relationships
Primary focus	Product or service	Customer needs and values
Approach to the customer	Mass	Individualized
Nature of interaction	Short-term transactions	Long-term cooperation
Marketing instruments	Advertising, price promotions, sales stimulation	Personalized offers, loyalty programs, CRM systems
Key performance indicator	Sales volume	Customer satisfaction and loyalty
Planning horizon	Short-term	Long-term
Role of the customer	Passive buyer	Active participant in value creation
Strategic result	Sales growth	Sustainable competitive advantage

Consequently, the customer-oriented approach covers the entire chain of interaction with the buyer, including post-purchase communication and service support. Its purpose is not limited to securing a transaction; it is aimed at maintaining stable and valuable relationships between the enterprise and its customers. The implementation of such a strategy requires an integrated system of customer interaction management, the structure of which is illustrated in Figure.

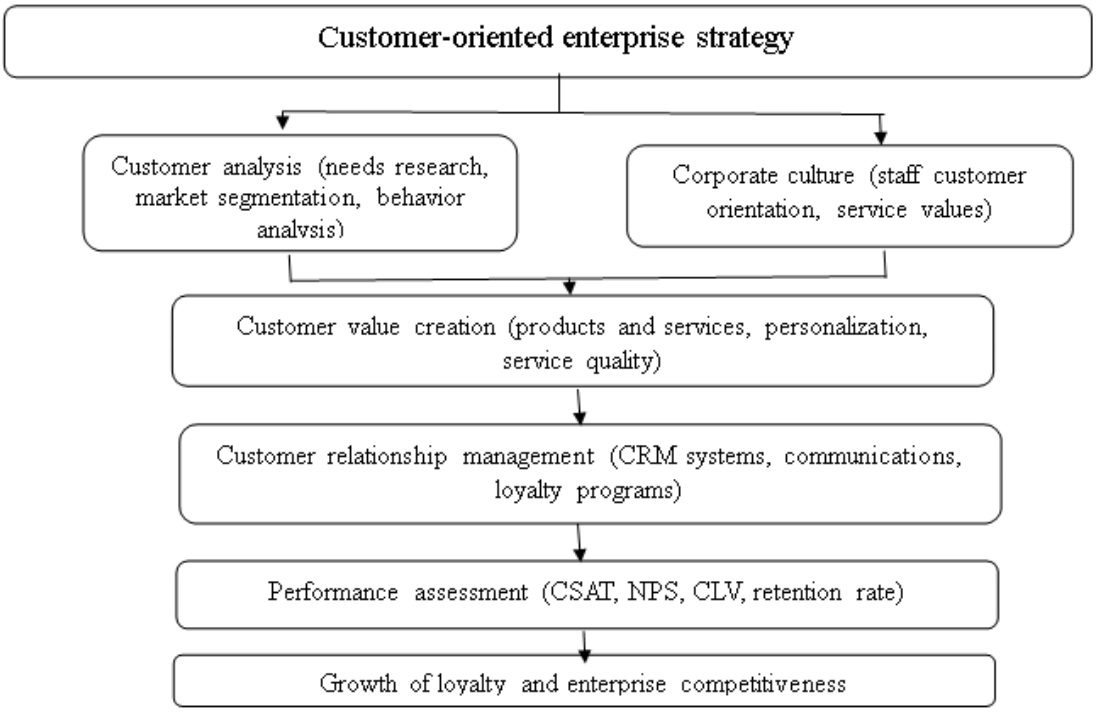


Figure. Model of enterprise customer orientation

The form of customer-oriented marketing strategy depends on the characteristics of the target segment and the nature of interaction required. In work with corporate customers and premium segments, enterprises often rely on high-touch marketing, which involves intensive personal communication and a significant degree of individual support. Tech-touch marketing is built around digital tools that allow firms to personalize contact with customers through data collection and automated adaptation of offers. Low-touch marketing, by contrast, presupposes minimal staff involvement and is better suited to standardized low-cost products intended for mass demand.

The practical implementation of customer-oriented marketing requires a set of interconnected managerial and marketing instruments that support relationship development and improve customer satisfaction. The main groups of such tools used in enterprise practice are systematized in Table 2.

Table 2. Tools for implementing an enterprise customer-oriented marketing strategy

Tool group	**Content of tools**	**Purpose of application**
Analytical tools	Marketing research, customer base analysis, market segmentation	Identification of customer needs and behavioral characteristics
Digital technologies	CRM systems, marketing automation systems, big data analytics	Personalization of customer interaction
Communication tools	Social media, email newsletters, omnichannel communication	Maintaining continuous customer contact
Loyalty-building tools	Loyalty programs, bonus systems, personalized offers	Increasing customer commitment to the company
Service tools	Service quality improvement, technical support, after-sales service	Formation of a positive customer experience

The evaluation of customer orientation requires the use of several complementary indicators, each reflecting a different aspect of interaction with customers. Their combined application makes it possible to assess how effectively the enterprise implements customer-oriented management in practice. Since this approach influences both market behavior and business performance, the highest results can be achieved only when customer value becomes a priority across the entire management system. The key indicators are presented in Table 3.

Table 3. Key indicators for assessing enterprise customer orientation

Indicator	Indicator content	Purpose of the indicator
CSAT (Customer Satisfaction Score)	Reflects the degree of customer satisfaction with interaction with the company	Helps identify weak points in customer experience and assess service quality
CRR (Customer Retention Rate)	Shows the share of customers who continue cooperation with the company during a given period	Characterizes the enterprise's ability to retain customers
Churn Rate	The proportion of customers who stopped interacting with the company	Makes it possible to identify problems in product or service quality
NPS (Net Promoter Score)	An index of customers' willingness to recommend the company to others	Reflects the level of loyalty and brand reputation

The development of customer orientation requires a systemic approach and should be embedded in the overall strategy of enterprise development rather than treated as an isolated marketing initiative. At the same time, the practical configuration of this approach depends on sectoral conditions, organizational scale, and the level of economic maturity. The study has made it possible to distinguish the core elements of customer-oriented marketing and to characterize the main strategic forms of interaction with different customer groups.

The core principle of the customer-oriented approach lies in the consistent study of customer needs and in the transformation of this knowledge into concrete managerial and marketing decisions. This involves regular analysis of customer information, the design of personalized formats of interaction, and the development of offers that correspond to the expectations of the target audience. The proposed model of customer-orientation assessment can be used as an analytical basis for improving enterprise marketing strategy and strengthening long-term competitive stability.

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УДК 332.1

BIOECONOMY AS THE FOUNDATION OF NEW FOOD POLICY PARADIGM IN RUSSIA: FROM CALORIE PROVISION TO QUALITY OF LIFE MANAGEMENT

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Abstract. Global economic shifts demand rethinking food policy. Russia's calorie-centered model ensures supply but neglects health, fiscal stability, and growth. This paper argues for a bioeconomy paradigm focused on quality of life. Integrating biotechnology, digitalization, circularity, and preventive healthcare transforms food systems into bio-industrial platforms that build human capital and macroeconomic resilience. The study analyzes constraints, transformation mechanisms, and institutional preconditions for Russia. Bioeconomy policy generates spillovers for productivity, demographics, innovation, and the environment.

Keywords: bioeconomy; food policy; food security; quality of life; human capital; preventive healthcare; circular economy; alternative proteins; institutional economics.

БИОЭКОНОМИКА КАК ОСНОВА НОВОЙ ПАРАДИГМЫ ПРОДОВОЛЬСТВЕННОЙ ПОЛИТИКИ РОССИИ: ОТ ОБЕСПЕЧЕНИЯ КАЛОРИЙ К УПРАВЛЕНИЮ КАЧЕСТВОМ ЖИЗНИ

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Аннотация. Глобальные экономические трансформации требуют пересмотра продовольственной политики. Калийно-калорийная модель России обеспечивает снабжение, но игнорирует здоровье, фискальную устойчивость и рост. В статье обосновывается биоэкономическая парадигма, ориентированная на качество жизни. Интеграция биотехнологий, цифровизации, циркулярности и профилактической медицины превращает продовольственные системы в биоиндустриальные платформы, формирующие человеческий капитал и макроэкономическую устойчивость. Анализируются ограничения, механизмы трансформации и институциональные предпосылки для России. Биоэкономическая политика создает положительные эффекты для производительности, демографии, инноваций и экологии.

Ключевые слова: биоэкономика, продовольственная политика, продовольственная безопасность, качество жизни, человеческий капитал, превентивное здравоохранение, циркулярная экономика, альтернативные белки, институциональная экономика.

The current phase of economic development is marked by the increasing importance of knowledge-intensive sectors, environmentally responsible resource use, and the integration of advanced technologies across industries [1, p. 12; 2, p. 45]. Within this context, the bioeconomy emerges as a systemic model in which renewable biological resources, biotechnologies, and digital innovations serve as primary drivers of value creation [3, p. 89; 4, p. 23]. This paradigm challenges traditional sectoral boundaries and redefines the relationship between agriculture, industry, healthcare, and environmental governance [5, p. 67].

In Russia, food policy has historically been shaped by the imperative of ensuring caloric sufficiency and reducing import dependence. This model, rooted in geopolitical and economic considerations, has achieved considerable success in stabilizing domestic food supply [6, p. 34]. However, the persistence of a calorie-centered framework reveals conceptual and structural inadequacies when evaluated against contemporary challenges, including demographic decline, rising prevalence of non-communicable diseases, fiscal pressure on healthcare systems, and environmental degradation [7, p. 78; 8, p. 112]. Theoretical foundations of strategic agricultural planning are examined in [9, p. 56; 10, p. 34].

The objective of this study is to substantiate the transition from a quantitative model of food security toward a qualitative paradigm grounded in bioeconomic principles [4, p. 45]. The paper argues that food systems must be reconceptualized as strategic infrastructures influencing human capital reproduction, labor productivity, demographic stability, and ecological sustainability [11, p. 202]. By integrating biotechnology, personalized nutrition, circular production systems, and digital platforms, the bioeconomy transforms food policy into an instrument of quality of life governance [3, p. 102]. The role of circular economy models in this transition is analyzed in [12, p. 88; 13, p. 14].

The research contributes to the theoretical development of food policy economics by linking bioeconomic transformation with macroeconomic performance and institutional reform [14, p. 156; 15, p. 73]. It also provides a framework for policy design in Russia aimed at aligning food systems with long-term socio-economic objectives.

The bioeconomy represents a stage in economic evolution where biological resources, biotechnologies, and knowledge-intensive innovations become primary sources of value creation [4, p. 23]. Unlike traditional extractive or industrial models, the bioeconomic paradigm is rooted in the principles of renewability, circularity, and technological convergence. It integrates agriculture, biotechnology, digital systems, and environmental management into a unified production and innovation ecosystem [7, p. 80].

Within this framework, food systems are reconceptualized as bio-industrial platforms embedded in broader socio-economic processes. They no longer function merely as supply chains delivering caloric commodities but as complex systems influencing public health, labor productivity, demographic sustainability, and ecological balance [16, p. 9]. The theoretical implication is clear: food policy must evolve from a sectoral regulatory instrument into a cross-sectoral development strategy grounded in bioeconomic logic [15, p. 88]. Recent Russian research on sustainable food

systems [17, p. 30] and bioeconomic development [18, p. 258] supports this view.

The calorie-oriented approach to food policy, which historically emerged due to risks of food shortages, geopolitical pressures, and dependence on imports, has generally accomplished its primary task in Russia – namely, guaranteeing the physical availability of food products and achieving substantial self-sufficiency in major agricultural goods [6, p. 35]. However, the persistence of this paradigm in the contemporary socio-economic environment generates structural constraints that limit long-term development.

The first constraint is qualitative distortion in consumption patterns. A policy architecture oriented toward production volumes and caloric output naturally incentivizes expansion of mass, standardized, and relatively low-cost food categories. This production logic tends to privilege energy-dense commodities with long shelf life and stable logistics characteristics. As a consequence, the structure of domestic supply may align with caloric sufficiency while simultaneously reinforcing nutritional imbalance. Excessive consumption of refined carbohydrates, saturated fats, and ultra-processed foods contributes to rising prevalence of cardiovascular diseases, obesity, type II diabetes, and other non-communicable conditions. From an economic perspective, this represents a negative externality embedded within the existing food production structure.

The second constraint concerns the misalignment between food policy and healthcare economics. The calorie-centered paradigm treats food as an object of agricultural policy rather than as a determinant of public health outcomes. As a result, the cost savings achieved through import substitution and domestic production growth may be offset by long-term increases in healthcare expenditures related to poor dietary quality [8, p. 115]. The fiscal burden of chronic disease treatment, disability payments, and productivity losses due to morbidity generates indirect macroeconomic costs that are not internalized within the traditional food security framework [19, p. 210].

The third structural limitation is demographic. Russia faces significant challenges in terms of declining population growth, aging demographics, and stagnation in healthy life expectancy. While caloric adequacy prevents acute food insecurity, it does not guarantee the biological quality of human capital reproduction. Insufficient consumption of essential micronutrients, an unbalanced diet, and the widespread incidence of nutrition-related diseases diminish the health capacity of the working-age population. Over time, this reduces labor productivity, increases pension system pressure, and constrains long-term growth trajectories [14, p. 160].

Finally, the calorie-centered model underestimates environmental and technological vulnerabilities. Such a model is frequently linked to agricultural methods that require significant natural resources and can contribute to soil degradation, declining biodiversity, and increased greenhouse gas emissions [20, p. 95; 7, p. 82]. Such environmental externalities indirectly affect food quality and public health [4, p. 29]. Moreover, a narrow focus on traditional agricultural outputs may slow the integration of advanced biotechnologies, alternative proteins, and digital nutritional platforms, thereby limiting Russia’s competitiveness in emerging global bioeconomic markets. Issues related to biotechnology adoption are discussed in [18, p. 260].

Thus, while the calorie-centered model has ensured short-term stability, it

reveals systemic inefficiencies when evaluated through the broader lens of human capital formation, fiscal sustainability, and structural modernization [1, p. 18].

The bioeconomic transformation of food systems represents not merely technological modernization but a reconfiguration of value creation mechanisms, institutional coordination, and socio-economic objectives [3, p. 95]. Within this paradigm, food systems are integrated into a broader bio-industrial ecosystem in which biological knowledge, biotechnology, and digital analytics function as primary productive forces.

A core dimension of this transformation is the shift from standardized mass nutrition toward functional and personalized dietary solutions. Advances in nutrigenomics, microbiome analysis, and digital health monitoring enable the identification of individual metabolic profiles and nutritional needs. In economic terms, this transition corresponds to the differentiation of food products and services, moving from commodity markets toward high-value, knowledge-intensive segments. Personalized nutrition reduces information asymmetry between producers and consumers regarding health effects, thereby increasing allocative efficiency [21, p. 160].

Simultaneously, biotechnological innovation reshapes production structures. Precision fermentation, cellular agriculture, plant-based protein engineering, and biofortification technologies expand the spectrum of available food inputs while reducing dependence on resource-intensive livestock systems [22, p. 150]. These innovations enhance resilience against climate variability and global supply chain disruptions. They also contribute to environmental sustainability by lowering greenhouse gas emissions and improving resource-use efficiency. From a structural perspective, biotechnology transforms agriculture from a primarily land-based activity into a hybrid bio-industrial sector characterized by higher R&D intensity and capital deepening.

Another crucial element of bioeconomic transformation is circularity. Closed-loop production systems, biorefining of agricultural residues, and waste-to-value technologies minimize resource losses and convert by-products into economically valuable inputs. This reduces environmental externalities while generating additional revenue streams. Circular bioeconomic models internalize ecological costs within production processes, thereby aligning economic incentives with sustainability objectives. The circular approach in agri-food systems is comprehensively analyzed in [12, p. 90; 13, p. 15].

Digital integration further amplifies transformation effects. At the same time, digital technologies – including artificial intelligence–based dietary guidance, blockchain systems ensuring product traceability, and real-time analysis of health data – are forming an integrated environment that connects food producers, consumers, and healthcare institutions. Food systems become data-rich platforms capable of continuous optimization. This digitalization enhances transparency, reduces transaction costs, and increases consumer trust, which is essential for adoption of innovative bio-based products.

In aggregate, the bioeconomic transformation redefines food systems as multi-functional infrastructures simultaneously generating nutritional, economic,

environmental, and health value. This systemic integration distinguishes the new paradigm from incremental agricultural modernization.

The macroeconomic consequences of shifting from a calorie-centered to a bioeconomy-based food policy are multidimensional and extend beyond the agricultural sector. At the core lies the revaluation of human health as an economic asset rather than a residual social outcome.

Enhancing the quality of nutrition has a direct impact on labor efficiency. Workers with better health tend to miss fewer workdays, demonstrate stronger cognitive abilities, and remain economically active for longer periods. In the long run, these outcomes contribute to the growth of total factor productivity and expand the economy's potential output. In aging societies, the extension of healthy life expectancy is particularly significant, as it mitigates the dependency ratio and stabilizes pension systems.

Fiscal implications are equally substantial. Chronic non-communicable diseases represent a significant share of public healthcare expenditures. Preventive nutrition strategies embedded within bioeconomic food systems reduce disease incidence and associated treatment costs [8, p. 118]. Although initial investments in biotechnology research, digital infrastructure, and regulatory development may be considerable, long-term savings in healthcare budgets and social insurance payments generate positive net present value for the state [19, p. 215].

The bioeconomic model also stimulates structural diversification. High-tech segments such as functional foods, bioactive ingredients, fermentation-based proteins, and digital nutrition platforms create new markets characterized by higher value added and export potential. This diversification reduces reliance on raw material exports and enhances resilience against commodity price volatility. Furthermore, increased R&D intensity strengthens national innovation systems and fosters cross-sectoral spillovers.

Environmental benefits produce additional macroeconomic gains. Reduced ecological degradation lowers long-term remediation costs and preserves natural capital, which is itself a production factor in agriculture and biotechnology. By aligning economic growth with environmental sustainability, the bioeconomic paradigm mitigates risks associated with climate change and resource scarcity.

Importantly, the transition also reshapes the measurement of economic success. Traditional metrics such as gross output volumes must be complemented by indicators of nutritional quality, healthy life expectancy, and bio-based value added. This implies a broader transformation in macroeconomic policy evaluation, where food systems are assessed in relation to their contribution to human capital and quality of life.

In sum, the macroeconomic implications of bioeconomic transformation extend from micro-level dietary choices to national growth trajectories [3, p. 110]. By integrating food systems with health, innovation, and sustainability objectives, the state creates a feedback loop in which improved quality of life reinforces economic resilience and long-term development potential.

The transition toward a bioeconomy-based food policy paradigm cannot be reduced to technological modernization or market-driven innovation alone. It requires a coherent institutional architecture capable of aligning incentives, reducing systemic risks, and coordinating cross-sectoral actors. In the Russian context, this transformation

presupposes structural adaptation of regulatory frameworks, strategic planning mechanisms, fiscal instruments, and governance models.

First, strategic integration at the national level is essential. Bioeconomy objectives must be embedded within long-term socio-economic development strategies, industrial policy, healthcare reform, and demographic programs. The absence of horizontal coordination between agricultural, health, environmental, and digital policy domains would inevitably lead to fragmentation, duplication of expenditures, and underutilization of technological potential. Therefore, institutional coherence – rather than isolated sectoral initiatives – constitutes the foundational precondition for systemic transformation. Methodological approaches to such strategic planning are elaborated in [9, p. 58; 10, p. 36].

Second, regulatory modernization is required to accommodate emerging categories of food and bio-based products. Functional foods, personalized nutrition services, microbiome-based interventions, and alternative protein technologies often fall into regulatory gray zones between agriculture, pharmaceuticals, and consumer goods. Clear standards of safety, efficacy, labeling, and data protection must be established to reduce uncertainty for investors and consumers. In institutional economics terms, the reduction of regulatory ambiguity lowers transaction costs and accelerates market formation.

Third, fiscal and financial instruments must stimulate long-term investment in bioeconomic infrastructure. Biotechnology research, fermentation facilities, digital health platforms, and circular production systems require significant capital expenditures with delayed returns [23, p. 7]. Targeted tax incentives, public-private partnerships, concessional financing mechanisms, and innovation grants can correct market failures associated with high initial risks and knowledge spillovers. Without such mechanisms, private actors may underinvest relative to socially optimal levels.

Fourth, human capital development represents a critical institutional dimension. The bioeconomy relies on interdisciplinary competencies combining biotechnology, data science, nutrition science, and economics. Educational reforms, specialized training programs, and research funding are necessary to build a workforce capable of sustaining technological convergence. Universities and research institutions must function as integrative hubs linking fundamental science with industrial application.

Fifth, institutional trust and public engagement play a decisive role. The adoption of personalized nutrition technologies and bioengineered food products depends on consumer confidence. Transparent communication strategies, participatory regulatory processes, and reliable traceability systems reduce informational asymmetries and mitigate resistance to innovation. In this context, digital platforms enabling supply chain transparency become not merely technological tools but instruments of institutional legitimacy.

Finally, evaluation metrics must be redefined. Traditional agricultural performance indicators – output volumes, yield per hectare, and self-sufficiency ratios – are insufficient to assess bioeconomic transformation. Institutional monitoring systems should incorporate indicators of nutritional quality, preventive health impact, environmental sustainability, and bio-based value added. The redesign of measurement frameworks is itself an institutional reform, as it reshapes policy priorities and resource

allocation.

Thus, the institutional preconditions for implementing a bioeconomy-driven food policy in Russia involve systemic coordination, regulatory innovation, fiscal support, human capital development, and reconfiguration of performance metrics. Only under these conditions can technological potential translate into sustainable socio-economic outcomes.

The reconceptualization of food policy as an instrument of quality of life governance represents a profound normative and analytical shift. In the traditional paradigm, food policy was primarily concerned with supply stability, price regulation, and trade balances. Its objectives were largely material and quantitative. In contrast, the emerging paradigm interprets food systems as strategic infrastructures influencing the biological, cognitive, and social dimensions of human development.

Quality of life governance implies that the state recognizes nutrition as a determinant of human capital formation. Food intake affects not only physical health but also cognitive performance, educational outcomes, labor productivity, and longevity. Consequently, food policy becomes intrinsically linked to economic growth, social stability, and intergenerational equity. The boundary between agricultural policy and social policy dissolves, giving rise to an integrated governance model.

Within this framework, preventive healthcare logic becomes central. Rather than allocating disproportionate resources to the treatment of chronic diseases, the state can influence upstream determinants by shaping nutritional environments. Fiscal instruments, public procurement standards, labeling policies, and support for functional food production collectively form a preventive architecture. This approach internalizes long-term health externalities within food system design.

Moreover, quality of life governance entails spatial and social inclusivity. Nutritional inequality across regions and income groups contributes to disparities in health outcomes and labor productivity. A bioeconomy-based food policy must therefore address access to high-quality, functional, and personalized nutrition not only in metropolitan centers but also in rural and remote regions. Digital platforms and decentralized production technologies may reduce territorial asymmetries and enhance cohesion.

Environmental sustainability further expands the governance dimension. Degradation of natural capital directly affects food quality and long-term public health. Thus, ecological stewardship becomes inseparable from nutritional policy. By embedding circular bioeconomic principles into food systems, the state ensures that improvements in quality of life do not come at the expense of future generations [24, p. 70].

Importantly, the shift toward quality of life governance requires transformation in public discourse and institutional culture. Food is no longer perceived solely as a commodity but as a strategic resource shaping national resilience. Policy evaluation must therefore integrate multidimensional indicators such as healthy life expectancy, dietary diversity, ecological footprint, and innovation intensity in bio-based sectors.

In this broader governance paradigm, food systems function as dynamic socio-economic regulators. They influence demographic stability, workforce competitiveness, healthcare sustainability, and environmental balance. The

management of quality of life through bioeconomy-driven food policy thus becomes a central pillar of long-term national development strategy.

The report shows that the conventional calorie-focused approach to food policy, although successful in maintaining short-term supply security, falls short in tackling the deeper structural issues of modern socio-economic development. Persistent dietary deficiencies, growing healthcare costs, demographic risks, and negative environmental impacts highlight the inherent inefficiencies of the current system.

The bioeconomy offers a coherent alternative framework in which food systems are integrated into a broader ecosystem of biotechnology, digital innovation, circular production, and preventive healthcare. Within this paradigm, nutrition becomes a determinant of human capital formation, and food policy evolves into a cross-sectoral development strategy aimed at managing quality of life.

The macroeconomic implications of this transition are substantial. Better overall population health boosts workforce efficiency and prolongs active involvement in economic activities, whereas preventive measures help lower the financial pressures linked to chronic illnesses.

Simultaneously, bio-based industries stimulate structural diversification, innovation capacity, and export potential. Environmental sustainability further reinforces long-term growth by preserving natural capital.

However, technological potential alone cannot guarantee successful transformation. Institutional coherence, regulatory modernization, fiscal incentives, human capital development, and new performance metrics are essential preconditions for implementation. The redefinition of policy evaluation criteria — incorporating nutritional quality, healthy life expectancy, and bio-based value added — reflects a deeper shift in economic governance philosophy.

In this broader perspective, food systems function not merely as supply mechanisms but as strategic regulators of demographic resilience, economic competitiveness, and intergenerational equity. The integration of bioeconomic principles into Russian food policy thus represents not a sectoral reform, but a structural reorientation of national development strategy toward sustainable quality of life management.

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УДК 332.143

MODELS AND SCENARIOS FOR THE DEVELOPMENT OF DEPRESSED REGIONS IN RUSSIA: EXPERIENCE IN OVERCOMING CRISIS SITUATIONS USING THE EXAMPLE OF BELGOROD REGION

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Abstract. This paper examines models and scenarios for the transformation of depressed territories using the example of the Belgorod region. It analyzes economic diversification, investments in human capital, infrastructural and institutional measures, and crisis response practices. The conclusion is drawn about the formation of a hybrid development model that combines federal measures and the mobilization of internal resources.

Keywords: depressed regions, subsidized regions, Belgorod region, economic diversification, infrastructure, regional policy, scenario analysis.

МОДЕЛИ И СЦЕНАРИИ РАЗВИТИЯ ДЕПРЕССИВНЫХ РЕГИОНОВ РОССИИ: ОПЫТ ПРЕОДОЛЕНИЯ КРИЗИСНЫХ СИТУАЦИЙ НА ПРИМЕРЕ БЕЛГОРОДСКОЙ ОБЛАСТИ

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Аннотация. В работе рассматриваются модели и сценарии преобразования депрессивных территорий на примере Белгородской области. Анализируются диверсификация экономики, инвестиции в человеческий капитал, инфраструктурно-институционные меры и практики кризисного реагирования. Делается вывод о формировании гибридной модели развития, сочетающей федеральные меры и мобилизацию внутренних ресурсов.

Ключевые слова: депрессивные регионы, дотационные регионы, Белгородская область, диверсификация экономики, инфраструктура, региональная политика, сценарный анализ.

The economic landscape of the Russian Federation at present is characterized by significant heterogeneity. The issue of depressed regions – specific federal subjects lagging behind in economic, demographic, and social terms – remains one of the key and most acute for Russian regional development policy. These areas are marked by declining production, high unemployment, population out-migration, and, due to

technological shifts or changes in market conditions, a loss of competitiveness. The high degree of spatial concentration of economic resources and employment, the dependence of numerous municipalities on a single enterprise or sector, and demographic trends collectively generate local crises. Addressing these requires comprehensive measures applied to specific industries and to the linkages between them. Formulating appropriate strategies necessitates systemic development models that integrate short- and long-term scenarios and are grounded in empirical evaluations of the effectiveness of implemented programs. The aim of this work is to analyze existing development scenarios for depressed regions and to synthesize the experience of their implementation in modern Russian realities.

In modern economic science, a depressed region is understood as a federal subject of the Russian Federation that, as a result of a profound crisis in its primary economic sector(s), has fallen into a state of extreme and sustained economic decline [1].

L. I. Abalkin offers the following characterization of the concept of a “depressed region”: “a depressed region is a local territorial entity, the distinctive feature of which is a significant and persistent lag behind other regions, coupled with an almost complete absence of opportunities and resources for economic growth–that is, the impossibility of the normal reproduction of economic, demographic, and other regionally mediated processes” [2].

Unlike traditionally underdeveloped regions, whose lagging status is determined by historical or geographical factors, depressed zones possess accumulated industrial and scientific-educational potential that is currently not being fully utilized. The key indicators of depressiveness include a profound decline in industrial output; high levels of registered and hidden unemployment; out-migration of the working-age and highly qualified population; low investment activity; and depreciation of fixed assets.

It is important, however, not to confuse a depressed region with a subsidized one. A subsidized region is characterized by a chronically low tax base, which prevents budget formation without external infusions, and a sustained dependence on federal transfers. Subsidized regions receive funds from the federal budget on a non-repayable basis and allocate them at their own discretion, having identified priority areas. An objective assessment of the status of Belgorod Oblast requires an examination of data from the Ministry of Finance of the Russian Federation. The key indicator in this context is the level of calculated budget capacity after the distribution of grants.

According to official data for 2025, Belgorod Oblast demonstrated a ratio of 1.145, compared with the national average of 1.000. This indicated that, even after fiscal equalization, the region remained above the average level for Russia and was not classified as requiring support [3]. However, preliminary data for 2026 suggest the situation has changed, though not as critically as it could be assumed. The indicator for Belgorod Oblast stood at 1.101, which still exceeds the national average and is significantly higher than the figures for regions traditionally considered subsidized [4]. Thus, the Belgorod region can be classified neither as depressed nor as subsidized in the conventional sense of the term.

Various approaches to the typology of regions are distinguished, depending on the policies implemented and the responses of regions to crisis phenomena. Of

particular interest is a classification based on the relationship between the intensity of anti-crisis measures and the dynamics of socio-economic indicators. According to this methodology, regions can be divided into four groups. The first category comprises those subjects that did not pursue an active industrial policy during a period of upheaval and, as a result, exhibited the most significant deterioration in key indicators. The second consists of regions with a high degree of internal economic resilience, which objectively did not require excessive support measures. The third category includes territories where, despite the implementation of specific policies, development indicators remained at an average or low level. Finally, the fourth group comprises leading regions that, through active and timely actions by the authorities, managed not only to mitigate the impact of the crisis but also to improve their positions [5]. It is noteworthy that correlation analysis does not always reveal a direct link between the volume of resources expended and the final outcome. This leads to the conclusion that the effectiveness of crisis management is influenced not only by financial investments but also by the quality of managerial decisions and the institutional environment.

To understand the specific nature of the anti-crisis measures, it is necessary to consider the structural characteristics of Belgorod Oblast that had developed by the onset of the crisis period. As early as 2020, experts were recording the first signs of stagnating economic growth in Belgorod Oblast against a backdrop of declining investment. The changing geopolitical situation in 2022, manifested in intensive shelling of border areas, caused serious damage to the regional infrastructure. According to data reported by Governor Vyacheslav Gladkov at a meeting with the President of the Russian Federation, over 400 social infrastructure facilities, including schools, kindergartens, and cultural centers, were damaged. The most severe destruction occurred in the town of Shebekino and adjacent populated localities. The agricultural sector lost 160,000 hectares of arable land withdrawn from use for security reasons [6]. Under these conditions, the regional authorities were faced with the task of simultaneously addressing several interrelated problems: ensuring the physical safety of the population, compensating businesses for losses, preserving jobs, and preventing a sharp decline in economic indicators.

In the general practice of regional policy, researchers identify three basic models for the revitalization of stagnating territories. The exogenous model focuses on external support, relying on massive federal funding of regions through mechanisms of interbudgetary transfers and targeted programs. The primary goal of this model is to equalize budget capacity. However, experience shows that this approach often leads to the formation of a dependent mentality among regional elites and fails to address the fundamental problems of the productive sector. The endogenous model relies on internal potential, presupposing the identification and active utilization of unique local resources. For many depressed regions of Russia, such resources could include the repurposing of old industrial sites for technoparks or the development of tourism and recreational zones. The institutional-innovative model is based on the creation of special legal regimes (Special Economic Zones, Territories of Advanced Development), which minimize the tax burden and administrative barriers for businesses.

Projecting the future development of crisis-affected territories allows for the

identification of two main vectors. First, a region may maintain its current trends. In this scenario, state assistance is limited to social payments, which ultimately entrenches its underdevelopment. In the long term, this leads to the complete degradation of production infrastructure and the transformation of the region into a “demographic desert”. According to statistics, in regions with inertial development, the level of real disposable income of the population remains 15-20 % below the Russian Federation average [7]. The alternative scenario presupposes a qualitative change in the structure of the Gross Regional Product (GRP). This implies the active integration of the region into new logistics chains and the implementation of import substitution projects.

An important tool for overcoming the crisis is the mechanism for restructuring budget loans. For example, the government of the Russian Federation is actively introducing and utilizing the practice of writing off constituent entities' debt, provided that the freed-up funds are directed toward the implementation of investment projects: regions may have two-thirds of their debt written off on condition that the released resources are used for infrastructure development and investment support [8].

The case of Belgorod Oblast illustrates the implementation of the institutional-innovative model. The key instrument of the anti-crisis policy in Belgorod Oblast has been the extension of the Special Economic Zone (SEZ) regime-originally established for the new regions – to the border territories. The legislative framework was formed in June 2024, and practical implementation began with the application of the preferential regime to actually operating and affected enterprises. The social impact of the SEZ’s functioning is also significant: as of January 2026, 4,000 jobs have been preserved, and the creation of new jobs is estimated at 700 units. Meanwhile, the anticipated volume of tax and insurance contributions benefits for SEZ participants will amount to 11.6 billion rubles [9].

The experience of the agro-industrial sector of Belgorod Oblast, traditionally the backbone of the regional economy, deserves particular attention. Despite the forced reduction in sown areas, the industry has demonstrated impressive resilience. In 2024, the region produced over one million tons of live-weight pork for the first time in its history. In terms of agricultural output per hectare, Belgorod Oblast maintains its leadership within the Russian Federation. Federal support played a substantial role here: 16 billion rubles were allocated from the federal budget to support the agro-industrial complex, with the region contributing an additional 3 billion [6].

The issue of the regional economy’s mono-dependence on the agro-industrial and extractive sectors is recognized by regional authorities as a priority to be addressed. To identify priority areas for diversification in Belgorod Oblast, researchers have proposed a methodology based on a multi-criteria assessment of economic sectors. The key criteria in this approach are their innovative activity and evolutionary conditioning.

The practical implementation of diversification is proceeding along several paths. First, the range of sectors covered by the preferential SEZ regime is expanding: in addition to agriculture and manufacturing, benefits now extend to logistics, computer technology development, and software [10]. Second, the region is placing its bet on the development of small and medium-sized enterprises. The number of SME entities has exceeded 61,000 and continues to grow, while the turnover of this sector has increased by 55 % compared to 2021. Currently, by this indicator, Belgorod Oblast ranks fourth

in the Central Federal District [11].

At the same time, experts note that investment activity in the region is declining: in the first quarter of 2025, the volume of investments decreased by 9.6 % in comparable prices relative to the same period in 2024 [12]. The introduction of the preferential SEZ regime is expected to improve the investment climate; however, the effect will only become apparent in the medium term.

Overcoming the depressed state of Russian regions requires abandoning universal templates in favor of individual transformation strategies. Hybrid scenarios that combine federal budget investments, the creation of special legal regimes (SEZs), and the mobilization of a territory's internal resources are coming to the forefront. The success of any given scenario is determined not so much by the volume of allocated funds as by the ability of regional authorities to correctly identify competitive advantages and establish effective communication with the federal center and business.

The experience of Belgorod Oblast demonstrates the formation of a hybrid model of anti-crisis development, adapted to the extreme conditions of a border region. The further development of Belgorod Oblast will be determined by the ability of regional authorities and the business community to convert anti-crisis measures into long-term competitive advantages. The expansion of the SEZ to non-border territories, the deepening of agricultural product processing, the development of the IT sector and creative industries, as well as the completion of environmental projects, create a solid foundation for post-crisis recovery and sustainable growth.

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УДК 65.011.56

TRANSFORMATION OF WAREHOUSE MANAGEMENT IN THE CONTEXT OF THE TRANSITION TO INDUSTRY 4.0

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Abstract. The article explores the transformation of warehouse management in the context of the transition to Industry 4.0. Based on an analysis of scientific publications from 2022 to 2025, the key areas of transformation in warehouse management have been identified: the algorithmization of replenishment, the enhancement of inventory traceability, the development of robotic solutions, the expansion of analytical support for management decisions, and the inclusion of sustainability parameters in the performance evaluation system. In the current environment, the warehouse is becoming a cyber-physical management environment that integrates digital platforms, automated execution systems, identification tools, and analytical instruments. It has been established that the practical effect of technology implementation is determined by the consistency of organizational and technological changes.

Keywords: warehouse management, warehouse logistics, Industry 4.0, digital transformation, warehouse robotization.

ТРАНСФОРМАЦИЯ СКЛАДСКОГО МЕНЕДЖМЕНТА В УСЛОВИЯХ ПЕРЕХОДА К ИНДУСТРИИ 4.0

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Аннотация. В статье исследуется трансформация складского менеджмента в условиях перехода к Индустрии 4.0. На основе анализа научных публикаций 2022–2025 гг. выявлены ключевые направления преобразования складского менеджмента: алгоритмизация комплектования, усиление прослеживаемости запасов, развитие роботизированных решений, расширение аналитической поддержки управленческих решений и включение устойчивостных параметров в систему оценки эффективности. В нынешней среде склад приобретает характеристики киберфизической управленческой среды, в которой интегрируются цифровые платформы, автоматизированные исполнительные системы, средства идентификации и аналитические инструменты. Установлено, что практический эффект внедрения технологий определяется согласованностью организационных и технологических

изменений.

Ключевые слова: складской менеджмент, складская логистика, Индустрия 4.0, цифровая трансформация, роботизация склада.

Introduction. In the context of Industry 4.0, warehouse management is losing its status as a purely auxiliary function of material flow and is increasingly evolving into a hub for the digital coordination of material, information, and management flows. This restructuring affects the architecture of operations, methods of recording inventory movement, the nature of dispatching intra-warehouse processes, and the decision-making model itself, where the role of WMS systems, sensor infrastructure, robotic complexes, and real-time analytical modules is growing. For the Russian warehouse sector, this development trajectory is also associated with a practical demand for more intensive space utilization, acceleration of cargo flow processing, and reduction of losses related to operational discrepancies.

In recent literature, the warehouse is already considered a cyber-physical environment where value is created through the integration of automation, traceability, algorithmic routing, and digital integration with other links in the supply chain. In a systematic review by L. N. Tikwayo and T. N. D. Mathaba, among the most significant effects of implementing Industry 4.0 technologies in warehouse management are increased process efficiency, real-time data availability, enhanced competitive advantages, and digital integration of business activities [1]. Russian publications from 2024–2025 shift the focus to more specific issues: the quality of warehouse automation, the architecture of robotic solutions, tools for digital coordination, and the assessment of the practical impact of technological re-equipment [2; 3; 4, p. 151].

Along with the expansion of the technological toolkit, a research gap persists. On the one hand, the categories "Logistics 4.0", "smart warehouse", and "Warehouse 4.0" are already firmly established in scientific discourse; on the other hand, a unified classification framework for describing the corresponding technologies, organizational outlines, and management effects remains fluid. An empirical study by E. M. Strøm, J. A. Busch, L. Hvam, and A. Haug directly points to the insufficient clarity of the very concept of Warehouse 4.0 and indicates a predominance of conceptual interpretations over applied models based on the observed practice of 3PL operators [5]. At the same time, the literature emphasizes that the barriers to transitioning to a new technological paradigm are interconnected: high lifecycle costs of solutions, warehouse layout constraints, resource deficits, energy loads, and digital security risks hinder the straightforward scaling of automation [1; 6, p. 358].

Under these conditions, research interest is naturally shifting from a declarative recognition of the benefits of digitalization to a more rigorous question of how warehouse management itself is transforming as a system of planning, coordination, control, standardization of operations, and distribution of responsibility between humans, software platforms, and automated equipment. It is this formulation that allows the transition to Industry 4.0 to be viewed not as a sum of individual technological implementations, but as an institutionally and organizationally linked process affecting the structure of management decisions, warehouse performance parameters, logistics service sustainability, and the economics of intra-warehouse

operations [7, p. 116; 8, p. 16; 9, p. 15; 10, p. 31].

The aim of the article is to reveal the content of the transformation of warehouse management in the context of the transition to Industry 4.0 and to identify the organizational and technological shifts that form the new warehouse management model.

Results of the Study. The conducted analysis shows that the transition to Industry 4.0 primarily changes the very subject of management in the warehouse sector. The study by L. N. Tikwayo and T. N. D. Mathaba examined 33 applied case-study publications distributed across 30 journals; thus, the empirical base of the issue goes beyond single technological descriptions and makes it possible to compare the real effects of implementing digital solutions [1]. Another fundamentally important observation by the authors is that the geography of the cases is distinctly asymmetrical the majority of the works focus on Asia, while Africa and North America were represented by only one research cluster per continent in their dataset. For warehouse management, this conclusion is significant because it shows that a universal model for digital modernization has not yet emerged, and implementation practices depend on the industry and regional environment [1].

Quantitative processing of this sample yielded another significant result. Pareto analysis showed that four effects – increased process efficiency, availability of real-time data, competitive advantage, and digital integration of operations – account for about 80 % of all mentions of benefits in the cases [1]. Thus, the practical value of Warehouse 4.0 technologies manifests itself primarily where the warehouse begins to function as an environment for continuous coordination of data and tasks, rather than as a point for the physical storage of goods. The same work identifies high lifecycle costs, complex facility layouts, resource constraints, increased security risks, and higher energy consumption as the most frequent barriers [1]. Consequently, in an applied context, the question is posed as follows: to achieve an effect, it is necessary to simultaneously align the investment framework, space architecture, digital infrastructure, and workforce readiness.

Substantively, this means a shift in warehouse management from retrospective control to event-driven management. In the review by L. Zhen and H. Li, four basic characteristics of smart warehouse operations are highlighted: information interconnectedness, equipment automation, process integration, and environmental sustainability [10]. Warehouse 4.0 is now evaluated not only by picking speed or storage density but also by the ability to integrate WMS, RFID, IoT, automation tools, analytics, and sustainability parameters into a single system. In practical terms, this changes the very structure of KPIs: in addition to traditional performance indicators, metrics for data accuracy, inventory traceability, service sustainability, and resource efficiency are added [10; 11].

The practice-oriented nature of the transformation is particularly clearly revealed in the study by E. M. Strom, J. A. Busch, L. Hvam, and A. Haug [5]. The empirical part of this work is based on a case study of an international logistics provider operating in more than 80 countries and employing over 70,000 people. To clarify the real profile of Warehouse 4.0, the authors conducted 16 semi-structured interviews with participants representing global, regional, and site-level management; in terms of

duration, this amounts to 780 minutes of expert material if the intervals provided in the publication are summed up. This example is important because it deals not with a laboratory model, but with a large-scale 3PL practice where digital solutions face contractual variability, customer heterogeneity, and high operational complexity [5].

The same work also provides specific technological examples. In the considered 3PL company, IoT was applied through sensors, RFID tags, cameras, smart labels, "pick-to-light" systems, "pick-by-voice" systems, and mobile applications; the scope of application covered tracking warehouse equipment, goods movement, temperature, humidity, shock load control, and object location [5]. In the automation block, AS/RS, automated forklifts, AGVs, shuttles, AMRs/RMFS, and drones were recorded; for augmented reality – smart glasses and AR-based solutions for picking and quality control; in the analytical circuit – AI/ML for decision-making, root cause analysis, and automation of customer requests; in the simulation module – simulation and digital twins for warehouse design and resource demand forecasting [5]. In other words, the practice of Warehouse 4.0 in large-scale logistics is already taking shape as a multi-level set of solutions, where the digital platform manages data, and the automated execution loop takes on a significant part of routine movement and control.

Another quantitatively significant foundation is provided in the critical review by K. Ellithy [9]. The authors analyzed 111 publications published between 1990 and 2022 and, on this basis, proposed a framework for flexible warehouse automation. The practical conclusion of their study is that a robotic warehouse project should be centered not around a single "trendy" technology, but around a combination of material handling, identification, task management, and digital data exchange tools. In conjunction with this, E. M. Strøm emphasizes that in the warehouse environment, the most promising are not isolated devices, but coordinated categories of solutions: IoT, automation and robotics, augmented reality, system integration, big data and analytics, simulation, cloud technologies, cybersecurity, and blockchain [5]. For management, this means a transition from the single implementation of equipment to the architectural management of a technological portfolio.

It is indicative that even within the automated block, a universal solution does not exist. In the article by D. Bianco, M. Baglio, and F. Dallari [12], automated picking systems are classified into four main groups: cranes and automated forklifts, carousels and dispensers, shuttles, and AGVs. The practical meaning of such a typology is obvious: the choice of technology is determined by the order structure, SKU density, picking frequency, loading horizon, and capital intensity of the project. A design error here is particularly sensitive, as it involves medium- and long-term investments in a node that directly affects warehouse throughput. In an applied sense, this requires management to first typologize its own flow, and then select the class of automation according to the operations profile, rather than the general idea of "digitalization for the sake of digitalization."

Russian scientists also confirm the shift from fragmented mechanization to a comprehensive restructuring of the warehouse circuit. In the article by T. V. Tretyachenko and D. S. Pozdnukhov, robotics, big data, electronic data interchange, and other digital management tools are highlighted among the prospects [4]. I. F. Zhukovskaya considers the digital transformation of logistics through the

change of the entire coordination environment, while A. O. U. Ganiev and I. S. Polevshchik – through the architectural optimization of robotic solutions, where modularity, multifunctionality, and adaptability become crucial [3; 8]. An important and early conclusion for Russian practice by I. D. Bekmurzaev, R. Kh. Akchurin, and A. V. Molokov is also relevant: Industry 4.0 technologies in warehouse logistics should be viewed as a means of reducing operational losses and accelerating intra-warehouse movement, rather than as an external attribute of innovativeness [7]. These publications lead to a managerial conclusion: in the domestic environment, the greatest return is brought by a phased trajectory, where accounting and traceability are first stabilized, then picking and routing are restructured, after which analytics and digital simulation are deployed.

Table. Practical manifestations of warehouse management transformation under Industry 4.0

Focus Area	Quantitative Indicator	Managerial Implication
Analysis of Industry 4.0 implementations in warehouses	33 case-study articles, 30 journals	Effects and barriers are already steadily observable in practice but are unevenly distributed across regions.
Most significant effects	4 effects account for about 80% of all mentions	Priority should be given to solutions that enhance efficiency, real-time data, and digital integration.
Empirics of a large 3PL environment	80+ countries, 70,000+ employees, 16 interviews, 780 minutes of interviewing	Warehouse 4.0 is implemented as a multi-level system, not as a single automation project.
Flexible automation	111 publications from 1990–2022	Warehouse design requires a combination of technologies, not the selection of a single device.
Classes of automated picking	4 groups of solutions	Technology is selected based on the flow profile, SKU structure, and economics of the operation.
Sustainability effect	Confirmed economic, environmental, and social effect	The KPI system of a 4.0 warehouse must include operational and sustainability indicators.

Sources: [9-12; 5-10].

Thus, the redistribution of functions within the warehouse takes on a clearly observable form. Where implementation is limited to a separate software module or partial mechanization, management retains its previous form and achieves only local acceleration. However, where identification, sensors, automated movement, digital dispatching, analytics, and simulation are combined, a different organizational regime emerges – the warehouse ceases to be a place of static storage and turns into a digitally managed execution environment.

Conclusion. In the context of the transition to Industry 4.0, warehouse management is undergoing a structural transformation affecting both the operational circuit and the very managerial logic of the warehouse. The focus is shifting from the local administration of receiving, put-away, storage, and shipping to the digital coordination of flows, resources, data, and execution mechanisms. In this system, the warehouse acts no longer as an isolated segment of goods movement, but as a cyber-physical environment where inventory traceability, algorithmic routing, analytical decision support, and automated execution form a single managerial complex.

The analysis established that the practical effectiveness of the transition to the Warehouse 4.0 model is determined primarily by the degree of alignment of technological and organizational transformations. The greatest effect is achieved by solutions where WMS, RFID, IoT, robotic complexes, analytics tools, and integration platforms are implemented as an interconnected circuit, rather than as a disparate set of digital tools. With such a configuration, the acceleration of intra-warehouse operations, increased accuracy of inventory records, growth in the transparency of managerial actions, enhanced adaptability of the warehouse to flow fluctuations, and expanded capabilities for predictive management are achieved.

At the same time, it was revealed that the technological re-equipment of the warehouse retains a number of significant limitations. These include the high capital intensity of solutions, the complexity of redesigning warehouse space, the dependence of the result on the maturity of the information infrastructure, the need for new personnel competencies, as well as increasing requirements for digital security and process sustainability. For this reason, the effective transformation of warehouse management implies a phased nature of implementation: at the first stage, it is advisable to ensure the stability of accounting and traceability, then to restructure picking, routing, and intra-warehouse movement, after which the system is brought to the level of predictive analytics, digital simulation, and extended KPI control.

The scientific significance of the work consists in clarifying the very nature of warehouse management in the era of Industry 4.0. Warehouse management should be interpreted as a system of digital orchestration, where performance is formed at the intersection of data, algorithms, equipment, and organizational regulations. The practical significance of the study is related to the possibility of using the obtained conclusions in designing warehouse modernization programs, selecting automation priorities, and forming indicators for evaluating the efficiency of warehouse complexes. Prospects for further development of the topic are associated with an in-depth study of the economic effect of individual classes of Warehouse 4.0 technologies, comparison of industry implementation models, and the development of applied methodologies for assessing the maturity of digital warehouse management.

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УДК 659.1

MARKETING FOR GENERATION Z IN THE ATTENTION ECONOMY

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Abstract. The article examines marketing strategies for Generation Z in the attention economy. Based on a survey of 210 respondents aged 16-25, the study identifies key engagement triggers: visual content, authenticity, micro-influence, and interactivity. Recommendations for creating short, viral, and socially oriented content are provided.

Keywords: attention economy, Generation Z, marketing, concentration, clip thinking, digital communications.

МАРКЕТИНГ ДЛЯ ПОКОЛЕНИЯ Z В УСЛОВИЯХ ЭКОНОМИКИ ВНИМАНИЯ

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Аннотация. В статье исследуются маркетинговые стратегии для поколения Z в условиях экономики внимания. На основе опроса 210 респондентов в возрасте 16-25 лет выявлены ключевые триггеры вовлечения: визуальный контент, аутентичность, микровлияние и интерактивность. Предложены рекомендации по созданию короткого, вирального и социально-ориентированного контента.

Ключевые слова: экономика внимания, поколение Z, маркетинг, концентрация внимания, клиповое мышление, цифровые коммуникации.

The modern digital environment is oversaturated with information. According to various estimates, an average urban resident encounters between 4,000 and 10,000 advertising messages daily. Under these conditions, a unique economic model emerged, which Canadian psychologist and economist Herbert Simon characterized as the “attention economy” as early as 1971. The key idea of this concept is that in the post-industrial world, consumer attention becomes the scarcest and most valuable resource, which leads to a major competitive struggle for it. The task of marketing in this new reality has shifted from simply informing the target audience to a fierce competition for seconds of consumer concentration [1, p. 121].

The most interesting and complex object of study in this context is Generation Z (centennials, “zoomers”) – the generation born between 1997 and 2012. Russian researchers clarify the periodization due to the specifics of digitalization in Russia, thus including in the group those born from 2001 [2, p. 39]. Centennials represent the first truly “digital” generation, who have never known a world without the Internet, smartphones, and social networks. Their socialization, education, leisure, and consumption are largely influenced by digital technologies from an early age, which forms a fundamentally different structure of information perception.

Representatives of Generation Z are active digital consumers who not only make purchases online but also build their identity through online interaction [3, p. 246]. Formed in the era of TikTok, Instagram Reels, and YouTube Shorts dominance, the perception of zoomers is characterized by the so-called “clip thinking” – the ability to quickly switch between disparate fragments of information, grasping the essence without deep immersion in long, linear formats.

The assertion about 8-second attention, although metaphorical to a certain extent, most accurately reflects the new reality: to capture a centennial’s interest, it is necessary to provide relevant and engaging content almost instantly. Their attention span is indeed shorter than that of their predecessors, the millennials (12 seconds) [1, p. 121]. Thus, the relevance of this study is due to the urgent need to adapt marketing tools, brand strategies, and communication formats to these altered patterns of information consumption.

The theoretical basis of the research is formed by several fundamental concepts. Firstly, it is the theory of the attention economy, developed in the works of M. Goldhaber, who viewed attention as a key resource of the digital age. Secondly, it is the generational theory of N. Howe and W. Strauss, which makes it possible to identify specific features of each age cohort formed under the influence of historical and technological conditions. Thirdly, the theory of clip thinking developed by Russian philosophers F. Girenok and K. Frumkin is essential as it clarifies the cognitive characteristics of centennials. Finally, modern models of digital engagement (engagement marketing, neuromarketing) provide tools for the practical application of this knowledge.

The information base of the study includes statistical data from international reports (including the Cassandra Report by the Deep Focus agency) [4], the results of the author’s online survey, as well as an analysis of audience behaviour on digital platforms (TikTok, VK, Telegram, YouTube). The research methodology includes theoretical methods (system analysis, synthesis, and generalization of scientific materials), empirical methods (content analysis of digital platforms, questionnaires), and analytical methods (comparative analysis of the effectiveness of various content formats and communication channels).

The practical significance of the study lies in the fact that understanding the psychological and behavioural characteristics of the digital generation allows for the creation of effective advertising strategies and business solutions adapted to the demands of the attention economy. The purpose of this research is to develop practical recommendations for effective interaction with Generation Z based on empirical data.

To empirically test the main theoretical propositions and identify key triggers for

engaging Generation Z, an online survey was conducted. The study was carried out in February–March 2026. The survey involved 210 respondents aged 16 to 25. Although formed spontaneously, the sample was mostly aimed at representatives of students and young people in the Tula region (based on the Tula branch of Plekhanov Russian University of Economics and other universities in the city).

The questionnaire was distributed through the main digital channels popular among the target audience: the Telegram messenger and the VK social network. The survey included 15 questions, divided into several thematic blocks:

1. Preferences in social networks and frequency of their use.
2. Attitude to traditional and digital advertising formats.
3. Factors that make one stop scrolling the feed and interact with content (like, comment, repost).
4. Perception of long and short content formats.
5. The most significant qualities of a brand or author for building trust.

Processing the obtained data revealed several stable trends in the consumer behaviour of Generation Z.

1. Dominance of Visual and Messenger Platforms. When asked about the most frequently used social networks, respondents indicated that they use different platforms for different purposes. However, the absolute leaders in daily use were Telegram (as the main messenger and news channel), TikTok (as the main source of entertainment content), and YouTube (as a platform for deeper immersion in topics, but with a preference for Shorts). VK retains its position as a universal platform for communication, music, and student communities. These data are visualized in Figure 1.

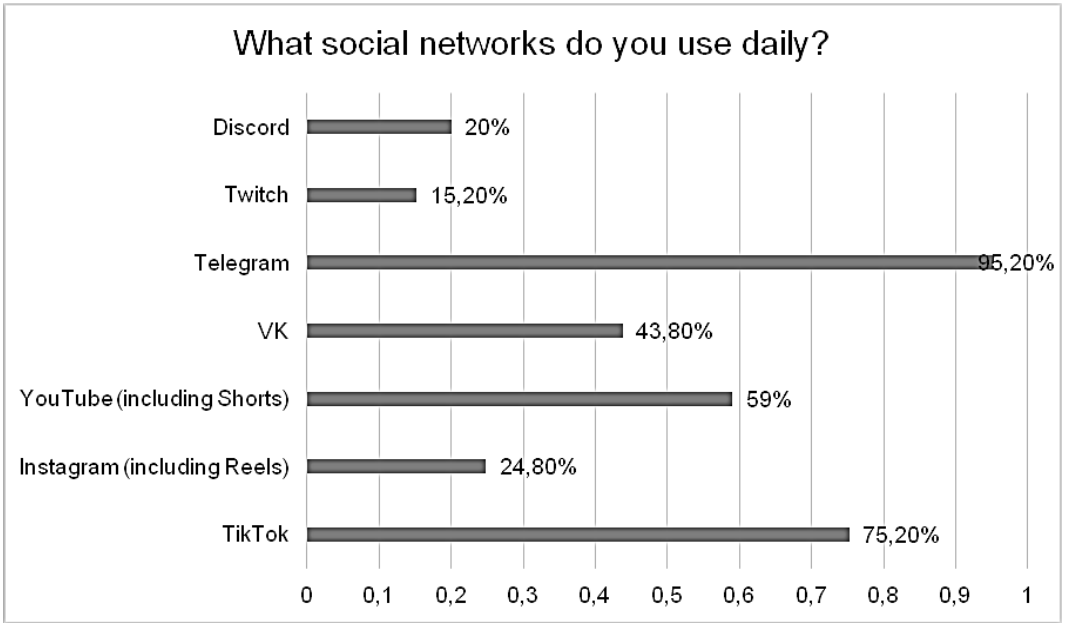


Figure 1. Frequently used social networks among Generation Z

2. Ineffectiveness of Traditional Advertising Formats. The key findings confirmed the thesis about “banner blindness” and irritation due to intrusive

advertising. 70.5 % of the respondents stated that they “very often” or “almost always” scroll past a post or video if it does not catch their attention in the first 3-5 seconds. Traditional interruptive advertising on the Internet, especially pre-roll adverts on YouTube, causes obvious irritation among 50.5% of the respondents. They admitted that they try to skip such adverts at the first opportunity. At the same time, 43.8% of the survey participants noted that native advertising and integrations into videos of their favourite bloggers are perceived much more tolerantly and do not make them feel the urge to immediately close the tab.

3. Key Engagement Triggers. The respondents were offered a multiple choice of factors that make them stop and pay attention to content. The results were distributed as follows (Figure 2):

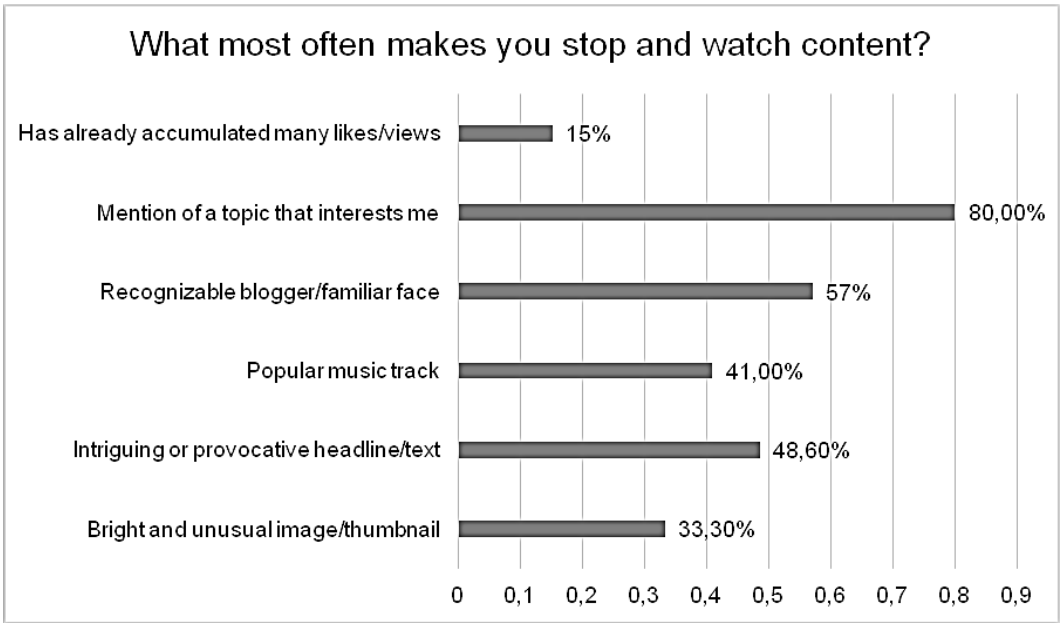


Figure 2. Factors that make Generation Z stop and watch content

These data clearly demonstrate that the emotional and aesthetic component of content plays a decisive role. Information must be packaged in an attractive, easily digestible, and emotionally colored shell.

4. Factors Influencing Purchase Decisions. The question about what is more likely to prompt a purchase or engagement with a brand revealed an important feature of Generation Z: they trust the community and context rather than brands (Figure 3).

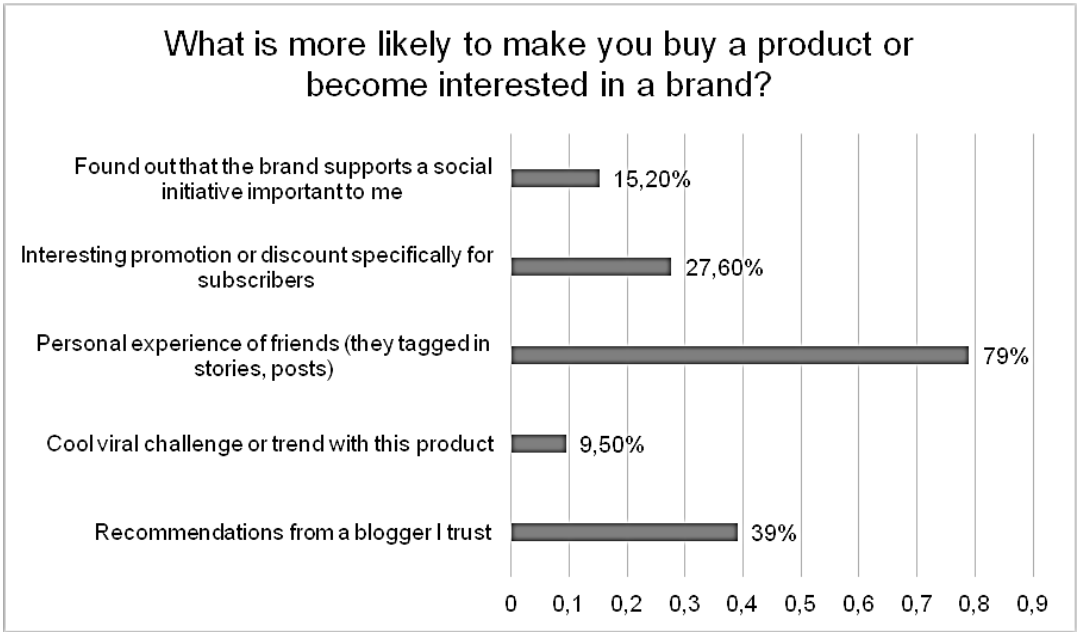


Figure 3. Factors influencing the purchase of a product or engagement with a brand

5. The Value of Authenticity. In response to an open question about what content they consider “ideal for their generation,” the respondents gave similar answers, which can be combined into two main clusters:

- “Honest, real, and without pretence” (35.2 %). The respondents emphasized that they are tired of staged photos and “gloss”; they value “life aesthetics”.
- “Short, bright, and with a trendy sound” (24.8 %). This reflects the habit of consuming dynamic, “remixed” content.

The greatest irritation among Generation Z is caused by intrusive, fake, and insincere advertising, where the brand tries to pose as “one of them” without good reason. In contrast, content from real people, even if it is an advertising integration, is perceived as more truthful if the blogger maintains their style and honestly tells the audience about the product. 80% of the respondents also confirmed that as an initial introduction to a product, they prefer short videos (up to 15-30 seconds) rather than long reviews or text articles.

Thus, the conducted study demonstrates that classical marketing models based on the principle of interruption marketing can hardly ever work for Generation Z. In the harsh conditions of the attention economy, brands need to radically change their approach: not to interrupt the user, but to become an organic part of their content flow, offering value in exchange for voluntarily given attention [5, p. 27].

The interests and behavioural patterns of Generation Z will be decisive for marketing and branding in the coming decade. The term “neobranding” has already appeared in the professional environment to describe this approach: it focuses not on creating an ideal image, but on building a sincere emotional connection with the consumer through shared values. Zoomers are more tolerant and open to diversity and inclusivity; they often advocate for minority rights and social justice, and expect the same from brands [6, p. 133].

Based on the synthesis of theoretical propositions and the obtained empirical data, the following practical recommendations can be formulated for developing

marketing strategies aimed at centennials:

1. Priority of Short-Form Video Content. Brands need to focus on creating vertical videos lasting up to 15-30 seconds for Reels, TikTok, and YouTube Shorts. The key rule is that the “hook” (the engaging element), whether it be a visual image, an unexpected statement, or dynamic editing, must be embedded in the first 3 seconds of the video.

2. Authenticity and Anti-Gloss. Generation Z values “reality” above the ideal picture. Content should be human-oriented, showing non-ideal situations, the “backstage” of the company’s work or the blogger’s life. This builds trust. According to the Cassandra Report by the Deep Focus agency, 63 % of Generation Z representatives want to see real people in advertising, not stars. The “Be real” trend is gaining popularity worldwide.

3. Micro-Influencer Strategy. Collaboration with niche bloggers (from 5,000 to 50,000 followers) who have a small but highly trusting and engaged community is often more effective than working with media personalities. The recommendation of a “familiar stranger” is perceived as advice from a friend.

4. Interactivity and Engagement. It is necessary to actively use interactive platform features: polls in Stories, tests, Q&A sessions, interactive broadcasts. This turns a passive consumer into an active participant of the dialogue and co-author of the content.

5. Social Responsibility as Part of Identity. Generation Z expects brands to have a clear ethical and social position (ecology, inclusivity, body positivity, support for social projects). Sincere (not “performative”) involvement in these topics becomes a powerful competitive advantage and a trigger for building loyalty.

6. Gamification and Working with Trends. Integration into current Internet trends, challenges, and the use of gamification mechanics (contests, sweepstakes with simple participation conditions) can increase the viral potential of content and engage the audience in the game.

Summarizing, it can be argued that marketing for Generation Z in the attention economy is not a primitive simplification of meanings, but, on the contrary, their concentration and skilful packaging. It is the art of creating a message in a bright, visual, and emotionally rich form that resonates with the deep values and identity of Generation Z, encouraging them not just to see it, but to be willing to interact. The result is voluntarily given attention, turning into long-term loyalty. The main task of a modern marketer is not to mechanically lengthen the time of contact with the brand, but to make every second of this contact truly valuable and meaningful for the consumer.

It is not intrusive advertising in the least that Generation Z values, but, by contrast, useful, entertaining, or inspiring content organically integrated into their digital environment. Successful marketing today is not interruption, but the addition of value, deserving the attention of the most sophisticated and demanding generation in history.

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УДК 659.126:316.7

THE RUSSIAN CULTURAL CODE IN COSMETICS BRANDING: SEMIOTIC APPROACH AND MARKETING PRACTICES

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Abstract. The paper explores how Russian cosmetics brands integrate national cultural codes into their branding strategies. Drawing on semiotic analysis, the study distinguishes three types of brand codes – visual, cultural, and ideological – and examines their practical application through recent cases of domestic beauty brands. The findings indicate that effective use of the cultural code goes beyond decorative folklore elements and requires integration into product formula, packaging design, and consumer communication.

Keywords: cultural code, branding, Russian identity, cosmetics, semiotics, brand design, marketing communications.

РУССКИЙ КУЛЬТУРНЫЙ КОД В БРЕНДИНГЕ КОСМЕТИЧЕСКОЙ ПРОДУКЦИИ: СЕМИОТИЧЕСКИЙ ПОДХОД И МАРКЕТИНГОВЫЕ ПРАКТИКИ

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Аннотация. В работе исследуется, как российские косметические бренды интегрируют национальные культурные коды в стратегии брендинга. На основе семиотического анализа выделяются три типа брендовых кодов: визуальный, культурный и идеологический – и анализируется их практическое применение на примере отечественных бьюти-брендов. Результаты показывают, что эффективное использование культурного кода выходит за рамки декоративных фольклорных элементов и требует интеграции в формулу продукта, дизайн упаковки и коммуникацию с потребителем.

Ключевые слова: культурный код, брендинг, русская идентичность, косметика, семиотика, бренд-дизайн, маркетинговые коммуникации.

Over the past several years, the Russian cosmetics market has undergone significant changes. The departure of foreign brands and the parallel implementation of import substitution programmes have created both new opportunities and new challenges for domestic manufacturers. One of the most visible strategies to emerge is

the deliberate use of the “Russian cultural code” – a set of symbols, narratives and values that resonate with local consumers on an emotional and identity level. However, practitioners face two key questions: what exactly should be considered part of the “Russian code”, and whether the recognisability of this code translates into actual economic performance [1; 2]. This paper attempts to answer these questions through an analysis of the semiotic foundations of the cultural code in branding and an examination of specific cases from the Russian cosmetics industry.

Theoretical framework: three types of brand codes. In the semiotic tradition, following Umberto Eco and Yuri Lotman, a cultural code is understood as a system of signs and rules that generate meaning within a particular community [3, p. 131]. Applied to branding, this means that every element of a product – colour, shape, material, name, scent – carries a message that the consumer decodes through shared cultural knowledge. When a brand speaks the same cultural “language”, trust and emotional connection emerge.

Zadaura (2023) applied this logic to cosmetic product branding and proposed three distinguishable types of codes: visual, cultural and ideological [3, p. 132-133]. The visual code includes logo, typography, colour palette and packaging geometry. The cultural code refers to references to a specific heritage – for example, L’Oréal’s frequent use of Parisian aesthetics in its advertising. The ideological code conveys a system of beliefs, as in Dove’s “real beauty” campaign. None of these codes works in isolation; strong brands build them into an integrated system.

Kozyreva (2026), in turn, identified five functions of the cultural code in brand design: identification (associating the brand with a particular culture or group), communication (transmitting meanings to the target audience), semiotic (using signs and symbols across different channels), value (positioning the brand within a price/quality hierarchy), and adaptive (allowing the brand to adjust to new markets or trends) [5, p. 38-39]. This framework makes it possible to assess how deeply a brand develops its cultural code rather than merely applying decorative elements.

The Russian cultural code: content and relevance

Defining the Russian cultural code remains a matter of debate. Lyubimova (2025) includes both material elements (architecture, folk crafts, images of nature) and intangible values (collectivism, spiritual resilience, sincerity, hospitality) [4, p. 62-63]. A study by SberMarketing (cited in [1]) offers a more dynamic classification, dividing cultural symbols into three categories: *outgoing*, *dominant*, and *emerging*.

The *outgoing* category includes direct references to epic heroes (Ilya Muromets, Dobrynya Nikitich), village archetypes (wooden izbas, felt boots, samovars), and the straightforward use of Russian classical writers’ names and portraits on packaging. According to the study, these symbols are gradually losing their emotional power because the market has become oversaturated with them, and consumers no longer perceive such references as original or meaningful. The *dominant* category includes nature as a source of pride (birch trees, wide fields, deep forests) and the family in its new interpretation – not the stereotypical smiling family around a mayonnaise jar, but sports families, creative families, multi-generational families with an emphasis on children and intergenerational bonds. The *emerging* category is particularly interesting for branding professionals. It includes old fairytale characters placed in contemporary

contexts (for instance, Ivan the Terrible in an insurance company advertisement), the re-interpretation of Soviet nostalgia (Cheburashka in the recent film), and the romanticisation of the 1990s as a period of youth and freedom for older millennials. This classification demonstrates that the cultural code is not static – it transforms alongside audience expectations and can be consciously shaped by brands.

The growing attention to the Russian cultural code has objective grounds. According to data from Ipsos (Trend Vision 2024) and VCIOM, the majority of Russian consumers, given equal price and quality, prefer domestically produced goods and associate local brands with reliability and shared values [4, p. 63]. The exit of Western brands has created not only a product vacuum but also a semiotic one, which local players are eager to fill. However, simply reproducing matryoshka dolls and kokoshniks no longer works – audiences expect deeper and more authentic communication. Another important trend is the rise of local patriotism: consumers are increasingly interested in regional cultures within Russia itself, from Vologda lace to Dagestani ceramics. Brands that manage to speak not just a general Russian language but a specific regional dialect of that language gain an additional competitive advantage.

Case studies of Russian beauty brands. *Arive Makeup: regional diversity.* In 2023, the brand launched a foundation in ten shades. Instead of a standard list of tones, Arive invited ten female artists from the corresponding regions and asked them to depict the beauty of their homeland without strict technical guidelines. The resulting illustrations were placed on limited-edition packaging. The campaign brought 50,000 new customers and 2 million reach with almost zero advertising budget [1]. The key success factor was the rejection of a single monolithic "Russianness" in favour of genuine diversity.

Holly Polly: Russian fairy tales revisited. The skincare line "Russian Girl" received names that reference folklore and proverbs: toner "Tablecloth-road", cleansing foam "Still waters run deep", lip balm "Life is a raspberry". The logo was temporarily changed to a girl in a kokoshnik, but the overall aesthetic remained modern and ironic. A closed party for bloggers and a New Year game with Wildberries ("rescue the princess") generated over 30 million organic reach [1]. The brand did not copy old images but reinterpreted them in a manner relevant to a young audience.

Russian Beauty Guru (RBG): four codes of Russian beauty. Founded by Natasha Rakoch (formerly of Vivienne Sabó), RBG positioned itself from the start as a brand "made in Russia" – so unusual in 2021 that printers asked whether it was a mistake [2]. Based on a semiotic study, Rakoch identified four stable codes: *character* (strength, inner energy), *realism/practicality* (the product must work, not just look good), *stylisation* (the ability to play with cultural forms), and *modesty* (inner dignity without provocation). These codes are consistently implemented across products – from the "Black Moscow" mascara to the "Literary palettes" inspired by school classics. A collaboration with the Ivanovo Chintz Museum (more than 50,000 historical patterns) produced the "Russian Nude" lipstick line, merging industrial heritage with contemporary cosmetics [2].

Estilab: honesty as a cultural value. The co-founders of Estilab argue that Russian consumers have grown tired of Western "marketing overload" and appreciate

transparency: effective concentrations of active ingredients, realistic promises (consultants may recommend a competitor if the product is not suitable), clinical studies in Russian medical institutions, and fair pricing. They call this the “new paradigm of Russian marketing”. The parent brand IconSkin reached a turnover of nearly 2 billion rubles [1]. Honesty here appears not merely as an ethical principle but as a culturally conditioned strategy.

Kosmo Beauty: functionality rooted in habits. The brand observed that Russian women live with extreme temperature shifts and rarely have time for multi-step Korean routines. The response was a cream-spray “17 in 1” (replacing several products) and a cream-wax stick for dry heels – a practical solution for gardeners. The formulations use local plant extracts and scents associated with Russian nature (cotton, wood, field herbs). As the product director notes, “the cultural code lives in the formula and the usage format, not only on the package” [1].

Discussion: from decoration to deep integration. The analysis of these cases allows us to identify several levels of cultural code integration. The first, superficial level involves direct borrowing of recognisable but already outgoing symbols (kokoshnik, sarafan, matryoshka). Such solutions fall into the “outgoing” category and generate minimal emotional response, as they are perceived as clichés. The second level involves integration into the product itself: formulas adapted to the local climate (Kosmo Beauty), clinically proven ingredients (Estilab). The third level is integration into packaging and naming: regional artists (Arive Makeup), historical patterns (RBG), ironic folklore names (Holly Polly). The fourth level is integration into communication: transparency and honesty as a core value (Estilab), themed events and games (Holly Polly). The fifth level is value-based: open pride in national heritage (RBG) or, conversely, the demonstration of cultural diversity (Arive Makeup).

A separate issue that deserves attention is the risk of using the cultural code in a manipulative or superficial manner. When a brand adds a patriotic slogan or a traditional ornament purely for commercial gain, without any deeper connection to the product’s formula, ingredients, or corporate values, consumers quickly detect this dissonance. According to Lyubimova (2025), such cases of “performative patriotism” can lead not only to a lack of loyalty but to active consumer rejection and negative word-of-mouth [4, p. 64]. Another risk is the oversimplification of complex cultural realities. Russia is home to over 190 ethnic groups, and reducing the entire country’s cultural code to a few Slavic symbols alienates consumers from other regions. Arive Makeup successfully avoided this trap by celebrating regional diversity, but many other brands still fall into it.

Multi-level integration corresponds to the five functions of cultural code identified by Kozyreva [5, p. 39]. Identification is achieved not only through the logo but through the entire sensory environment of the product – its scent, texture, and the sound of its name. The adaptive function becomes critical when entering foreign markets: a deeply developed cultural code can become a unique selling proposition. RBG, for example, is considering the Middle East as a promising market precisely with this strategy [2]. At the same time, over-reliance on patriotic slogans without substantive backing is perceived as manipulation and undermines trust [4, p. 64].

Conclusion. The Russian cultural code has ceased to be a decorative element and has become a full-fledged branding tool in the domestic cosmetics industry. However, the effectiveness of its use depends directly on the depth of integration. Superficial symbols generate short-term attention, whereas deep integration at the level of product, packaging, communication and values builds long-term trust. The cases of Russian brands show that “Russianness” works when it is not imitated but lived through honest dialogue with the consumer and an understanding of the context of their daily life.

Several directions for further research emerge from this study. First, a comparative analysis of how different age cohorts (Generation Z, millennials, and consumers over 45) perceive the same cultural symbols would help brands tailor their strategies more precisely. Second, longitudinal studies measuring the economic efficiency of deep code integration – specifically customer lifetime value (LTV), repeat purchase rates, and net promoter scores (NPS) – could provide quantitative evidence for the claims made in this paper. Third, cross-cultural research comparing the Russian case with other post-Soviet markets or with emerging markets in Asia and Latin America would reveal whether the mechanisms described here are unique to Russia or part of a broader pattern of “cultural code branding” in times of economic transformation.

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УДК 338

DIGITALIZATION OF BUSINESS PROCESSES: THE ROLE OF INNOVATION IN INCREASING THE INVESTMENT ATTRACTIVENESS OF ENTERPRISES

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Abstract. The article examines the impact of digitalization of business processes and related innovations on the investment attractiveness of enterprises. The analysis of the theoretical foundations of digitalization, criteria for assessing investment attractiveness, as well as the mechanisms of the impact of innovation through cost reduction, increased efficiency, increased transparency and transformation of business models. Recommendations have been formed for the implementation of innovations in digitalization, including the introduction of digital platforms, the development of IT partnerships and the use of government support, in the future until 2026-2030.

Keywords: digitalization, business processes, innovation, investment attractiveness, digital transformation, enterprises.

ЦИФРОВИЗАЦИЯ БИЗНЕС-ПРОЦЕССОВ: РОЛЬ ИННОВАЦИЙ В ПОВЫШЕНИИ ИНВЕСТИЦИОННОЙ ПРИВЛЕКАТЕЛЬНОСТИ ПРЕДПРИЯТИЙ

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Аннотация. В статье рассматривается влияние цифровизации бизнес-процессов и связанных с ней инноваций на инвестиционную привлекательность предприятий. Проведен анализ теоретических основ цифровизации, критериев оценки инвестиционной привлекательности, а также механизмов воздействия инноваций через снижение издержек, рост эффективности, повышение прозрачности и трансформацию бизнес-моделей. Сформированы рекомендации по реализации инноваций в цифровизации, включая внедрение цифровых платформ, развитие IT-партнерств и использование государственной поддержки, в перспективе до 2026–2030 гг.

Ключевые слова: цифровизация, бизнес-процессы, инновации, инвестиционная привлекательность, цифровая трансформация, предприятия.

In the context of the accelerated development of digital technologies, the transformation of business processes is no longer just a tool for improving operational efficiency and is increasingly becoming a key factor in the formation of competitive

advantages and investment attractiveness of enterprises. According to global forecasts, digital transformation is becoming the dominant vector of economic development: McKinsey reports emphasize that artificial intelligence and a cluster of related technologies (Big Data, cloud platforms, IoT, cyber physical systems) are the main drivers of business model restructuring, and the share of companies systematically implementing digital technologies is steadily growing, with a significant part Investments in technological development are concentrated precisely in the field of digitalization of processes. At the same time, the reports of the World Economic Forum indicate that digital and intelligent technologies are becoming the basis for productivity growth, the creation of new sales markets and the transformation of employment structures, which increases the dependence of investment activity on the degree of digital maturity of companies.

In such an environment, it is particularly important to analyze how the innovative component of the digitalization of business processes affects the investment attractiveness of enterprises, since it is innovation that determines the depth and consistency of transformation, its ability to generate a sustainable economic effect and reduce risks for investors. The purpose of this study is to identify the contribution of innovations implemented as part of the digitalization of business processes to increasing the investment attractiveness of enterprises, including both financial and non-material aspects of attractiveness (transparency of management, data quality, sustainability, etc.).

In order to achieve this goal, the following tasks are set: to analyze the theoretical foundations of the digitalization of business processes and the concepts of investment attractiveness; to study the mechanisms of the impact of innovative digitalization on key indicators of investment attractiveness; to conduct an empirical analysis, including a comparative assessment of companies with different levels of digital maturity; to formulate scientifically sound recommendations on the management of innovative digitalization to increase investment attractiveness.

The object of the research is enterprises in the real sector of the economy, including Russian and international ones, and the subject is the processes of digitalization of business processes and innovations implemented within their framework, including technological, organizational and managerial solutions.

The methodological basis of the research is a systematic approach that considers digitalization as a complex process encompassing technological, organizational and economic aspects, as well as the use of comparative analysis and econometric modeling to identify the dependencies between the level of digital maturity and indicators of investment attractiveness.

The leading methods used are the analysis of scientific literature and international reporting arrays, correlation and regression modeling, case studies of specific companies, as well as a comparative analysis of their indicators before and after the implementation of digital innovations.

The novelty of the research lies in the emphasis on the innovative component of digitalization (as a source of added value), as well as in the construction and justification of a model that reveals the mechanism of the impact of digitalization innovations on the investment attractiveness of enterprises, which allows not only to

establish the existence of a link, but also to clarify its nature and strength for practical application in investment decision management.

The digitalization of business processes in modern literature is considered not as a simple introduction of information technologies, but as a systemic transformation of the way economic processes are organized and managed based on digital solutions. Within the framework of theoretical works based on the concepts developed by M. Porter and E. Brynjolfsson, digitalization is understood as the process of integrating digital technologies into key parts of a business model: from production and logistics operations to sales channels, marketing and customer interaction. At the same time, it is emphasized that digitalization goes beyond simple automation and encompasses rethinking the organizational structure, reallocation of resources and changing decision-making mechanisms, which is especially evident when analyzing the effect of digitalization from the perspective of the "five forces" model Porter and the paradigm of "shared technologies" by Brynjolfsson, where digital technologies are considered as a factor in the restructuring of the industry's competitive environment and productivity structures [1].

An important element of the theoretical understanding of digitalization is the identification of the stages of its development, which allows us to talk not about a static state, but about the trajectory of increasing digital maturity. In particular, Gartner's digital business maturity model presents digitalization as a step-by-step process that includes the stages of initiating experiments with digital tools, scaling successful solutions, transforming key processes, and finally achieving the status of a "digital leader" when an organization manages a business as a digital ecosystem. At the Initiation stage, there is a fragmented implementation of individual technologies (CRM, electronic document management), at the Experiment stage, pilot projects and digital initiatives are formed, at the Scaling stage, best practices are scaled and digital solutions are standardized, at the Transformation stage, the business model and processes are reviewed and rebuilt, and at the Digital Leadership stage, the organization not only uses digital technologies effectively It also forms its own digital platforms and standards, which significantly affects its market and investment position.

Of particular importance in the context of digitalization is the role of innovation, understood within the framework of traditional and modern economics as the purposeful introduction of new or significantly improved products, processes or business models. According to J. Schumpeter's approach, innovation was viewed as a combination of new combinations of resources created by entrepreneurial activity, and included new products, new production methods, new markets, new sources of supply, and a change in organizational form. The modern statistical and methodological framework outlined in the Oslo Manual develops this line and defines innovation as a new or improved product or process (or a combination thereof) that differs significantly from previous ones and is either marketed or integrated into the organization's production and management procedures. According to these concepts, innovations in digital transformation are classified, in particular, as technological (new IT solutions, software, platforms), organizational (new management structures, approaches to change management, digital culture) and marketing (new sales channels, personalized offers, digital content marketing), which allows them to be systematically evaluated.

the impact on the efficiency of business processes and the competitive position of the company [2].

Key technologies such as artificial intelligence (AI), big Data analytics systems, the Internet of Things (IoT), and blockchain solutions that transform the typical repertoire of business processes serve as the instrumental basis for the innovative component of digitalization. Artificial intelligence and machine learning algorithms enable the transition from descriptive to predictive and prescriptive analytics, which enhances an enterprise's ability to predict demand, optimize inventory, and manage risks, thereby increasing the predictability of financial results for investors.

Big Data systems process large amounts of structured and unstructured information, which improves the transparency of operations and the quality of management decisions, while IoT technologies connect physical objects (equipment, transport, goods) into a single information network, ensuring continuous monitoring of production and logistics processes. Blockchain solutions, in turn, expand the possibilities of ensuring the immutability and transparency of transactions, which is especially important for supply chains and financial transactions and is directly relevant to assessing investment attractiveness in terms of information security and trust in business processes.

Thus, a theoretical analysis of the digitalization of business processes shows that it is not just a technical implementation of digital tools, but a complex innovation process in which technological, organizational and marketing innovations are interconnected and jointly form a new level of organizational and economic efficiency that determines the potential of an enterprise as an investment object.

The mechanisms of the impact of digitalization on the investment attractiveness of enterprises are revealed through a system of interrelated criteria and channels of innovation impact, which determine both the market assessment of the company and the level of risk perceived by the investor. In domestic and foreign literature, investment attractiveness is considered as a multidimensional characteristic combining financial and non-financial indicators, and it is in this context that the role of digitalization as an integrated factor in the transformation of business processes becomes apparent.

The key criteria for assessing investment attractiveness are traditionally divided into financial and non-financial groups. Financial indicators include such basic metrics as return on investment (ROI), net discounted income (NPV), internal rate of return (IRR), return on sales and assets, as well as indicators of liquidity and financial stability. These indicators allow an investor to assess the company's ability to generate positive cash flows and ensure a profitable return on capital, and their dynamics largely depend on the effectiveness of cost and income management, which is directly related to the level of automation and digitalization of operational processes. Modern research highlights that digitalization reduces transaction costs, increases the accuracy of planning and forecasting, and accelerates capital turnover, which translates into increased profitability and NPV of investment projects, making the company a more attractive target for capital.

At the same time, the role of non-financial criteria is significantly expanding, primarily sustainability and ESG factors (Environmental, Social, Governance). Studies

analyzing the impact of ESG ratings on investment attractiveness have shown that an increase in ESG indicators correlates with an increase in market value (Tobin's Q) and a decrease in the weighted average cost of capital (WACC), which indicates a lower perceived risk on the part of investors. Digitalization contributes to the improvement of not only financial, but also ESG parameters: the introduction of monitoring systems for energy consumption, environmental emissions, automated accounting of social and corporate indicators increases transparency and manageability of intangible risks, which strengthens investor confidence and improves the company's reputation. Thus, digitalization acts as a tool that simultaneously increases financial results and strengthens the sustainability of the business model, expanding the overall vector of investment attractiveness.

At the level of the mechanisms of impact of innovations implemented within the framework of digitalization, several key channels of influence on investment attractiveness can be identified. First, it is cost reduction and increased operational efficiency. Automation of routine processes, the use of digital platforms for supply chain management, the use of AI models for forecasting demand and optimizing inventories can reduce administrative and production costs, increase productivity and reduce equipment downtime. Cost savings and increased efficiency are directly reflected in the growth of marginal profits and free cash flows, which increases the investment attractiveness in terms of financial performance and reduces the company's sensitivity to market fluctuations.

Secondly, the most important channel is to increase transparency for investors. Digital corporate governance systems, electronic document management, blockchain platforms for tracking transactions and supply chains, as well as integrated BI and analytical platforms allow you to create a single digital footprint of all key operations, which reduces information asymmetry and reduces the risk of agency conflicts and manipulation. For investors, this means higher reliability of reporting, the ability to quickly track key performance indicators (KPIs) and make decisions based on up-to-date data, which reduces perceived risk and improves the assessment of the company's value in the capital market.

Thirdly, digitalization creates prerequisites for the transformation of the business model and the formation of new types of economic value, including the platform and digital economy. The introduction of online platforms, digital marketplaces, and subscription-based service models (SaaS, BaaS, etc.) opens companies up to wide mass markets, reduces barriers to entry into new segments, and allows them to monetize data and digital services. Such transitions, accompanied by innovative changes in products and customer interaction channels, improve long-term profitability and diversify income sources, which increases long-term investment attractiveness and reduces dependence on physical assets.

Graphically, the model of the impact of digitalization on investment attractiveness can be represented as a chain: "Digitalization of business processes → implementation of technological, organizational and marketing innovations → impact through channels of cost reduction, efficiency growth, increased transparency and transformation of business models → change in key indicators of investment attractiveness (KPIs)." Within this model, KPIs include both financial indicators (ROI,

NPV, marginality, return on assets) and non-financial ones (ESG ratings, transparency of reporting, level of digital maturity, integration into digital ecosystems). Thus, digitalization, based on innovation, acts as a systemic driver that, through these mechanisms, increases the investment attractiveness of enterprises, forming a more predictable, sustainable and transparent investment facility [3].

The implementation of innovations within the framework of digitalization of business processes requires a well-formed systematic approach that combines strategic measures at the enterprise level, government support and consideration of long-term prospects for the development of digital markets. For enterprises themselves, the key direction is to build a digital transformation strategy focused not on the episodic implementation of individual IT solutions, but on the gradual restructuring of the business model and the integration of digital platforms into key operational and management activities. The introduction of digital platforms – ERP systems, CRM platforms, cloud-based data management solutions, and digital counterparts of production facilities – allows you to consolidate information, automate processes, improve planning, and accelerate decision–making, which directly increases operational efficiency and investment attractiveness [4].

An equally important strategic measure is the development of partnerships with IT companies and digital solution integrators. Given the high dynamics of technology and the increasing complexity of digital ecosystems, it is advisable to move from single projects to the formation of long-term alliances, in which external partners provide expert support, tools, platforms and engineering competencies, and the company focuses on change management and adaptation of business processes. Such partnerships make it possible to accelerate innovation, reduce the risks of technological choice, and gain access to best practices and scalable solutions, including in the fields of AI, cloud computing, big data analytics, and cybersecurity, which is especially important for medium and small businesses that do not have their own large R&D units.

At the level of state policy, a significant role is played by a system of measures to support the digitalization of the real sector of the economy, including within the framework of the federal target program "Digital Economy of the Russian Federation" and related strategic directions. The key instruments are tax incentives and grant mechanisms aimed at stimulating investments in their own technological base and digital modernization of enterprises. In Russian practice, special tax regimes for IT organizations are already in place, including reduced income tax rates and insurance premiums, as well as tax vacation programs and preferential regimes for special economic zones and technology parks, which reduces barriers to entry into digital business and accelerates the development of domestic partner IT companies. At the same time, the Russian government is announcing an expansion of support measures for industrial enterprises, including concessional lending and other forms of subsidizing digital transformation projects, and plans to create a proactive model of government support by 2030, when enterprises are automatically offered support measures based on their digital profile and maturity level.

Government support also affects the creation of infrastructural conditions for digitalization: the development of digital infrastructures, the formation of industry and cross-industry platforms, the creation of digital "clouds" and data rooms, the

standardization of interfaces and integration protocols. This makes it easier for enterprises to connect to digital ecosystems, participate in platform markets, and use shared services and data, which increases the effectiveness of innovation and expands the scale of its impact on investment attractiveness. In addition, government policy in support of artificial intelligence, autonomous systems and digital platforms is aimed at stimulating private investment in enterprise modernization, which makes enterprises that actively use this institutional potential more attractive to investors focused on long-term growth and technological readiness.

In the future, on the horizon of 2026-2030, we can expect a further strengthening of the role of digitalization as one of the key factors in the formation of investment attractiveness. First, it is expected to move from isolated automation to building holistic digital ecosystems, where enterprises integrate into industry and cross-industry platforms, exchange data and services, and innovations are implemented at the ecosystem level as a whole. Secondly, strengthening regulatory regulation in the field of AI, data and cybersecurity will increase the requirements for the level of digital maturity and sustainability of companies, which will gradually transform digitalization from an optional measure into a necessary condition for attracting capital in large markets. Thirdly, the development of government support programs and digital infrastructure will allow companies with limited resources to invest more effectively in innovation, which will lead to an increase in the share of organizations with high digital maturity and, as a result, to an overall increase in the investment attractiveness of the domestic real sector against the background of a global digitally oriented competitive environment [5].

Thus, for the effective implementation of innovations in digitalization, it is advisable for enterprises to build a comprehensive strategy that includes the introduction of digital platforms, the formation of sustainable partnerships with IT organizations, the active use of government support mechanisms and consideration of long-term trends in the development of the digital economy. In turn, the government, by developing the institutional framework for digitalization and ensuring the availability of preferential treatment and infrastructure solutions, significantly strengthens the conditions for increasing the investment attractiveness of enterprises and the formation of a sustainable digital-oriented economy for the period up to 2030.

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УДК 332.122.6

SPECIAL ECONOMIC ZONES AS GROWTH DRIVERS: A COMPARISON OF THE EXPERIENCE OF CHINA AND THE REGIONS OF THE RUSSIAN FEDERATION

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Abstract. The article provides a comparative analysis of special economic zones in Russia and China, identifies the key efficiency factors of the Chinese model, and proposes recommendations for improving Russian practices in the field of SEZs.

Keywords: special economic zone, preferential regime, tax incentives, national economy.

ОСОБЫЕ ЭКОНОМИЧЕСКИЕ ЗОНЫ КАК ДРАЙВЕРЫ РОСТА: СРАВНЕНИЕ ОПЫТА КИТАЯ И РЕГИОНОВ РОССИЙСКОЙ ФЕДЕРАЦИИ

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Аннотация. В статье приводится сравнительный анализ специальных экономических зон России и Китая, выявлены ключевые факторы эффективности китайской модели и предложены рекомендации по совершенствованию российской практики СЭЗ.

Ключевые слова: специальная экономическая зона, преференциальный режим, налоговые льготы, национальная экономика.

Introduction

The development of a country's economy in modern conditions largely depends on international trade. To maintain macroeconomic stability, governments resort to complex organizational and economic mechanisms. Special economic zones are one such tool that promotes export growth, employment, and the inflow of foreign capital.

The experience of China is of particular interest, as the introduction of special economic zones played a key role in the "Chinese economic miracle", transforming the country from an agrarian state into the world's largest economic power. For Russia, this topic is especially relevant due to the challenging foreign policy situation. In recent years, the country has faced massive sanctions and economic isolation from Western states, making the development of internal, local, and regional points of economic growth a priority.

The purpose of this research is to study the implementation experience of special economic zones in the Russian Federation and the China, as well as to identify key factors contributing to the most effective functioning of this economic tool.

Theoretical Aspects

"A special economic zone is understood as a limited territory with a special legal status, within which a special regime for entrepreneurial activity is established. Under Russian legislation, the general concept is a 'special economic zone' (SEZ), or sometimes in textbooks, a 'free economic zone' (FEZ). In general, the concept of a SEZ is equivalent to the term FEZ" [1, p. 241].

Special economic zones have several classification options. "One of the most common classifications is according to the type of economic activity carried out. In accordance with it, five types of zones are distinguished: trade, industrial, technological, service, and complex" [1, p. 241].

Special economic zones are not an innovation of recent decades. "Their first prototype can be considered foreign trade zones, which appeared in the USA in the 1930s and were created to restore the country's economy after the Great Depression" [2, p. 5].

Since the 1970s, Asian and Latin American countries used SEZs to attract investment into labor-intensive industries. Initially, this yielded results, but later the zones turned into enclaves due to weak links with the local economy and reliance solely on benefits. In response to changing global conditions, many states transitioned to a new model: modern SEZs became multifunctional, larger, integrated into the regional economy, and less dependent on preferences.

China is among the Asian countries that have proven the success of implementing the new SEZ concept and using preferential mechanisms. In 1980, the first special economic zones were established in the cities of Shantou, Shenzhen, and Zhuhai. A special tax regime was in effect in Chinese SEZs: corporate tax was not levied until profit was earned, and thereafter a reduced rate applied for five years. Companies were also exempt from import duties on equipment, received reduced social fund contributions, and a unique measure was the refund of "input" VAT when selling products within the zone. The combination of these factors, along with China's natural advantages (primarily an abundance of cheap labor), led to significant economic growth.

By 1984, the program expanded. The pace of economic development from that point onward began to increase – the tools tested in SEZs gradually covered almost the entire territory of the state. "Thus, by the mid-1990s, a vast network of nearly fifty territories, united under the name 'Economic and Technological Development Zones', had formed on the territory of China" [3].

The emergence of Russian SEZs dates back to the late Soviet period of perestroika. The worsening problems of the command economy by the mid-1980s pushed the leadership towards partial implementation of market mechanisms and new economic policy instruments. Since the USSR purposefully used the Chinese experience in creating SEZs, a comparative analysis of the results of the two countries is most revealing.

In December 1988, Resolution No. 1405 approved the Unified State Concept of Free Economic Zones, where they were viewed as a tool for integrating the USSR into

the world economy, attracting investment, and as an experimental platform for market reforms. Zones for joint entrepreneurship with benefits only for foreigners were planned, but this idea never materialized. In 1989, the first two SEZs were established in Nakhodka and Vyborg, and a year later the government intended to open up to 60 such zones. In the 1990s, development of new SEZ projects began. "SEZs were established in 11 regions of the USSR; tax benefits were the same for all operating zones, only the status differed: a free enterprise zone; a special economic zone. Zones were formed in the following cities: Vyborg, Nakhodka, Leningrad, Zelenograd; as well as in the Altai Territory, Sakhalin, Chita, Kemerovo, Novgorod regions, and the Jewish Autonomous Republic" [4, p. 80-81]. The Soviet experiment with SEZs by the end of 1991 was deeply contradictory. Against the backdrop of the "parade of sovereignties", the process became chaotic: regions proposed projects themselves, some without grounds trying to obtain zone status. The activities of SEZs were based on individual decrees of varying legal force, which led to the absence of a universal and transparent strategy.

In 2005, in order to stabilize the SEZ structure and establish a unified legal framework for them, Federal Law No. 116-FZ of July 22, 2005, "On Special Economic Zones in the Russian Federation" was adopted. Subsequently, a decree was issued on the creation of technology-innovation zones in the Moscow region, St. Petersburg, and Tomsk, as well as industrial-production zones in the Lipetsk region and Yelabuga. However, already in 2007, the structure of existing zones underwent new serious changes after the adoption of the Cluster Policy Concept, which implied the unification of a number of special zones into a single entity under the management of a single company.

The effectiveness of Russian SEZs is assessed ambiguously. There are many examples that have had a positive impact on the country's economy. The "Alabuga" zone, which consistently attracts significant investment volumes, has become a regional driver, creating a large number of new jobs, while the private zone "Stupino Kvadrat" has become an example of one of the most effective public-private partnerships. On the other hand, according to a report by the Control Directorate of the President of the Russian Federation from 2016, the financial investments directed towards the functioning of special zones were too significant relative to the results obtained. From 2006, customs and tax payments received from 33 SEZs amounted to 40 billion rubles, with 186 billion rubles (24 of which were unused) spent from the budget on their creation and maintenance. Meanwhile, the cost of creating one job corresponds to the average national salary for 25 years.

The key differences between the Russian and Chinese SEZ models relate to the institutional structure and development strategy. Russia has focused its SEZs on solving internal problems: import substitution, regional development, and economic diversification, frequently changing approaches and management structures. China initially focused on integration into the global economy, attracting foreign capital and technology, and using the zones as a testing ground for market reforms, adhering to a consistent, uniform policy.

Quantitative and qualitative indicators of the functioning of free economic zones in Russia and China are reflected in the following tables.

Table 1. Comparison of SEZ indicators in China and the Russian Federation

Indicator	China	Russian Federation
Number of SEZs	232 (national zones) (2024)	33 (2025)
Total number of economic entities in SEZs	over 4.9 million (2024)	over 1300 (2025)
Share of national GDP	about 22 % (2024)	about 2.5 % (2024)
Share of exports	over 19 % (through complex zones only) (2025)	no single indicator, but some zones (Alabuga, Stupino) provide up to 30 % of regional exports
Resident investments (capital)	about $150 billion USD	2.7 trillion rubles (accumulated)
Tax and customs revenues	$381.25 billion USD	over 122 billion rubles (budgetary effect)
Jobs created	over 900 thousand (per year)	over 110 thousand (accumulated)

Sources: Ministry of Commerce of China (2025), Ministry of Economic Development of the Russian Federation / JSC "SEZ" (2025 report), Accounts Chamber of the Russian Federation (2024 report)

Table 2. Comparison of institutional characteristics

Criterion	China	Russian Federation
Year of systematic policy start	1978	2005
Consistency of approaches	high, long-term planning	low, frequent reorganizations
Role of SEZs in the economy	strategic tool for modernization and openness	tool for regional development and import substitution
Consideration of foreign experience	active borrowing, adaptation	focus on Chinese experience of the 1980s, but without systematic reproduction
Legal regulation	specialized laws for different types of zones, stability	single Federal law, but constant by-law changes
Profit tax	preferential rates (0-15 % depending on zone type and industry)	0 % – first 5 years from profit receipt; 5 % – years 6-10; 13.5 % – after 10 years (in Tatarstan)
Property tax	exemption for the period of resident status	exemption for 10 years
Customs benefits	exemption from import duties for equipment; free customs zone regime	free customs zone regime, exemption from import duties
Current priorities	integration into global value chains, digitalization, "green" zones, development of high-tech clusters	technological sovereignty, pharmaceuticals, microelectronics, import substitution, support for investments from friendly countries

Source: compiled by the authors based on the studied literature

Conclusion

The conducted comparative analysis allows for several fundamental conclusions. The Chinese model demonstrates higher and more sustainable effectiveness, accumulating about 22 % of GDP, while in Russia this indicator reaches only 2.5%. Despite the noticeable difference in scale, where China is undoubtedly the leader, the key aspect is the depth of integration into the national economy. China has maintained a high consistency of approaches for over four decades, whereas Russian practice is characterized by frequent changes in priorities and periodic reorganization of management institutions.

To increase the effectiveness of special economic zones in the Russian Federation, based on the successful Chinese experience, it is advisable to reorient the model from short-term incentive-based stimulation towards a long-term integration strategy, to repurpose some SEZs into highly specialized technological clusters, and to improve assessment methodologies using counterfactual analysis with synthetic control groups. An additional reserve for increasing efficiency is the activation of intergovernmental agreements with China focused on pooling the resources of special economic zones. The implementation of such agreements would open opportunities for deeper production partnerships and the transfer of advanced competencies.

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УДК 338

THE DUALITY OF PERSONNEL POLICY: THE ROLE OF MANAGEMENT INNOVATION IN BALANCING TRADITION AND TRANSFORMATION

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Abstract. The article examines the duality of personnel policy as a managerial phenomenon, expressed in the need to simultaneously maintain the stability of social and organizational practices and ensure adaptation to technological, economic and institutional changes. It is shown that innovations in personnel management are not a "substitute" for traditions, but a mechanism for their rethinking and reconfiguration to new work contours: digitalization, the spread of data analytics, a lack of competencies, the growth of flexible forms of employment and increased demands on corporate responsibility. The logic of designing a "two-circuit" HR architecture is proposed: a stable contour (rationing, compliance with legislation, guarantees, uniform standards) and an adaptive contour (experiments, product approach in HR, data-driven management, personalization).

Keywords: HR policy, innovations in management, organizational ambidexterity, dynamic abilities, institutional sustainability, change management, personnel analytics, hybrid employment.

ДУАЛЬНОСТЬ КАДРОВОЙ ПОЛИТИКИ: РОЛЬ ИННОВАЦИЙ В ОБЛАСТИ УПРАВЛЕНИЯ В БАЛАНСЕ ТРАДИЦИЙ И ТРАНСФОРМАЦИЙ

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Аннотация. В статье рассматривается дуальность кадровой политики как управленческого феномена, выражающегося в необходимости одновременно сохранять устойчивость социальных и организационных практик и обеспечивать адаптацию к технологическим, экономическим и институциональным изменениям. Показано, что инновации в управлении персоналом выступают не «заменой» традиций, а механизмом их переосмысления и перенастройки под новые контуры труда: цифровизацию, распространение аналитики данных, дефицит компетенций, рост гибких форм занятости и усиление требований к корпоративной ответственности. Предложена логика проектирования «двухконтурной» HR-архитектуры: стабильного контура (нормирование, соблюдение законодательства, гарантии, единые стандарты) и адаптивного контура (эксперименты, продуктовый подход в HR, data-driven управление, персонализация).

Ключевые слова: кадровая политика, инновации в управлении, организационная амбидекстрия, динамические способности, институциональная устойчивость, управление изменениями, аналитика персонала, гибридная занятость.

Modern personnel policy is increasingly showing a dual nature. On the one hand, it has historically been associated with ensuring the sustainability of the organization: maintaining regulatory order, reproducing the qualification structure, preserving corporate identity and preventing social risks. On the other hand, HR policy is becoming a key tool for transformation, since it is through people that an organization learns technology, changes business models, rebuilds operational processes, and forms new competencies. This duality is not reduced to a simple contradiction of "old" and "new". In this aspect, we are talking about the need to simultaneously perform two management tasks: exploitation of accumulated resources (exploitation) and research/creation of new ones (exploration). In organizational theory, this ability is described by the concept of ambidextrity, according to which sustainable companies systematically combine the effectiveness of current processes with the search for new solutions, without destroying the foundations of trust, norms and culture.

Based on theoretical approaches (the resource concept of the company, dynamic abilities, institutional theory, sociotechnical systems, the concept of ambidextrity, psychological contract) and practical data from international research and corporate practice, the principles of personnel policy are substantiated, maintaining a balance between the exploitation of accumulated human capital and the study of new management solutions. The scientific novelty of the article lies in the integration of the concept of organizational ambidexterity with the practices of digital HR and in clarifying the role of innovation as a tool for reconciling values, norms and technologies, and not just improving efficiency.

Traditionally, HR policy was perceived as a set of rules and procedures: recruitment, adaptation, training, evaluation, remuneration, promotion, personnel reserve, labor relations. However, in the conditions of the digital economy and high uncertainty, these elements cease to be exclusively an "administrative contour" and turn into a space of managerial innovations. In this article, innovations in HR

management are understood as new or significantly improved practices, tools, and organizational solutions in the field of working with people that change the way HR makes decisions and the distribution of responsibility between the HR function, line managers, and employees themselves. These can include digital platforms, data analytics and turnover forecasting, a product-based approach to HR services, new competency and training models, flexible employment formats, new mechanisms for engagement and recognition, as well as the implementation of the principles of DEI and corporate well-being. It is fundamentally important that innovations do not guarantee improvement by themselves; their effect occurs only when integrated into the institutional context of the organization and while maintaining the psychological contract between the employee and the employer [1].

It is advisable to consider the theoretical basis of the duality of personnel policy through several complementary approaches. The company's Resource Concept (RBV) interprets personnel and organizational competencies as strategic resources that are difficult to replicate by competitors. In this logic, the traditions of personnel policy ensure the accumulation and protection of human capital: quality standards for recruitment, sustainable training systems, career paths, and corporate values. At the same time, the theory of dynamic abilities emphasizes the need to "feel" changes, "capture" opportunities and "reconfigure" resources. Here, HR innovations become a mechanism for rapid reconfiguration of competencies: accelerating hiring, reskilling, role reassignment, and creating project teams. Institutional theory, in turn, shows that personnel policy is embedded in the norms and expectations of the external environment: labor legislation, industry standards, cultural ideas about fairness and acceptability of management practices. Therefore, innovations must be legitimized, otherwise they are perceived as a threat and cause resistance. Finally, the sociotechnical approach captures that efficiency is ensured by the coordination of the technical subsystem (digital tools, processes) and the social subsystem (values, attitudes, leadership). Therefore, innovations in HR cannot be exclusively technological; they must include changing roles, communications, competencies, and norms of interaction.

The practical context of the duality of personnel policy is set by several stable trends. First, digitalization and the development of AI have changed expectations for the speed and accuracy of management decisions. International research (for example, reports from Deloitte Global Human Capital Trends over the years, McKinsey analytics on the future of work) shows that organizations are actively investing in HR analytics, recruitment automation, and employee self-service through portals and mobile applications. However, the real effect is often limited if digital tools are implemented without reviewing processes and responsibilities. Secondly, skills shortages and competition for talent have increased, especially in the high-tech and service sectors.

According to international labor market surveys (including the OECD, WEF Future of Jobs), digital skills, analytical thinking, the ability to work in cross-functional teams and manage change remain critical over the coming years. This increases the importance of corporate training and internal mobility as an element of the "traditional core" of personnel policy, but at the same time requires innovations: personalized trajectories, micro-training, internal project marketplaces and competencies. Thirdly, after the pandemic period, the hybridization of labor was consolidated: remote and

mixed work, distributed teams, and the growth of project employment. This has increased the need for new models of control and trust, for a rethink of performance assessment (the transition from time control to result management), and for the development of a digital culture of interaction. Fourth, the role of the ESG agenda and the employer's social responsibility is increasing, which expands the scope of personnel policy: health and well-being, inclusion, occupational safety, transparency and ethics of data application are becoming important [2].

The duality of personnel policy is manifested in the fact that the organization must maintain predictability and fairness of the rules, while allowing variability and experiment. Stability is necessary for trust: if employees do not understand the criteria for evaluation, payment, and promotion, then innovation is perceived as arbitrary changes "in favor of the system," which undermines engagement and increases turnover. At the same time, the excessive rigidity of traditional regulations hinders adaptation: the organization is slowly closing vacancies, does not have time to teach people, and loses its technological window of opportunity. Therefore, the task of modern HR policy is to build a manageable balance, where some practices are standardized and protect basic rights and expectations, and some practices are designed as an adaptive system that can quickly change to meet business objectives [3].

Let's consider practical cases of "two-circuit" in work tasks [4].

Case 1: Retail/logistics: digital shift planning without violating guarantees. Thus, there are high peaks in demand, processing, an increase in complaints and turnover, while labor standards and payment rules must not be violated.

The adaptive loop implements algorithmic shift planning (based on demand, supply forecast, and actual turnout), plus a "shift exchange" for voluntary replacements. The managerial effect is expressed in a reduction in overwork and conflicts over payment, an increase in schedule predictability, and a decrease in turnover in mass positions. The key point is compliance-by-design: the algorithm initially "does not know how" to build an illegal graph.

Case 2: production (reskilling for automation while maintaining the tariff model). The introduction of automated lines requires new skills, but the traditional tariff and qualification system and trade union agreements limit drastic changes. The solution in this case will be a stable contour that preserves tariff grids and tolerance requirements, and an adaptive contour adds a "skill add-on": a skill matrix, modular training programs, and skills validation through a practical exam. For temporary tasks – project roles (adjuster/operator 4.0) with additional payment for a proven set of skills.

Case 3: Banking/finance (remote hiring and onboarding under strict security requirements). The problem with this approach is the rapid onboarding of employees and their appointment, but there are strict requirements of information security, compliance and the regulator. The solution in the context will also be a stable contour that sets uniform admission rules and control points (background checks, access control, mandatory training). Adaptive Contour builds "end-to-end digital onboarding": electronic documents, role training scenarios, mentor, checklist for the first 30/60/90 days, regular short pulse surveys.

Designing a "two–circuit" HR architecture becomes a timely solution for business units. Let's take a step-by-step look at this process and describe in detail the

key aspects of implementation [5].

Step 1. It is necessary to fix what exactly should be stable and what can be adaptive. Thus, the organization defines "red lines" (what should not be violated): labor legislation, labor protection, information security and compliance, principles of non-discrimination, minimum guarantees, mandatory quality standards. This is the core of a stable circuit.

In parallel, a zone of controlled experiments is being defined: where pilots are allowed, different approaches in departments, and personalization of conditions within the rules.

Step 2. It is necessary to decompose HR into domains and make a two-circuit solution for each domain. It is convenient to use the following domains: hiring, onboarding, training and development, evaluation and efficiency, remuneration, talent pool/talent, communication and engagement, labor organization (hybrid/schedules), HR analytics.

A) A minimum standard (stable outline) is formulated for each domain: uniform requirements and mandatory procedures;

b) a set of "modules" (adaptive contour): options and products that can be changed and tested.

Step 3. It is important to design the "interfaces" between the contours so that there is no chaos. The main mistake is to introduce innovations without defining how they fit into the mandatory rules.

Practically, this means:

- a single directory of roles and competencies (so that innovative solutions do not spread across terms);
- uniform decision-making rules (who approves, who is the owner of the process, who is responsible for the risk);
- uniform data and data quality (the source of truth on staffing, rates, skills, training).

Step 4. Legislative aspect: roles, responsibilities, management contours.

Recommended design:

- Owners of a stable contour: HR Operations, C&B, Labor relations, Compliance/Legal, HSE (Occupational Safety), Information Security.
- Owners of the adaptive contour: HR Product Owners, HR Analytics, L&D (as a "constructor" of skills), HRBP together with the business.
- General approval body: HR Architecture Board (or HR Committee), which checks: legality, risks, impact on equity, resources and expected effect.

Step 5. Product approach in an adaptive loop: "HR as a product portfolio" rather than a set of disparate initiatives

Every HR product should have:

- target audience (for example, "new to sales", "development team leaders");
- value promise (for example, "reduce time to plan by 20%");
- result metrics (not only activity, but also business effect);
- roadmap of improvements;
- the owner and the budget.

This is how innovations stop being one-time projects and become managed

services.

Step 6. Data-driven management with constraints (ethics and trust)

To prevent data-driven from becoming a "digital control", rules are set in advance:

- what data is collected and why (the principle of minimization);
- who has access and on what basis;
- how is the absence of discrimination (bias checks) checked in models and rules;
- how the employee is informed and how he can challenge the decision.

Technically, this is supported by the data model (unified reference books, data quality, access audit) and the regulations for the use of analytics.

Thus, considering the duality of personnel policy, it should be emphasized that its central feature is not the mechanical coexistence of "traditions" and "innovations", but the need for a managerial synthesis that simultaneously ensures institutional stability and the ability to develop. In modern organizations, HR policy is increasingly acting not only as a regulatory function that supports compliance with standards and the reproduction of human resources, but also as a strategic transformation mechanism through which changes in business models, technological contours and organizational forms of work are implemented. At the same time, the stability of the personnel system (predictability of rules, social guarantees, legal correctness, standardization of critical procedures) does not oppose innovation.; On the contrary, it is a condition for the acceptability of transformations, since it creates trust and legitimacy of management decisions. It is trust, in the context of a psychological contract and a perception of fairness, that sets the limits of the acceptable rate of change and determines whether innovation will be interpreted by employees as development or as a hidden form of risk redistribution in favor of the organization.

The concept of dynamic capabilities, in turn, shows that a sustainable competitive advantage in an environment of uncertainty depends on an organization's ability to recognize changes in a timely manner, seize opportunities, and reconfigure resources. From this perspective, innovations in personnel management are a practical tool for reconfiguration: they accelerate hiring, increase training efficiency, support internal mobility, and allow for a more accurate correlation of the skill structure with current and future business objectives. The institutional perspective adds an important clarification: human resource innovation is subject to the requirements of legitimacy, that is, compliance with legal norms, professional standards, cultural expectations and ideas of justice. The sociotechnical approach completes this theoretical framework, pointing out that technological innovations have an effect only when coordinated with the social subsystem – roles, responsibilities, management practices, communications, culture. This leads to the main conclusion: managerial innovations in HR are not equal to digitalization as such.; They represent a change in the ways of decision-making, distribution of powers and coordination of interests, implemented in a technical and social context [6].

Practical data and observed labor market trends confirm that the duality of personnel policy is being strengthened under the influence of several factors. First, digitalization and the proliferation of data analytics increase the pressure on the speed and evidence of decisions, but at the same time increase the risks of reducing

management to metrics and algorithms, which can weaken the human dimension of work and worsen the quality of relationships in the organization. Secondly, the lack of competencies and the acceleration of technological cycles make development and reskilling not an auxiliary, but a system-forming task of personnel policy. Thirdly, the expansion of hybrid and project-based forms of employment leads to a revision of the mechanisms of control, motivation and performance assessment, shifting the managerial focus from "presence" to "result", as well as increasing the requirements for leadership, communication and corporate culture of interaction at a distance. Fourth, the agenda of social responsibility and well-being increases the importance of management ethics, non-discrimination and transparency of decisions, including decisions supported by data and digital tools. Collectively, these factors create a situation in which HR policy must be both "rigid" in basic guarantees and "flexible" in ways to achieve results.

In this regard, the proposed logic of a "two-circuit" HR architecture can be considered as a practice-oriented model for coordinating sustainability and change. The stable outline includes a regulatory core: compliance with labor protection legislation and requirements, ensuring equal treatment and non-discrimination, uniform principles of pay and benefits, quality standards for key HR processes, as well as understandable mechanisms for resolving labor issues. It creates predictability, reduces social risks, and supports institutional legitimacy. The adaptive contour forms a space of managed innovations: a product approach to HR services, experimentation and piloting, data-driven analytics, personalization of development and corporate services, new training formats and internal mobility, flexible organizational solutions for project and hybrid work. At the same time, a fundamental condition for efficiency is the presence of "interfaces" between the contours: unified directories of roles and competencies, agreed decision-making rules, data quality and transparent governance, which prevent chaotic fragmentation of practices and ensure the transfer of successful solutions from the pilot zone to the organization scale.

A significant result of the study is the conclusion that innovations in personnel management should be interpreted as a means of balancing traditions and transformations, and not as an autonomous goal. At the level of management practice, this means that digital tools, analytics, or new work formats have a lasting effect only when they are embedded in the organization's system of values and norms and supported by changes in leadership competencies. Otherwise, innovation can lead to the opposite results: increased distrust, a sense of injustice, increased turnover and resistance, as well as formal "performance optimization" without a real improvement in productivity. The risks of algorithmic management are particularly significant here, including the possibility of data bias, decision opacity, and shifting responsibility from managers to the "system." Consequently, the architecture of modern HR requires mechanisms for ethical and legal control of the use of data, including the principle of minimization, access audit, verification of discriminatory effects, and procedures for challenging decisions. Such mechanisms do not slow down innovation, but rather increase its social acceptability and sustainability.

From a methodological point of view, the article leads to the recognition that the effectiveness of personnel policy cannot be assessed solely by economic metrics (speed

of hiring, cost of recruitment, turnover, productivity) or only by social indicators (satisfaction, engagement, well-being). Duality requires an integral approach: a stable contour sets the measures of reliability and fairness (compliance, reduction of conflict, stability of labor relations, safety), adaptive – measures the speed of learning and reconfiguration of competencies (time-to-productivity, internal mobility, closing skill gaps, the effect of HR products on the results of departments). In practice, this means the need for a system of indicators that does not provoke "skewing": speeding up processes without maintaining quality and legality, or maintaining procedural integrity while losing the ability to change. The logic seems to be the most productive, where HR metrics are related to business goals, but interpreted in the context of organizational culture and social sustainability.

Thus, the duality of personnel policy is a natural reflection of the increasing complexity of the socio-economic environment and technological restructuring of labor, and innovations in management are a key tool for coordinating this duality. An organization striving for sustainable development must simultaneously maintain the normative and value core of labor relations and create a controlled experiment circuit that allows for rapid reassembly of competencies and forms of labor organization. At the same time, the innovation of HR policy is expressed not in the number of implemented digital solutions, but in the ability to transform data and technology into more fair, transparent and effective management practices. The combination of stability and adaptability becomes not a compromise, but a design feature of the HR system a stable contour ensures trust and legitimacy, while an adaptive contour ensures speed and development.

The prospects for further research are related to the empirical verification of the "two-circuit" model for different types of organizations and industries, including a comparative analysis of the effectiveness of governance mechanisms and approaches to scaling pilots. An in-depth assessment of the socio-ethical implications of data-driven management and AI tools in HR is also required, including the development of techniques to identify and reduce algorithmic bias and measure the impact on trust.

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УДК 338

INNOVATIONS IN REGIONAL COMPANIES: PROJECT MANAGEMENT AND MINIMIZATION OF ARTIFICIAL INTELLIGENCE-RELATED RISKS

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Abstract. Regional companies are increasingly using artificial intelligence (AI) as a tool to accelerate innovation, improve operational efficiency, and expand markets. However, the introduction of AI increases design, legal, cybernetic, personnel and reputational risks, especially in conditions of limited resources and lack of competencies outside large centers. The article suggests a practice-oriented approach to managing innovative AI projects in regional organizations: from choosing a portfolio of initiatives to a risk management system and quality metrics. Recommendations for minimizing risks at all stages of the life cycle of AI solutions are formulated and typical application scenarios are presented.

Keywords: innovations, regional companies, project management, artificial intelligence, AI risks, risk minimization.

ИННОВАЦИИ В РЕГИОНАЛЬНЫХ КОМПАНИЯХ: УПРАВЛЕНИЕ ПРОЕКТАМИ И МИНИМИЗАЦИЯ СВЯЗАННЫХ С ИСКУССТВЕННЫМ ИНТЕЛЛЕКТОМ РИСКОВ

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Аннотация. Региональные компании все чаще используют искусственный интеллект (ИИ) как инструмент ускорения инноваций, повышения операционной эффективности и расширения рынков. Однако внедрение ИИ усиливает проектные, правовые, кибернетические, кадровые и репутационные риски, особенно в условиях ограниченных ресурсов и дефицита компетенций вне крупных центров. В статье предлагается практико-ориентированный подход к управлению инновационными ИИ-проектами в региональных организациях: от выбора портфеля инициатив до системы управления рисками и метрик качества. Сформулированы рекомендации по минимизации рисков на всех стадиях жизненного цикла ИИ-решений и приведены типовые сценарии применения.

Ключевые слова: инновации, региональные компании, управление проектами, искусственный интеллект, риски ИИ, минимизация рисков.

In the modern world, digitalization and the introduction of artificial intelligence (AI) are key drivers of innovative economic development, especially at the regional level. In Russia, according to Rosstat data for 2025, the share of companies using AI in production and management processes increased to 28 % in the federal districts, but

in the regions of the Volga Federal District, including the Samara Region, this figure does not exceed 15 %, due to limited infrastructure, a shortage of qualified personnel and high implementation risks. The Ministry of Economic Development of the Russian Federation, in its National Strategy for the Development of AI until 2030, emphasizes the need to accelerate innovation in small and medium-sized businesses in regions where AI can increase competitiveness by 20-30 % by optimizing projects, but it comes with risks ranging from technical failures and biased algorithms to regulatory and ethical problems [1].

In the Samara Region, as an industrially developed region with a focus on mechanical engineering and IT, challenges are compounded by dependence on local supply chains and lack of financing, which leads to failures of up to 40 % of AI projects (data from the regional Ministry of Economy for 2025). The relevance of the topic is determined by the need to develop adapted approaches to AI innovation management that can minimize risks and contribute to the sustainable growth of regional companies in the face of sanctions and technological lag.

The purpose of this article is to develop a comprehensive model for managing innovative projects using AI in regional companies in Russia, as well as risk mitigation strategies.

To achieve this goal, the following tasks are being solved: to analyze the classification and specifics of AI risks in the context of regional innovations; to study domestic and foreign AI project management practices; to offer practical recommendations and a risk minimization model based on empirical data.

The object of the study is regional companies in Russia, mainly small and medium-sized businesses (SMEs) in industrial regions such as the Samara Region. The subject of the research is the process of managing innovative projects using AI and mechanisms for minimizing associated risks.

The work is of a review-analytical and applied nature. The approaches of project management (portfolio/program/project), risk-based management (identification–assessment–response–control), as well as the principles of the life cycle of AI systems (data preparation, training, implementation, monitoring) are used. For the regional context, the emphasis is on organizational feasibility: minimally sufficient practices that have an effect without excessive strain on staff.

The scientific novelty of the article lies in the proposal of an integrated AI project management model adapted to the regional conditions of Russia, taking into account the specifics of risks (technical, ethical, operational), which is absent in existing approaches focused mainly on large businesses. The practical significance lies in the development of ready-made risk minimization strategies applicable to managers of regional companies, as well as recommendations for government authorities to support AI innovations, which contributes to a 15-25 % increase in project efficiency and the implementation of national digitalization programs.

The topic of innovation in regional companies in connection with project management and risk minimization of AI is usually considered as a practical task: how to get a measurable effect from technology with limited resources, a lack of competencies and a higher sensitivity to errors. The regional context reinforces typical barriers to innovation: data is often scattered and of varying quality, IT teams are small

and combine roles, access to specialized ML competencies is limited, and infrastructure and budget do not always allow long-term experiments. Therefore, the key aspect here is not to “implement AI”, but to build a managed process for the selection, implementation and operation of initiatives, where risks are visible in advance, distributed among owners and monitored throughout the entire lifecycle of the solution.

AI projects differ from classical automation: the result is determined not only by the software implementation, but also by the quality of the data, the correctness of the markup, the resilience of the model to environmental changes, as well as legal and ethical constraints. This leads to the first important aspect of project management: the correct formulation of tasks through business metrics and the cost of error. In regional companies, it is especially important to start with tasks where the effect can be quickly verified (for example, demand forecasting, inventory optimization, predictive maintenance, quality control, anomaly detection), and set criteria for success and criteria for stopping the project so as not to “burn” the budget for long uncertain developments.

The second aspect is portfolio selection of innovations and prioritization. The solution to the problem of resource dispersion is usually based on an assessment of initiatives along four axes: expected business effect, feasibility (availability of data, experts, understandable integration), risk level (what damage is caused by an error) and time to receive value (pilot opportunity in 6-12 weeks). This allows you to form a portfolio of several “quick wins” and 1-2 more complex projects without overloading the organization.

The third aspect is data management as a separate circuit. In practice, most AI failures are not related to algorithms, but to data: incompleteness, errors, inconsistent reference books, different sources of truth, and irregular updates. Typical solutions include assigning responsibility for the data (the source owner and the person responsible for quality), introducing minimum quality standards (completeness, relevance, uniqueness, consistency), documenting the origin of the data and the legal grounds for its use, as well as organizing regular updates of datasets. This reduces the risk that the model will work “correctly” only on test and “break down” in real operation.

The fourth aspect is the design organization of AI development, where iterativity and reproducibility are important. To reduce uncertainty, short prototyping cycles, comparison with the baseline solution, and mandatory tests for resistance to emissions and changes in conditions are used. An important practical solution is to record the requirements for the model not only in the form of technical metrics (accuracy, completeness), but also in the form of business metrics and acceptance thresholds, including the acceptable error rate. Additionally, MLOps/ModelOps practices are applied: data and model versioning, experiment logging, standardized deployment, quality and drift monitoring, retraining and rollback procedures [2].

The fifth aspect is the minimization of legal, compliance and ethical risks. Regional companies often use personal data from customers or employees and may not have a mature compliance system, so the risk of violations is particularly significant. Typical solutions include the principle of data minimization (use only what is necessary), access differentiation, depersonalization where possible, consolidation of

the legal grounds for processing, storage and timing requirements, as well as ensuring explicitness and logging of decisions in sensitive areas (personnel decisions, tariffs, lending, benefits). For generative systems, restrictions on topics and sources are added: it is preferable to respond based on a proven corporate knowledge base in order to reduce the risk of confident incorrect answers.

The sixth aspect is cyber risks and information security. AI increases the value of data and expands the attack surface: possible leaks during integrations, compromise of accounts, substitution of input data, the introduction of malicious data into training samples, as well as the risks of transferring confidential information to external AI services. In practice, the problem is solved through data classification and a ban on the transfer of sensitive data to external systems without control, segmentation of access, encryption, audit of actions, verification of suppliers, and for models, anomaly monitoring and input data control.

The seventh aspect is the operational and organizational risks of implementation: staff resistance, lack of a product owner, “project for the sake of the project”, unwillingness of the business process to accept the recommendations of the model. The solution usually lies in change management: the appointment of a result owner by the business, user training, usage regulations, man-in“the-loop scenarios for critical decisions, as well as the availability of manual mode and rollback rules. It is important to immediately determine who is responsible for the decision if the model has made a mistake: the model cannot be “responsible”, responsibility is always organizational.

The eighth aspect is the exploitation and control of the effect, which is often underestimated. The AI solution does not end with a release: the quality of the model may deteriorate due to data drift, equipment changes, customer or market behavior. Therefore, a sustainable solution to the problem includes constant monitoring (model quality, drift, failure rate), business effect control (comparison with a control group or period), retraining regulations and incident management. It is this contour that turns the pilot into a working product and reduces the risk of “silent degradation” when the model formally works, but it no longer brings benefits.

As a result, the key aspects come down to the fact that AI innovations in regional companies require a combination of three management contours: project (goals, deadlines, budget, roles), product (value, user, process implementation) and risk-oriented (data, law, information security, ethics, operation). The main solutions to the problem are to choose projects based on feasibility and cost of error, invest in data and responsibility for it, build iterative development with reproducibility, ensure compliance and security, implement “safeguards” in decision – making, and be sure to maintain the model in operation through monitoring and retraining [3].

Innovation is a key driver of economic growth, defined as the introduction of new or significantly improved products, processes, or organizational methods that lead to increased efficiency and competitiveness. According to the classical definition of J. According to Schumpeter, innovation is "creative destruction," implying radical changes in production functions through the combination of resources in new forms. The Organization for Economic Cooperation and Development (OECD) in the Oslo Manual (2018) classifies innovations into product, process, marketing and organizational, with an emphasis on measuring their contribution to GDP [4].

In the regional context, especially in Russia, innovations acquire specifics due to

geographical, resource and institutional heterogeneity. Regional companies, mainly small and medium – sized businesses (SMEs), are characterized by limited financial resources (the average budget for R&D is 1-3 % of revenue according to Rosstat in 2025), a shortage of highly qualified personnel and dependence on local infrastructure (transport, energy, digital networks). In the Samara Region, as an example of an industrial region, innovations are often focused on adapting federal technologies to local needs, but they face barriers: low digitalization (only 12 % of SMEs use cloud services) and weak integration into national chains. This leads to the fact that the innovation potential of the regions is realized only by 40-50 % of the federal level, requiring special management models [5].

Innovation project management is a systematic process of planning, organizing, and controlling resources to achieve innovation goals under conditions of uncertainty. According to the PMBOK standard (7th edition, PMI, 2021), the key stages include: ideation (idea generation), development (prototyping), implementation (integration into operations) and scaling (distribution). For AI projects, a hybrid approach with Agile elements is effective: iterative sprints (2-4 weeks) allow you to quickly adjust models based on data, minimizing costs by 20-30 % [6].

The role of AI in such projects is multifaceted: automation of routine tasks (RPA – robotic process automation) frees up to 40 % of employees' time; predictive analytics (machine learning) predicts demand and risks with an accuracy of 85-95 %; generative AI (such as GPT models) accelerates ideation, generating thousands of variants of ideas. In regional companies, AI is integrated into projects to optimize logistics or personalize services, but requires adaptation to local data (for example, in Samara, traffic analysis for mechanical engineering). However, without adequate management, the transition from pilot to scale fails in 60 % of cases.

AI risks in innovative projects are classified by nature and impact, requiring an integrated approach to identification and mitigation. Technical risks include bias (algorithm bias due to unbalanced data, leading to errors of up to 30 %) and failures (hallucinations in generative models). Ethical risks are associated with data privacy (privacy violations in 25 % of projects according to Deloitte 2025 reports) and discrimination. Operational risks are manifested depending on the quality of data (garbage in – garbage out) and cyber threats, and regulatory risks are in non – compliance with standards: in Russia, FZ-152 "On Personal Data" (as amended in 2024) and the draft Federal Law "On AI" (analogous to the EU AI Act), providing for fines of up to 500 million rub. for violations.

Thus, the theoretical foundations emphasize the need for an integrated management approach that takes into account the specifics of regions and the risks of AI for sustainable innovation.

An empirical analysis of the introduction of AI in Russia confirms the growing role of technology in innovation, but reveals significant regional disparities. According to surveys in the second quarter of 2025, the share of Russian companies using AI and predictive analytics increased to 43 % (from 28 % a year earlier), with leadership in manufacturing (31 %), energy (18 %) and finance (16 %). In the report "Artificial Intelligence in Russia – 2025" (Yakov and Partners, Yandex), generative AI is used in 71 % of companies, mainly in marketing and customer service; by 2030, an effect of 7.9–12.8 trillion rubles is expected annually. RANEPA and PwC note that 18 % of

small enterprises use AI in SMEs (an increase from 7% over the year), but in the regions it is lower: more than 40 % of entrepreneurs in the Volga region (Kazan 62 %, Rostov 46 %) use AI for automation.

In the Samara region and the Volga region, the cases illustrate the specifics. A successful example is the MANGO OFFICE pilot in Samara (Digital Transformation 2025 conference): AI has optimized business processes in telecom, reducing costs by 25 % through voice assistants and analytics. In Perm (Perm Region, near the Volga region), a Smart intersection with AI reduced traffic jams by 20 %. A problematic case is regional AI systems (about 500 in the Russian Federation): the Ministry of Digital Affairs classified most of them as a "risk zone" due to the lack of trusted security technologies; data leaks and failures in 30 % of systems were recorded in the Volga region (Tatarstan pilot). In Samara, the 2025 conference revealed risks in SMEs: 25 % of projects failed due to data scarcity and sanctions (refusal of foreign services).

In April 2025, the Ministry of Finance of the Russian Federation reported about 500 regional information systems using AI in the fields of healthcare, social protection, transport and public services, built by different developers at different times. Deputy Head of the department Alexander Shoitov noted that in most cases (about 70-80 %) there are no trusted information security technologies, which creates significant risks, including data leaks, cyber attacks and algorithm failures. The systems do not use certified Russian solutions such as Alfa or Kaspersky for AI, making them vulnerable to hacking.; White hackers identified more than 6,000 vulnerabilities in Russian government systems in 2024, including 20 % of critical vulnerabilities in the public sector. Potential threats include the leakage of personal data in violation of FZ-152, AI failures due to bias or hallucinations affecting decisions (for example, in social payments), as well as cyber risks of unauthorized access, especially in regions with weak infrastructure such as the Volga region and Siberia. Regional pilots of the Ministry of Digital Affairs in three regions, including Tatarstan, identified problems in 90 % of the tested systems, in particular in transport and public services in the Volga region. To minimize risks, the Ministry of Finance is developing recommendations on information security, introducing risk-based regulation through the draft law of 2026 and experiments with "trusted" AI.

In conditions of high uncertainty of AI projects in regional companies, an integrated management model is proposed that combines the principles of PMBOK with Agile and regional adaptations. The model includes four cycles: pre-design (feasibility assessment), development (iterative prototyping), implementation (pilot testing) and scaling (integration with risk monitoring). Adaptation for regions takes into account local factors: data localization (own datasets), partnerships with universities, and flexible budgets (up to 20 % for continuity).

Key tools: AI audit (AI Fairness 360 from IBM to identify bias); ethical checklists (based on the EU AI Act: transparency, accountability); risk insurance (policies from Rosgosstrakh for cyber threats, coverage up to 100 million rubles). Using the model reduces project failures by 35 %, as simulations based on PwC data show.

The recommendations are structured according to the stages of risk minimization: pre-project audit (data assessment and compliance with FZ-152); monitoring (real-time dashboards with KPIs: accuracy > 90 %, downtime < 5 %); post-

implementation (annual audit and feedback loops). Hybrid governance is offered for regional companies: local PM + external experts (Samara IT clusters).

Government support enhances implementation: grants from the Innovation Assistance Fund (up to 300 million rubles for AI projects under the UMNIK program); regional programs (Samara Region – Digital Region 2030, 50 % subsidies for R&D).

Thus, the key success factors are pre-project data audit, ethical checklists and government support (grants from the Federal Migration Service); in the Samara region, this will allow SMEs to increase innovation by 20 %. AI risks are manageable with a systematic approach, but require localization. Research prospects – AI in the sustainable development of regions (ESG integration), the impact of quantum computing on risks and longitudinal studies of implementation in the Volga region. Practical implications for managers: implementing the model through pilots, training (Skolkovo courses) and partnerships, which will provide competitive advantages in the national innovation system.

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УДК 338.242.4

CURRENT ISSUES OF DIGITALIZATION OF LOGISTICS PROCESSES IN PUBLIC ADMINISTRATION

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Abstract. The relationship between public administration and logistics in the context of digitalization is analyzed. The influence of state digital platforms on logistics efficiency and economic competitiveness is examined. Key challenges are identified: data fragmentation, digital inequality, and problems of technological sovereignty. Integration measures are proposed. The necessity of interdepartmental coordination and standardization unification is substantiated. The results can be used in the development of digital transformation strategies for the transport complex and the optimization of state services in the field of supply chain management.

Keywords: logistics, supply chain management, digital transformation, information systems, digital platforms.

АКТУАЛЬНЫЕ ВОПРОСЫ ЦИФРОВИЗАЦИИ ЛОГИСТИЧЕСКИХ ПРОЦЕССОВ В ГОСУДАРСТВЕННОМ УПРАВЛЕНИИ

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Аннотация. Анализируется взаимосвязь государственного управления и логистики в условиях цифровизации. Рассмотрено влияние государственных цифровых платформ на эффективность логистики и конкурентоспособность экономики. Выявлены ключевые вызовы: фрагментация данных, цифровое неравенство и проблемы технологического суверенитета. Предложены меры по интеграции. Обоснована необходимость межведомственной координации и унификации стандартов. Результаты могут быть использованы при разработке стратегий цифровой трансформации транспортного комплекса и оптимизации государственных сервисов в сфере управления цепочками поставок.

Ключевые слова: логистика, управление цепями поставок, цифровая трансформация, информационные системы, цифровые платформы.

Formation of a unified national logistics space capable of becoming a driver of economic growth and a factor of technological sovereignty runs into a complex of deep systemic challenges. These challenges are not technical but institutional and

infrastructural in nature, requiring for their overcoming a coordinated strategy rather than piecemeal solutions. The first and most large-scale challenge is systemic fragmentation and low interoperability of state information systems (SIS) regulating commodity flows [1]. The modern logistics chain, especially in the segment of regulated goods (food, medicines, alcohol, tobacco, fur, timber, etc.), is forced to sequentially pass through a number of digital "gateways," each of which represents an isolated SIS. In addition to the systems mentioned in the literature (FSIS "Mercury," Honest Sign, LesEGAIS), it is also necessary to note the SIS "Alcohol" (EGAIS), the monitoring system for the turnover of hazard classes I and II waste FSIS "OPVK," and the prospective system for tracking hydrocarbon raw materials [2]. Each system has a unique user interface, its own authorization regulations, and data formats. For a logistics operator, this means not just repeated entry of the same data, but also the need to maintain an entire staff of specialists who are proficient in the specifics of working in each particular SIS. According to expert estimates, such fragmentation can increase the time costs for customs and logistics clearance of complex cargoes by 40-60% compared to a hypothetical integrated environment [3, p. 22]. This creates the effect of a "digital labyrinth," where the main cycle time is spent not on physical transportation but on navigating through departmental digital procedures. The second challenge is critical dependence on foreign logistics software and the absence of a competitive domestic ecosystem. Key processes of transport management (TMS), warehouse management (WMS), supply chain planning (SCP), and enterprise resource planning (ERP) in the largest Russian companies have historically been automated on platforms of Western vendors (SAP, Oracle, IBM). Sanctions restrictions, including the cessation of technical support, updates, and licensing agreements, have threatened the continuity of core business processes. The problem is exacerbated by the fact that these systems are deeply integrated into operational activities and their replacement is comparable in complexity to a heart transplant in a living organism. Domestic analogues present on the market often do not possess comparable functionality, scalability, and, most importantly, readiness for deep integration with state SIS via API. This creates a risk of a "digital collapse" in the logistics of the largest corporations. The third challenge is regional digital inequality as a constraint on creating a unified logistics space. The effectiveness of modern digital logistics solutions (telematics, IoT monitoring, cloud TMS) directly depends on the quality and ubiquitous availability of telecommunications infrastructure. The significant gap in high-speed internet and fifth-generation (5G) network coverage between metropolitan agglomerations and remote regions, especially in the Arctic zone, the Far East, and rural areas, creates "logistics digital deserts" [4, p. 75]. In such conditions, the implementation of advanced technologies becomes impossible, which perpetuates the technological backwardness of regional logistics, increases its cost, and reduces the investment attractiveness of territories. This undermines not only economic efficiency but also strategic objectives for the development of the Northern Sea Route and the Eastern Range.

An analysis of the existing regulatory framework allows us to identify several promising mechanisms that can be adapted and scaled for the purposes of logistics integration. First, this is the mechanism of experimental legal regimes (ELR) or "regulatory sandboxes," successfully tested in the field of artificial intelligence on the

basis of Federal Law No. 123-FZ of July 31, 2020 [5]. For logistics, there is a pressing need to create sectoral "logistics sandboxes" that would allow testing of complex technological and organizational solutions in a simplified legal environment. The priority areas for experimental activity could be several key directions. The first of these is associated with the implementation of end-to-end chains based on blockchain technologies and smart contracts for working with highly liquid goods, for example, pharmaceutical drugs. In this case, the distributed ledger will ensure immutability and transparency of all transactions performed, while smart contracts will allow automation of payment processes and transfer of property rights. The second promising direction is the creation of a single digital window for international multimodal transportation along a specific route, for example, along the China – Kazakhstan – Russia – European Union direction. Such a system would make it possible to aggregate at one point all necessary permitting and control procedures, including customs, phytosanitary, and transit control. The third direction is associated with conducting experiments in the field of autonomous (unmanned) transport. Such tests should be carried out on specially designated territories, for example, within the closed perimeters of port terminals, at mining enterprise sites, or in large logistics parks. Second, the most important tool is the development and legislative consolidation of national standards for electronic logistics document flow. We are talking about creating a Russian analogue of international standards, such as Universal Business Language (UBL) or Electronic Data Interchange for Administration, Commerce and Transport (EDIFACT), but taking into account the specifics of domestic regulation and integration with SIS. Such a standard should define unified formats for electronic transport waybills (e-TW), bills of lading, warehouse receipts, phytosanitary certificates, etc., ensuring their automatic processing in all links of the chain. This is the technical basis for implementing the principle of a "digital twin of cargo" – an end-to-end digital profile that accompanies a physical object along its entire path and contains all the data and permits necessary for its movement. Third, systematic state support is needed for the formation of a domestic ecosystem of logistics software. This support must be multi-level. The first level can be demand stimulation, that is, the introduction of mandatory requirements for the use of software from the Unified Register of Russian Programs in procurement by state companies with a state participation share (especially in the infrastructure sector – Russian Railways, Rosatom, state corporations) and in the implementation of projects with state co-financing. The second level is cooperation stimulation. At this level, financing (through grants from the Innovation Assistance Fund, VEB.RF) of consortia uniting leading logistics operators (as customers) and Russian IT developers to create pilot industry solutions is one of the important support tools. The final level in the formation of a domestic ecosystem is infrastructure support. It will provide domestic developers with access to the capacities of state cloud platforms for hosting and scaling their SaaS solutions.

Based on the analysis conducted, a concept for a strategy of digital logistics integration (SDLI) is proposed, which should become an integral part of state policy in the field of transport and the digital economy. The concept is built on four fundamental principles. The first of these is the principle of "one window and one data entry." It assumes that both individuals and legal entities interact with state bodies on all logistics

issues through a single access channel – a special super-service on the Gosuslugi portal for businesses. At the same time, information entered by the user once is automatically distributed across all necessary state information systems. The second principle is technological neutrality. According to this principle, state bodies define mandatory open standards for data exchange and establish API protocols. At the same time, they do not impose specific technological solutions, which creates a healthy competitive environment among developers of digital products. The third principle is synchronous infrastructure development. It requires that plans for the construction and modernization of transport infrastructure (including roads, seaports, and cargo terminals) be developed and implemented in close conjunction with plans for the deployment of digital infrastructure (fiber-optic communication lines, cellular base stations, data processing centers) in the same territories. The fourth principle is phased implementation through "logistics sandboxes." This approach provides for preliminary testing of complex integration solutions under the controlled conditions of experimental legal regimes. Such tests are carried out either in limited territories, or for specific categories of goods, or for participants in the logistics process. The goal of the SDLI is to create by 2030 a Unified National Logistics Space (UNLS) – a digital environment in which data on commodity flows circulate unhindered among all market participants (suppliers, carriers, warehouses, customs, regulatory bodies), ensuring maximum speed, transparency, and low transaction costs.

The conducted research allows us to assert that the integration of logistics systems with the digital infrastructure of public administration is not a technical but a strategic task, on which the future competitiveness and sustainability of the Russian economy depend. The existing challenges – fragmentation of SIS, dependence on foreign software, and digital inequality – are systemic in nature and require consolidated efforts of the state and business. As practical recommendations, specific measures have been formulated for various participants in the process of digitalization of the logistics industry. For federal executive authorities, primarily for the Government of the Russian Federation and the Ministry of Digital Development of Russia, it is proposed to implement the following initiatives. It is necessary to initiate the development and subsequent approval of the Strategy for Digital Logistics Integration. It is also necessary to form an interdepartmental working group that will harmonize data requirements and standards in key state information systems. In addition, it is recommended to extend the law on "regulatory sandboxes" to the field of logistics technologies. The Ministry of Transport of Russia and the Ministry of Industry and Trade of Russia are recommended to synchronize sectoral strategies for the development of transport and industry with digitalization plans. These ministries are also invited to act as customers and co-investors in the creation of pilot domestic logistics platforms, especially for critically important sectors of the economy. The business community, represented by such organizations as the Association "National Logistics Chamber," "Business Russia," and "OPORA Russia," is recommended to take an active part in the formation of technical requirements for standards and "sandboxes." It is also proposed to create consortia for the joint development and implementation of domestic IT solutions. An important area of work is investing in improving the digital literacy of company personnel. The implementation of the

proposed approach will make it possible to transform logistics from a sphere of high costs into a driver of economic growth, create new high-tech markets, and strengthen Russia's technological sovereignty.

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УДК 336.64

THE ROLE OF THE FINANCIAL SECTOR IN RUSSIAN ENTREPRENEURSHIP

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Abstract. The article discusses the functions and main role of the financial sector in the Russian Federation. As a result of the work, the state's expenses on supporting entrepreneurship will be determined, and the emerging problems in attracting and managing finances for entrepreneurs will be analyzed.

Keywords: financial sector, finances, the letter of credit, loans, subsidies, stocks, bonds, financial lease (leasing), financial management.

РОЛЬ ФИНАНСОВОГО СЕКТОРА В РОССИЙСКОМ ПРЕДПРИНИМАТЕЛЬСТВЕ

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Аннотация. В статье рассматриваются функции и основная роль финансового сектора в Российской Федерации. В результате работы определены затраты государства на поддержку предпринимательства, а также проведен разбор ключевых проблем, с которыми сталкиваются предприниматели при привлечении и управлении финансами.

Ключевые слова: финансовый сектор, финансы, аккредитив, кредиты, субсидии, акции, облигации, финансовая аренда (лизинг), финансовый менеджмент.

Financial sector is a broad concept that includes many specialized terms that describe it. But, from the specific point of view, financial sector is a set of many institutions (for example, banks or insurance companies) that ensure the redistribution of funds (capital), as well as savings or risks in the country`s economy [1, p. 64]. That is, the financial sector acts as an intermediary between the two parties – investors and borrowers.

From these judgements the main role of the financial sector follows, namely the effective redistribution of funds capital from owners to those who need it. It is very important that this role is enshrined to be in many legislative acts, such as in the federal laws of the Central Bank of the Russian Federation or commercial banks, as well as in

the Budget Code of the Russian Federation. Moreover, in these legislative acts the basic principles of a financial institution can be prescribed [1, p. 81-85].

Any financial institution has its own individual functions, but the general functions of the entire financial sector are:

a) Transformations of savings into investments: redirection of funds to the real sector of the economy. The real sector of the economy is a set of industries and activities of enterprises related to the production of goods or services, with the exception of financial exchange and credit operations. An effective redirection of funds is achieved through the use of various tools and means for their purposes [2, p. 11];

b) Risk assessment and sharing: reducing uncertainty. It is necessary in order to protect financial institutions, as well as to ensure that any mistake in one bank does not lead to problems for the entire economy as a whole. Also, it is important for the system to work stably and to avoid "domino`s effect" (a situation when a financial organization takes a big risk, for example on deposits, and it goes bankrupt, which means that people who put money on deposit are left with nothing) [2, p. 11];

c) Securing payments: acceleration of cash flow. It is very important to support the continuity of economic processes and for effective capital allocation. It is also necessary to maintain the efficiency and speed of payment systems, as they are increasingly replacing intermediaries, thereby accelerating the redistribution of capital. Moreover, it is necessary to increase liquidity when mobilizing savings from financial institutions that direct them to investments [2, p. 11];

d) Control: monitoring the efficiency of resource usage. In conditions of high competition in the market, it is important for financial organizations to optimize costs and competently distribute assets, so they use monitoring and control. Also, they are interested in enterprises maximizing profits because in this case they will be able to pay off their debt to the organization faster. Besides, monitoring and control are used for strategic development and digitalization, as access to accurate, for example, about consumed resources, helps management to make a quality management decision. The transition to digitalization requires monitoring the effectiveness of IT-structure [2, p. 10].

To successfully perform their roles and functions, financial institutions use a variety of financial instruments. These financial instruments are divided into subtypes, such as primary, conditional and derivative instruments [1, p. 54]. Primary financial instruments are a means by which, when a buyer purchases an asset, they immediately acquire ownership of that asset. More specifically, ownership of the asset is directly and fully transferred. Conditional financial instruments are a method that depends on the occurrence of specific conditions or the completion of any planned events. This type of financial instruments can create rights or obligations that arise due to certain conditions [1, p. 60]. For example, options provide the right to execute a contract upon its expiration or during its validity period. Derivative financial instruments (or derivatives) are contracts, whose terms depend on the value or dynamics of an asset. The underlying asset can be represented by securities, currency or goods and etc. The main features of this type of financial instrument link to the underlying asset and fix the terms of the transaction (price, execution date) at the time of contract execution [1, p. 62]. Primary financial instruments are the most popular, as they have several

advantages: the immediate transfer of rights and obligations to the asset at the time of payment, ensuring the legitimacy of the parties at the date of contract signing, and the settlement of the contract here and now.

Primary financial groups are divided into several items (figure 1):

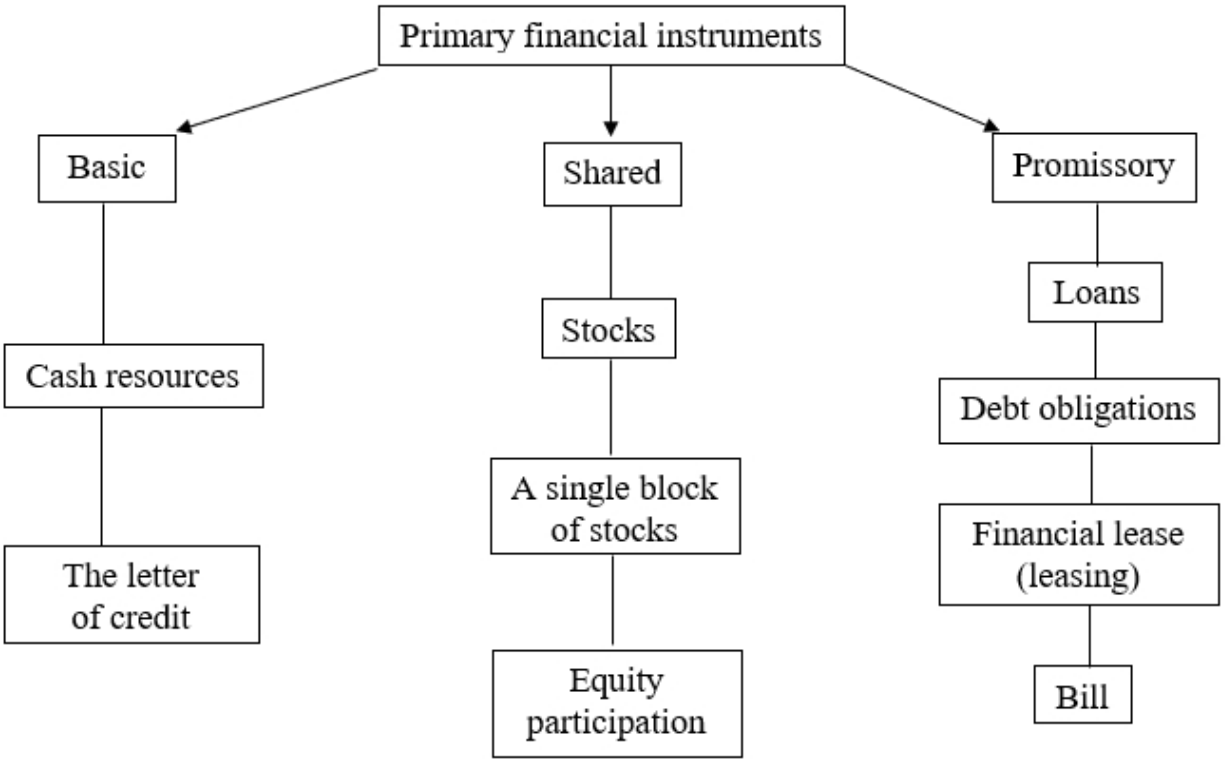


Figure 1. Primary financial groups [3, p. 1]

There are a lot of popular contracts:

a) The letter of credit. It is a document that guarantees secure cashless payments between a buyer and a seller. In order for the conditions of the letter of credit to be met and for the seller to be able to receive payment for the service provided (delivery of goods), the seller must provide the issuing bank with a package of documents (acceptance and transfer act, transport invoice) that confirm their actions. Only then the seller will be able to receive their funds under the letter of credit. Letters of credit are widely used in large-scale transactions (purchase and sale of real estate), transactions with unfamiliar partners to avoid risks, and transactions where strict control over the proper execution of documents is important. The advantages of using letters of credit include reducing the risk of non-performance by the parties, guaranteeing payment for the seller if all the terms of the contract are met, protecting a buyer's funds until the performance is confirmed, and so on. The disadvantages include the bank's commission (if any), the complexity and duration of the application process and strict requirements for the documents [4, pp. 100-105];

b) Stocks. It is an issue security that grants its owner the right to a share in the authorized capital of the company that issued the share. A shareholder receives a number of rights, such as receiving a part of the company's profits (dividends), participating in the company's management, and receiving a share of the company's assets in the event of the company's liquidation. Stocks are divided to be ordinary and

preferred stocks. Ordinary stocks give you the right to participate in the company's management, to participate in the distribution of dividends, and to claim a portion of the company's assets in the event of liquidation. Preferred stocks usually do not give anyone the right to vote (except in some cases, such as when the company is reorganized or the dividend amount is changed), but they have a priority right to receive dividends and assets in the event of liquidation. The amount of minimum payments on preferred stocks may be specified in the company's bylaws and dividend policy. Stocks can be purchased on the stock exchange market independently or with the help of a broker. The main goal of stocks for issuing companies is to increase capital by attracting funds from buyers. It should also be noted that dividends received on shares are a subject to personal income tax of 13% or 15%, depending on the amount of income received on shares [1, pp. 440-443];

c) Debt obligations. This is a debt security in which an issuer (a person who issued it) borrows money from an investor and promises to return the bond's face value and pay interest for the use of the funds during the bond's term. These facts suggest that bonds are similar to loans. An investor lends money to a company or the government and in return they receive a guaranteed income. There are several types of bonds: government bonds (issued by the government for citizens), municipal bonds (similar to government bonds, but issued by municipalities), corporate bonds (issued by companies), Eurobonds (denominated in foreign currency and issued by Russian companies or the government), and replacement bonds (similar to Eurobonds, but denominated in the Russian ruble). The important advantages of bonds include the fact that they guarantee income (if an issuer does not default), a variety of terms and conditions, and a predictable cash flow. Some of the disadvantages of bonds include the risk of default by an issuer, dependence on inflation, and income taxation (13% or 15% personal income tax) [1, pp. 440-442];

d) Loans. This is a financial transaction in which a lender (for example, a bank) provides a borrower with money on the basis of repayment, urgency and payment and a borrower undertakes to return the received amount with interest within the specified timeframe. There are many types of loans, but the most well-known are consumer loans, mortgages, and car loans. The loan agreement must include the following information: the loan amount, the interest rate on the loan, the monthly payment, the total cost of the loan, penalties and interest for late payments, and the loan term. Loans are also distinguished by the method of repayment, namely, annuity payments (equal amounts each month) or differentiated payments (the monthly payment amounts decrease every month) [1, pp. 336-339];

e) Financial lease (leasing). It is a service in which a lessor (a specialized company) transfers the property to a lessee for temporary possession and use, with the possibility of subsequent redemption. The property remains the property of a lessor until the end of the contract period. Anyone can lease any non-consumable item that retains its properties for a long time (for example, machinery or fixed assets). However, there are some similar items that cannot be leased (such as land plots and cultural monuments). The main advantages of leasing include a flexible payment schedule, which does not require a large down payment to obtain the property, quick transaction processing, and the ability to purchase the property (property that is leased is not

included in this option). The disadvantages of leasing are that the property is owned by a lessor if it is not purchased (the rights of ownership are held by a lessor, as there is no provision for purchasing the property), and a lessor may repossess the property if payments are late [5, p. 543];

f) Bill. This is a debt security that gives its holder the right to receive a certain amount of money from a debtor within a specified timeframe. This is a strict form document that does not require additional conditions for its execution. There are many types of bills, but the most common are the simple bill and the transferable bill. The main difference between these types of bills is the number of parties involved in the execution of the obligation. A simple promissory note involves two parties: a promissor (a person who is obligated to pay the specified amount of money within a specified timeframe) and a promisee (a creditor). When a bill of exchange is executed, the two parties mentioned earlier are also involved, but a payer (a third party to whom an issuer gives a written order to pay the amount) is also involved. The payer's consent, known as acceptance, is required for payment. If a payer refuses to pay, a holder of the bill of exchange can file a protest with a notary [6, p. 1].

Subsidies are also to be mentioned. They cannot be classified as any of the above-mentioned types of financial instruments, but they exist, as the government specifically allocates funds to support businesses in the Russian Federation. Subsidies are provided free of charge to citizens and organizations. Their main goal is to help. Subsidies can be provided in the form of cash payments, tax benefits, or certificates that entitle you to certain assistance. They should always be intended for a specific purpose, and the funds must be spent strictly in accordance with the program's conditions.

Finally, the government also provides support in the form of credit holidays and special tax regimes, such as the Simplified Taxation System, the Patent Taxation System and the Professional Income Tax. Credit holidays are a grace period that allows borrowers to temporarily stop making payments on their loans. This period lasts from one month to six months. During this time, the bank freezes the monthly payments, and when the grace period ends, the bank creates a new payment schedule. To qualify for this benefit, a borrower's income must have decreased by at least 30% in the last two months, and a borrower's property must have been affected by an emergency situation. Additionally, a borrower must be registered as a small or medium-sized enterprise [7, pp. 1-6]. Special taxation regimes give entrepreneurs the legal right to pay less taxes, but there are a number of conditions that must be met in order to use them (for example, one of the criteria of using the Simplified Taxation System "Income" or "Income Minus Expenses" is that the total income for 2026 must be less than 490,5 million rubles) [8, pp. 890-941].

For a business, attracting finance is very important for a number of reasons. These reasons are related to scaling, financial sustainability in the market, developing strategic goals and fulfilling current tasks.

First, as mentioned earlier, it is necessary for business scaling development. Scaling development involves purchasing equipment, modernizing production, launching new projects and etc. Also, it is especially relevant for companies that cannot cover their expenses with their own funds [2, pp. 38-40].

Second, it is necessary to solve financial difficulties and increase financial stability in the market. Attracted finances help businesses cover financial expenses and survive in economic crises. An economic crisis is a deterioration in a country's economy due to specific causes (unemployment, stagflation, increased debt obligations and etc.). Attracted finances increase the financial stability of an enterprise. Financial stability is the ability of an enterprise to carry out its economic activities in the long term and maintain its solvency even during crisis periods. Moreover, the financial stability of an enterprise can be assessed with the help of coefficients and indicators such as the financial dependence coefficient, the financial independence coefficient, the financing coefficient, the current debt ratio and so on. The financial stability of an enterprise is also influenced by indicators of liquidity, profitability and solvency [2, pp. 89-94].

Finally, raised funds help to develop strategic goal. The company's strategic goals cover various aspects such as achieving a certain level of profit, solving production issues, improving product quality and variety, and more. In other words, strategic goals are a guide for the company's operations. It is also important to ensure that strategic goals align with the company's mission [2, pp. 10-11].

Additionally, some financiers have shared their opinions on the role of finance in business operations. Dmitry Panchenko, the Vice President of "T-Bank" and the Head of "T-Investments" emphasizes the importance of companies’ using financial instruments to raise funds. According to his article, corporate lending will decrease, prompting businesses to shift towards equity and debt financing. This approach can help mitigate inflationary pressures and provide resources for growth. Furthermore, Dmitry Panchenko highlights the potential of digital financial assets. He notes that they have much more promising prospects than the obligation`s market. [9, p. 1].

Sergei Yulievich Witte, who served as Minister of Finance from 1892 to 1903, has played a significant role in the development of the financial sector in Russia. He attached key importance to finance as a tool for industrialization and support for entrepreneurship in the country. He realized that public funds, such as the budget and loans, were necessary for the development of industrialization. Moreover, he supported private entrepreneurship through government orders, legal guarantees, lenient taxation, and the development of loans for entrepreneurs. One of the key events in his life was the "Monetary Reform of 1894-1897," also known as the introduction of the gold standard. This meant that the ruble had a fixed gold content and could be freely exchanged for gold. This reform led to the stabilization of the economy, the strengthening of the ruble on international exchanges, and the influx of capital into the economy [10, pp. 7-42].

In order to characterize the impact of the financial sector on Russian entrepreneurship, it is important to look at the cash flow in Russian entrepreneurship over several years. These indicators will also help to characterize the role of the financial sector and identify the challenges that businesses face in attracting finances to improve their operations. All indicators will be presented from the Bank of Russia website over a period of 8 years [11, p. 1]. The volume of loans provided to legal entities and individual entrepreneurs is presented in Figure 2. The volume of loans provided to small and medium-sized enterprises is presented in Figure 3. The funds on

the accounts of organizations, bank deposits (contributions), and other attracted funds of legal entities and individuals are presented in Figure 4. The data in the graphs are presented to be the amounts of funds expressed in the Russian ruble and foreign currencies.

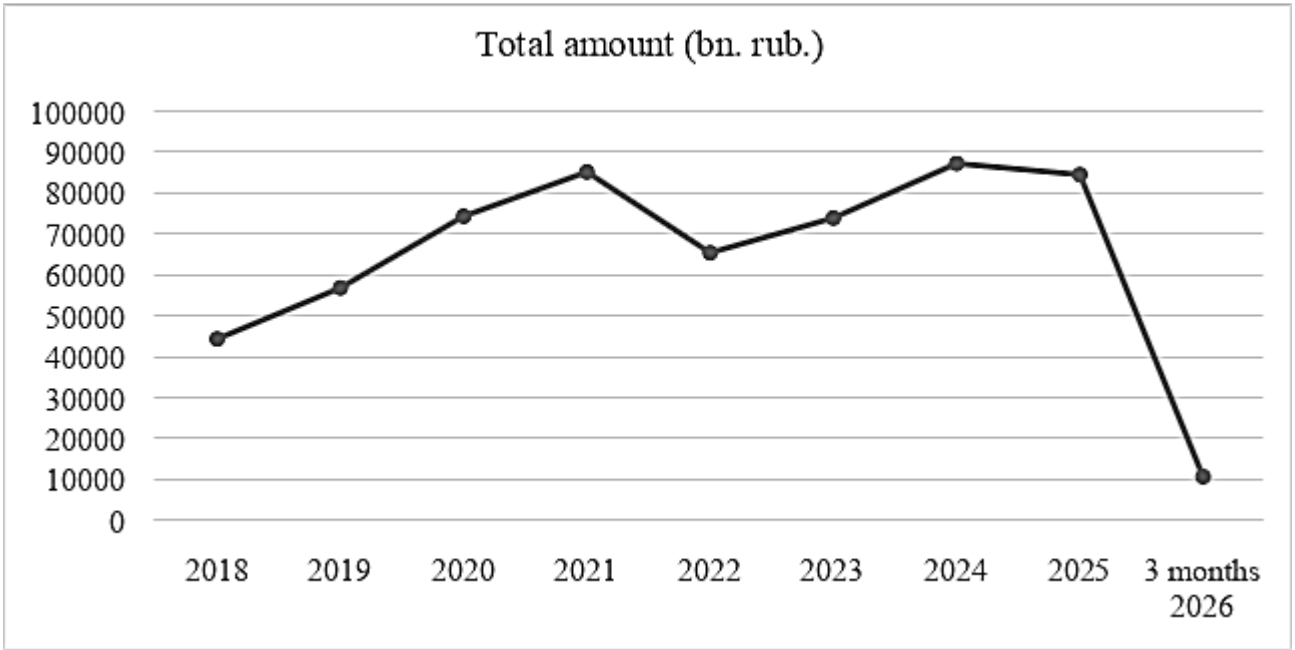


Figure 2. The volume of loans provided to legal entities and individual entrepreneurs [11, p. 1]

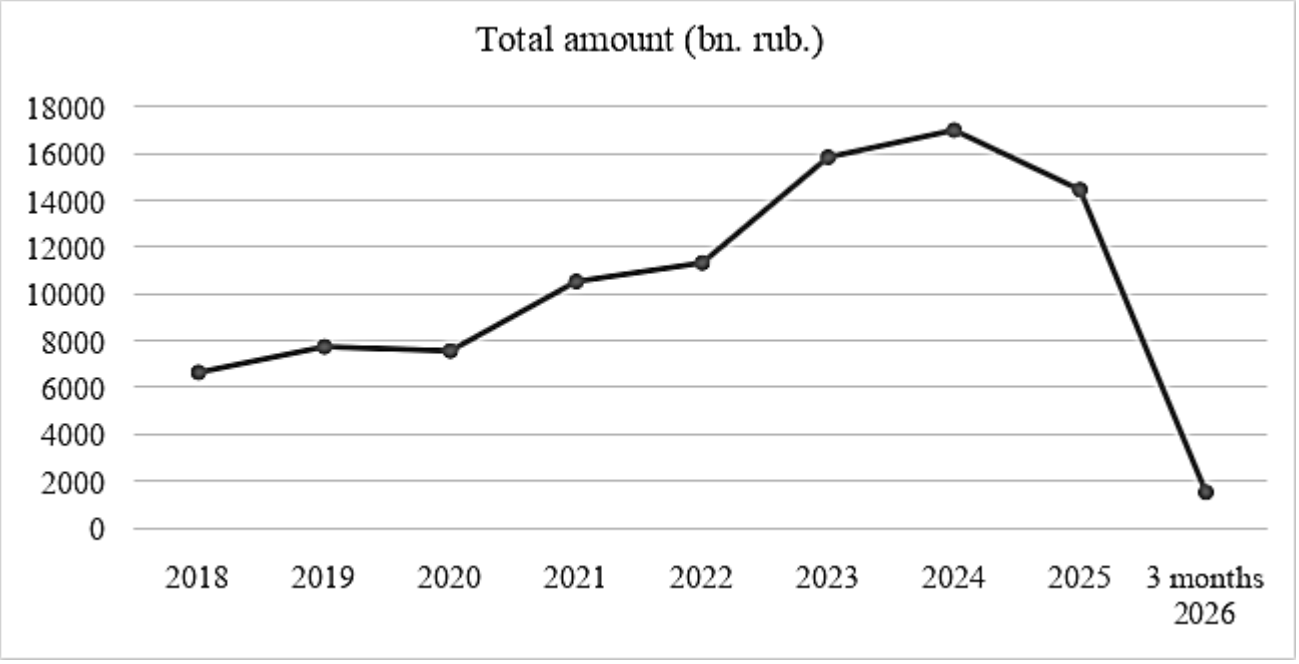


Figure 3. The volume of loans provided to small and medium-sized enterprises [11, p. 1]

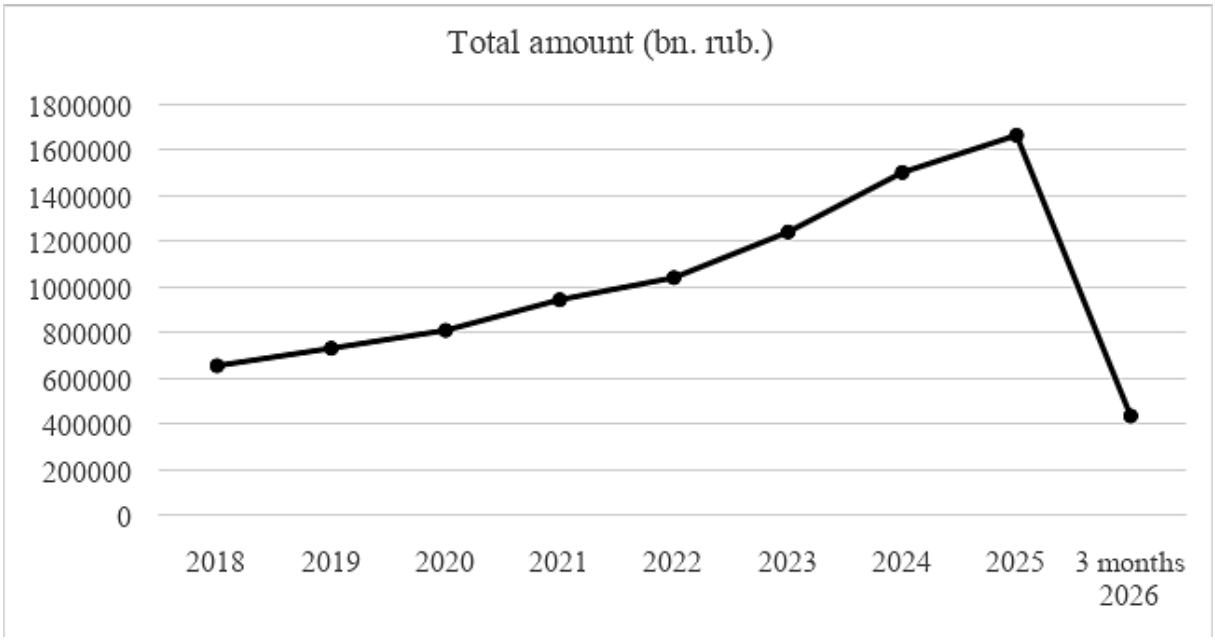


Figure 4. The funds on the accounts of organizations, bank deposits (contributions), and other attracted funds of legal entities and individuals [11, p. 1]

Based on these indicators, it can be concluded that financial institutions (banks) are successfully conducting their financial activities. Also, it is important to note that the government plays a significant role in supporting small and medium-sized businesses in the country. For example, from 2025 to 2030, 329.5 billion rubles will be allocated to be support small and medium-sized businesses. Moreover, 481.5 billion rubles were allocated for the period from 2018 to 2024. However, many entrepreneurs face barriers for attracting financial resources for the development of their company, and in order to receive a subsidy, an entrepreneur must meet certain conditions (for example, registration in the register of small and medium-sized enterprises, regional affiliation to the region where the business is located and where the entrepreneur plans to receive a subsidy, the business must not be in the process of reorganization, liquidation, or bankruptcy, and the business must meet the target activity of the organization and specific criteria such as the "age" of the business). The most common problems are:

a) Lack of own funds. Many entrepreneurs invest a small amount of capital in their business at the start, which later leads to problems with investment development and obtaining a loan from banks, as banks focus on the following principles when issuing loans to individuals: profitability, urgency and repayment;

b) High cost of borrowing. With a high key rate, loans become expensive, increasing the debt burden on businesses. Banks may set high interest rates on long-term loans due to the increased risk;

c) Incompleteness of the stock market. A low level of stock market development and high investment risks can make it difficult to attract long-term investments through the issuance of securities;

d) Sanctions restrictions. Sanctions make it difficult to finance companies that depend on imported technologies or international partnerships;

e) Legal issues. Financial legislation is complex, and its changes are unpredictable, which can pose risks for investors.

Finally, there are problems that are specific to certain groups of businesses. For small and medium-sized businesses, the most common problem is a small market share, as well as limitations in financing and self-financing, and difficulties in raising funds through stocks and bonds. For large companies, the situation is much better, but this does not change the fact that they will face similar problems as small and medium-sized enterprises (for example, high costs due to poor business practices, which can lead to low self-financing due to declining profits).

Financial management is the process of managing company`s cash flows. This process includes planning, organization, control, budget analysis and so on [2, p. 7]. Also, financial management has principles: strategic orientation (purposefulness, prospects, and feasibility), complexity (integration with the enterprise's overall management system, systemic approach), optimization (transparency and accessibility of information, optimization of debt burden, and a systematic approach to reporting) and risk management (assessment and elimination of risks, planning and response to them, monitoring and control) [2, pp. 16-17].

The main goal of financial management is to maximize profits and increase the company's value by managing a wide range of financial activities (from accounting to capital raising) [2, p. 7]. However, a lot of companies do not pay enough attention to improving the organization's financial management, while focusing on its principles can help optimize financial problems.

From the point of view of modern financial scientists, such as E. I. Kholin and N. A. Kalmakova, the problems with financing in entrepreneurship (including innovative activities) are largely related to be strategic orientation [5, pp. 537-538]. Financial management can help enterprises to increase financial stability in the market by reducing the debt burden, optimizing risks and expenses, and maximizing the company's profits in the long term [2, p. 10]. However, these aspects require significant time investment to improve the company's financial and operational performance.

Consequently, the financial sector plays a significant role in Russian entrepreneurship. The government allocates sufficient funds to support businesses in the country, and banks provide large amounts of loans to entrepreneurs (sometimes at preferential rates, subject to certain conditions) [1, pp. 87-88]. However, many entrepreneurs do not take advantage of these opportunities due to a lack of focus on financial management.

Also, the financial activity of an enterprise is an integral part of it, along with its operating and investment activities. Financial and investment activities complement each other. The financial activity of an enterprise aims to ensure financial stability, liquidity, and optimal capital management, which involves managing capital and liabilities (the enterprise's assets or sources of assets), while the investment activity focuses on long-term growth and expansion through the optimal use of investments in long-term assets (such as stocks, bonds and etc.) [2, pp. 10-11].

Financial sector in Russia is assumed to be actively developing in the long term, as it directly affects the maximization of profits for enterprises, which in turn affects the improvement of the country's gross domestic product growth.

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При написании статьи были применены технологии искусственного интеллекта.

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УДК 338.24

CUSTOMER-ORIENTED MANAGEMENT IN THE HOSPITALITY INDUSTRY: FROM PHILOSOPHY TO COMPETITIVE ADVANTAGE

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Abstract. Based on the analysis of modern scientific approaches (including the Service-Profit Chain model, the LEAN concept and hybrid business models), an integrative management system has been developed that combines technological innovations, personnel policy and a methodology for assessing performance. That confirm the growth of key indicators (NPS by 25–30 %, LTV by 15–20 %) when implementing customer-centric strategies.

Keywords: customer-oriented management, NPS, Service-Profit Chain, LEAN technologies, hybrid hotels, post-pandemic trends.

КЛИЕНТООРИЕНТИРОВАННЫЙ МЕНЕДЖМЕНТ В ИНДУСТРИИ ГОСТЕПРИИМСТВА: ОТ ФИЛОСОФИИ К КОНКУРЕНТНОМУ ПРЕИМУЩЕСТВУ

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Аннотация. В статье исследуются теоретико-методологические основы клиентоориентированного менеджмента в гостиничной индустрии в условиях постпандемийных трансформаций. На основе анализа современных научных подходов (включая модель Service-Profit Chain, LEAN-концепцию и гибридные бизнес-модели) разработана интегративная система управления, сочетающая технологические инновации, кадровую политику и методологию оценки эффективности. Эмпирической базой послужили исследования российских отелей 2021–2024 гг., подтверждающие рост ключевых показателей (NPS на 25–30 %, LTV на 15–20 %) при внедрении клиентоцентричных стратегий.

Ключевые слова: клиентоориентированный менеджмент, NPS, Service-Profit Chain, LEAN-технологии, гибридные отели, постпандемийные тренды.

Introduction. According to the UNWTO, the drop in international tourist flow in 2021 was 72 % compared to 2019 [1]. Russia was no exception: in the first half of 2021, only 64.4 thousand foreign tourists visited the country, which is 31 times less than in 2019. As services have become more personalized, and this, in turn, has required a revision of the management paradigm. Customer focus has evolved from a

marketing tool to a strategic philosophy, where guest satisfaction determines the economic sustainability of the enterprise. The study uses a mixed methodological approach that combines quantitative analysis of indicators and qualitative methods of data collection.

The relevance of the study is confirmed by:

– Increased competition against the backdrop of the withdrawal of international hotel chains from the Russian market;

– Shift in consumer priorities (contactlessness, security, flexibility);

– Lack of uniform methods for assessing customer focus in domestic practice.

The purpose of the study is to develop a comprehensive model of customer-oriented management for hotels, adapted to modern challenges.

The evolution of customer-oriented management is a natural response to the change in paradigms of the global service market, where the dominance of the manufacturer has given way to consumer preferences. Theoretical analysis of the works of P. Drucker, J.-J. Lamben and domestic researchers (Gulakov O.V., Perezhogina O.N.) [3, 4] allows us to distinguish three qualitative levels of maturity of this concept:

– The reactive level (elimination of complaints) historically corresponds to classical management theories. Focuses on error correction through process standardization. In hotel practice, this is expressed in the priority of operational indicators (room occupancy, minimization of downtime) over individual requests of guests. The role of the staff was limited to the implementation of regulations, and feedback from customers was perceived as an obstacle to the process;

– The proactive level (customer-centricity) became possible thanks to the integration of the behavioral school of management and relationship marketing. The main achievement was the ability to anticipate and accurately form a picture of needs through deep and comprehensive data analysis. The most prominent example is the introduction of CRM systems in the 2000s, which allowed Ritz-Carlton hotels to predict guest preferences based on the history of previous visits. Research by Bain & Company shows that companies that have reached this level have increased customer lifetime value by 15–25% by reducing churn by 5–7% annually [2];

– The integrative level (clientocracy) is a modern stage in which the client takes an active part in the formation and improvement of the service, becoming its co-author. The staff has been transformed into a subject of service interaction, combining developed empathy and decision-making authority in the interests of the guest. The theoretical basis is a synthesis between two concepts: Customer Success Management (CSM), where an employee acts as an "agent of the client's interests", and the theory of "flexible ecosystems", which integrates guests into service development processes.

Implementing the mature customer-centric management model discussed earlier inevitably faces three key barriers: bureaucratic rigidity at the reactive level, lack of predictive tools at the proactive level, and resistance from guests and staff in the transition to a customerocracy. These problems cannot be solved by single methods – a synchronous approach is needed that combines technology, personnel policy, and process optimization. Let's consider how Russian hotels overcome these barriers.

The theoretical and methodological basis of technological solutions in customer-oriented management is aimed at digitalizing the ecosystem, where the integration of

components creates a synergistic effect of personalization. Technological solutions perform a differentiating function:

- Overcoming reactivity through API integration of isolated systems:

1. Empirical data: 73 % of Russian 4-5* hotels have implemented middleware platforms for synchronizing Opera PMS, IoT sensors and CRM [4];

2. Case study: Cosmos Hotel (Moscow) reduced request processing time by 40 % after integrating the Hotelier platform with SoundEar noise sensors, which increased CSI from 6,8 to 8,2.

- Implementation of clientocracy through participatory architecture:

1. Crowdsourcing platforms such as the Hyatt Lab API enable co-creation (Prahalad & Ramaswamy, 2004);

2. Quantitative indicators: in the City Center Hotel, 73 % of guests participate in the design of spaces, generating 17 % of additional revenue.

In today's service economy, the effectiveness of an organization is increasingly determined not only by the quality of the services provided, but also by the degree of staff involvement in the process of creating a customer experience.

According to a study by HTRS (2023), 89 % of employees in the hotel sector do not solve guest problems without prior approval from management, which significantly reduces the efficiency and quality of service. At the same time, only 12 % of initiatives come from the staff, which indicates a low level of internal motivation and the lack of a stimulating environment for initiative [6, 5].

To overcome this problem, a three-level motivational model was developed, including:

- Financial motivation: implementation of a bonus formula that takes into account both customer experience and staff initiative:

Bonus = Salary × (0,7 × NPS (guest) / 10 + 0,3 × CSI (department) + 5 % × Number of Initiatives

Where:

1. NPS (Net Promoter Score) – guest loyalty index;

2. CSI (Customer Satisfaction Index) – department satisfaction index;

3. Number of initiatives: The number of proposals implemented by the employee.

- Non-financial motivation: recognition of initiatives at the team level, public encouragement, participation in strategic sessions.

- Organizational support: simplification of approval procedures, delegation of authority, introduction of digital tools for collecting and implementing ideas.

As part of a pilot project, the described model was implemented at the Ibis Siberia-Omsk hotel. A comparative analysis of the indicators for 2022 and 2024 shows significant improvements:

Table 1. Dynamics of the project results at the Ibis Siberia-Omsk hotel

Indicator	2022	2024	Dynamics
On-site complaint resolution	48 %	92%	+91,7 %
Employee initiatives	7	41	+485 %
Staff turnover	31 %	11%	–64,5 %
CSI	6.5	8,1	+24,6 %

These results confirm the effectiveness of the model: an increase in staff initiative directly correlates with an improvement in customer experience and a decrease in staff turnover. A 24.6 % increase in CSI indicates an increase in guest satisfaction, which in turn affects the reputation and financial performance of the hotel.

Conclusion. Anthropocentric transformation, based on the principles of clientocracy, requires a systematic approach to motivation and organizational culture. The introduction of a three-level incentive model allows not only to improve the quality of service, but also to create an environment in which employees become active participants in the process of creating value for the client.

The methodological basis of LEAN transformation in hospitality is based on the adaptation of the principles of Womack and Jones (2003) to the service environment:

1. **VSM analysis as a diagnostic tool**:

- In 17 hotels in St. Petersburg, 48 types of operating losses were identified, accounting for 32 % of the service time;
- Optimization of the check-in process reduced the cycle from 25 to 10 minutes through:

1. Biometric verification (FAR ≤ 0,001 %);
2. Integration with the Ministry of Internal Affairs API (GOST R 52633.5-2021).

2. **Value-Based Segmentation**:

- The use of cluster analysis of RFM data made it possible to identify 4 stable segments with differentiated needs;
- Elimination of unclaimed services freed up 12-18 % of operational resources.

Table 2. Matrix of value priorities by segments

Segment	Core Value	Eliminated service	Savings ($/year)
Business Traveler	Uninterrupted Wi-Fi	Minibar	28,500
Family Holidays	Child safety	Premium Bathrobes	17,200
Luxury guest	Personalization	Standard Names	42,800

Synergetic Effect: Empirical Verification of the Model

A longitudinal study of the Ibis Siberia-Omsk network (2022-2024) confirmed the hypothesis about the cumulative impact of CCS tools:

Methodology:

- Panel analysis of 2,3 KPIs;
- Structural Modeling (SEM) with Latent Variable Estimation.

Results:

- The simultaneous introduction of technology, personnel and process optimization accelerated the transition from the reactive level to clientocracy by 2,3 times;
- Exogenous variables explain 78 % of the CSI variance ($R^2 = 0,78$, $p < 0,001$).

Theoretical Implication: Practical CCS tools form a system with positive feedback, where the technological infrastructure creates conditions for personnel transformation, and LEAN optimization consolidates the achieved effects through the institutionalization of changes. This conclusion correlates with the provisions of the theory of the resource base (Barney, 1991) in relation to the service sector.

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УДК 339.7

THE ROLE OF BLOCKCHAIN IN FACILITATING CROSS BORDER TRADE

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Abstract. As the digital economy becomes deeply integrated into the development of global trade, cross border payment and settlement has been constrained by complicated processes, high costs, and slow fund arrival, posing a significant obstacle for micro small and medium sized cross border trade enterprises seeking to operate internationally. Blockchain technology, with its core features of decentralization, data tamper resistance, and full transaction traceability, offers a feasible technical pathway for optimizing and innovating cross border payment systems. This paper takes Yiwu Pay as a case study, which is the cross-border payment platform of Yiwu Commodity Market in Yiwu, China. The study outlines the full timeline of the platform's blockchain technology application, and based on officially disclosed data, empirically analyzes the actual growth changes in cross border trade volume of Yiwu Pay after the implementation of blockchain technology. The study clarifies the intrinsic relationship between technology application and trade development, providing practical references for fintech to help improve the quality and efficiency of cross border trade.

Keywords: blockchain, cross border payment, foreign trade, trade volume, fintech.

РОЛЬ БЛОКЧЕЙНА В СОДЕЙСТВИИ ТРАНСГРАНИЧНОЙ ТОРГОВЛЕ

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Аннотация. В условиях глубокой интеграции цифровой экономики в развитие мировой торговли трансграничные платежи и расчеты долгое время сдерживаются сложными процедурами, высокими издержками и медленным поступлением средств, что создает серьезное препятствие для микро-, малых и средних предприятий, работающих в сфере трансграничной торговли. Технология блокчейн благодаря своим ключевым характеристикам, таким как децентрализация, неизменяемость данных и полная прослеживаемость

операций, предлагает технически реализуемый путь для оптимизации и обновления трансграничных платежных систем. В данной работе в качестве примера рассматривается Yiwu Pay, который является трансграничной платежной платформой Товарного рынка города Иу (Китай). В статье описывается полная временная шкала внедрения технологии блокчейн на этой платформе, и на основе официально опубликованных данных эмпирически анализируется фактический рост объема трансграничной торговли Yiwu Pay после внедрения технологии блокчейн. Исследование проясняет внутреннюю связь между применением технологии и развитием торговли, предоставляя практические ориентиры для использования финтех в повышении качества и эффективности трансграничной торговли.

Ключевые слова: блокчейн, трансграничные платежи, внешняя торговля, объем торговли, финтех.

Yiwu Small Commodities Market, located in Zhejiang Province, China, is the world's largest wholesale market for small commodities. It serves as a global distribution hub for small commodities and hosts a large amount of micro, small and medium sized foreign trade merchants. Its transactions are characterized by small amounts, high frequency, multi-currency settlement, and scattered orders. The traditional SWIFT cross border payment model, with its numerous intermediaries, long settlement cycles, high fees, and difficult reconciliation processes, has long constrained the operational efficiency and market expansion of local merchants. Yiwu Pay, as the exclusive cross border payment institution under Yiwu Market Group, focuses on addressing these pain points. It has gradually advanced the integrated application of blockchain technology, digital renminbi (e CNY), and the multiple central bank digital currency (m CBDC) bridge to restructure the cross-border payment and settlement process. Through phased comparative analysis (relevant transaction data and technology implementation timelines are derived from the financial reports of listed companies, platform announcements, and authoritative industry media, all traceable and reliable), Yiwu Pay has significantly reduced settlement time, lowered costs, and decreased settlement complexity after adopting the above technologies. This has directly driven a continuous rise in the platform's cross border trade volume, empirically demonstrating the driving effect of integrated technologies such as blockchain on cross border trade growth.

The application of blockchain technology by Yiwu Pay has gone through three core stages: pilot exploration, formal commercial use, and large-scale promotion. The key milestones and corresponding trade data for each stage are as follows.

(a) Blockchain Technology Pilot Exploration Stage (September 2023).

On September 26, 2023, the Second Global Digital Trade Expo was held in Hangzhou. Yiwu Pay, in collaboration with Bank of China, officially launched a special solution for cross border payments using digital renminbi (e CNY). For the first time, blockchain distributed ledger technology was adopted as the underlying support for cross border payment settlement, initiating the pilot application of blockchain technology in the cross-border trade scenario of Yiwu [1].

According to the 2023 annual report data disclosed on the Shanghai Stock Exchange by Zhejiang China Small Commodity City Group Co., Ltd. [2], during the

blockchain pilot operation period from September to December 2023, Yiwu Pay's cross border transaction volume reached 8.5 billion yuan, representing a 135% increase compared to the transaction volume under the traditional payment model during the same period before the pilot. The number of foreign trade merchants served by the platform exceeded 8000 (see Figure 1.)

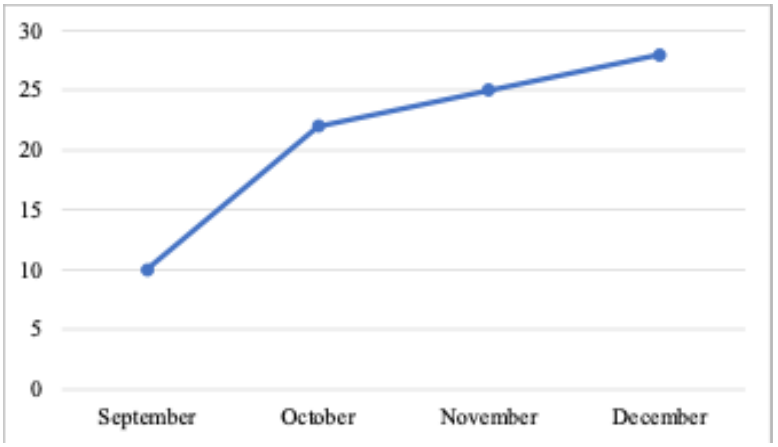


Figure 1. Transaction volume from September to December 2023
(unit: 100 million yuan)

(b) Blockchain Technology Formal Commercial Application Stage (June to September 2024).

In June 2024, the multiple central bank digital currency bridge (mBridge) officially entered the real transaction operation phase. Yiwu Pay, through its partner banks, completed system integration and began to fully rely on blockchain technology for cross border payment and settlement services, gradually replacing the traditional SWIFT payment network. This enabled point to point real time settlement of cross border transactions and fund arrival in seconds [3].

On September 24, 2024, at the Third Global Digital Trade Expo, Yiwu Pay once again partnered with Industrial and Commercial Bank of China (ICBC) to launch Cross border Linked Payment Version 2.0, further optimizing blockchain smart contract and multi-currency real time settlement functions, and improving the full service system of the cross-border payment process [1]. As shown in Figure 2, Yiwu Pay's total cross border transaction volume for the full year of 2024 reached USD 4 billion, equivalent to approximately RMB 28 billion, representing a 233% year on year increase from the USD 1.2 billion recorded in 2023. Among this, cross border transactions completed via blockchain accounted for over 75%, and the number of cross border transactions on the digital renminbi blockchain exceeded 8 million [4; 5].

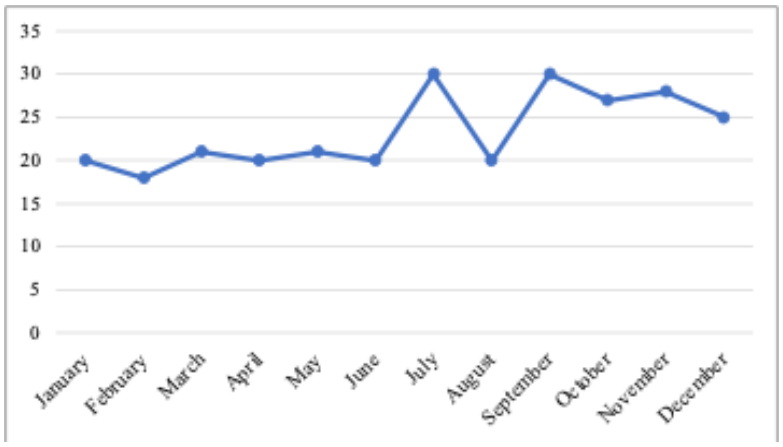


Figure 2. Transaction volume from January to December 2024
(unit: 100 million yuan)

(c) Blockchain Technology Large Scale Promotion Stage (January to December 2025)

In 2025, Yiwu Pay continued to deepen its application of blockchain technology, successfully obtaining qualification for direct acceptance of digital renminbi payments. It was also selected as one of the first batch of expanded institutions for the multiple central bank digital currency bridge at the national level, further increasing transaction limits, expanding service coverage, and achieving comprehensive large-scale application of blockchain technology in cross border payment scenarios [6]. As shown in Figure 3, Yiwu Pay's total cross border transaction volume for the full year of 2025 increased to USD 6 billion, representing a 50% year on year increase compared to 2024. As of the end of 2025, Yiwu Pay had completed a cumulative cross border receipt of RMB 61.2 billion through blockchain technology, served over 24,500 foreign trade merchants, and covered 172 countries and regions worldwide [3; 6].

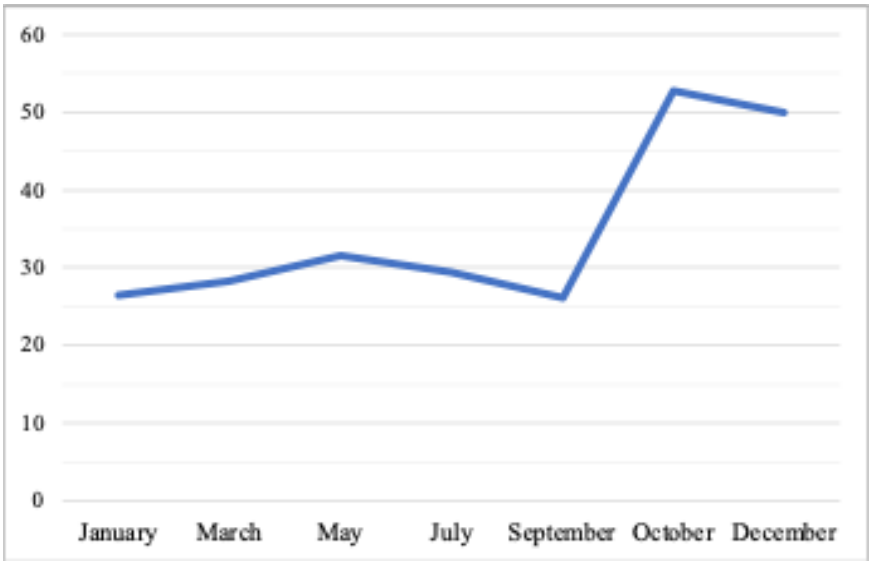


Figure 3. Transaction volume from January to December 2025
(unit: 100 million yuan)

Based on the above analysis, it can be confirmed that since Yiwu Pay officially implemented blockchain technology in September 2023, as the technology moved from pilot application to full scale commercial use, the platform's cross border trade volume has achieved significant growth. Over three years, trade volume has multiplied several times. The mechanisms enabling this growth can be summarized in the following three aspects:

(a) Reducing transaction costs and increasing merchant profit margins. Blockchain technology eliminates intermediate clearing links in cross border payments, significantly reducing various costs such as bank handling fees and clearing service charges. According to official data from Yiwu Pay, blockchain based cross border payment fees are 60% lower than those of the traditional SWIFT model. This directly reduces transaction expenses for foreign trade merchants, increases order profitability, thereby stimulating merchants' willingness to transact and driving overall trade volume growth [1].

(b) Improving settlement efficiency and accelerating capital turnover. Traditional SWIFT cross border payments take three to five business days for funds to arrive, tying up a substantial number of merchants' working capital. Blockchain technology enables real time settlement and instant fund arrival for cross border transactions, significantly shortening the payment collection cycle for merchants and improving capital turnover efficiency. This allows merchants to have sufficient working capital to take on more overseas orders, directly promoting the expansion of cross border trade volume [4].

(c) Strengthening transaction trust and expanding overseas market channels. The blockchain distributed ledger features data tamper resistance and full traceability of the entire process. It effectively prevents risks such as transaction fraud and accounting disputes, while also meeting cross border foreign exchange regulatory requirements and anti-money laundering compliance standards, thereby enhancing the transaction trust of overseas purchasers. Relying on a secure and compliant payment system, foreign trade merchants in Yiwu have been able to further explore emerging overseas markets such as those along the Belt and Road, expanding trade coverage and transaction scale [5].

The research findings indicate that blockchain technology has effectively optimized the entire cross border payment process across three dimensions: cost, efficiency, and compliance trust. It has become the core driving force behind the sustained growth of Yiwu Pay's cross border trade volume, while also providing a replicable and referential practical case for the digital transformation of China's cross border payment and the empowerment of foreign trade development through fintech.

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УДК 336.71

DIGITAL BANKING AS A NEW SOLUTION FOR SMALL AND MEDIUM-SIZED ENTERPRISE FINANCING

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Abstract. Small and medium-sized enterprises (SMEs) have long faced difficulties in accessing financing and slow disbursement. Traditional credit models heavily rely on collateral and financial statements, and the approval process is quite long, resulting in delayed plans and missed business opportunities due to capital shortages. This study analyzes how digital banks have improved the efficiency of SME financing based on the practices of digital banks in Hong Kong. Taking PAO Bank as a case study, which is the first bank in Hong Kong to participate in the Commercial Data Interchange (CDI) facility launched by the Hong Kong Monetary Authority (HKMA) and to serve as a pilot in the Port Community System, this paper examines three aspects: operational mechanism, efficiency improvement, and coverage expansion. The findings show that digital banks effectively lower the financing threshold for SMEs, significantly shorten the financing cycle, and expand credit coverage, thereby significantly improving SME financing efficiency.

Keywords: digital banking, small and medium-sized enterprises (SMEs), financing, financial statement, efficiency.

ЦИФРОВОЙ БАНКИНГ КАК НОВОЕ РЕШЕНИЕ ДЛЯ ФИНАНСИРОВАНИЯ МАЛЫХ И СРЕДНИХ ПРЕДПРИЯТИЙ

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Аннотация. Малые и средние предприятия (МСП) сталкиваются с проблемами доступа к финансированию и медленного получения средств. Традиционные кредитные модели в значительной степени зависят от залога и финансовой отчетности, а процесс одобрения кредитов занимает много времени, что приводит к задержкам планов и упущенным коммерческим возможностям из-за нехватки капитала. Данное исследование, основанное на практике цифровых банков Гонконга, анализирует, каким образом цифровые банки повысили эффективность финансирования МСП. В качестве кейса

рассматривается PAO Bank, первый банк в Гонконге, который участвует в системе Commercial Data Interchange (CDI), запущенной Управлением денежного обращения Гонконга (HKMA), и выступает пилотным участником системы портового сообщества. В статье анализируются три аспекта: механизм работы, повышение эффективности и расширение охвата. Результаты показывают, что цифровые банки эффективно снижают порог финансирования для МСП, значительно сокращают сроки получения финансирования и расширяют кредитный охват, тем самым заметно повышая эффективность финансирования МСП.

Ключевые слова: цифровой банкинг, малые и средние предприятия (МСП), финансирование, финансовая отчетность, эффективность.

Introduction

Small and medium-sized enterprises (SMEs) are the crucial part of Hong Kong's economy, accounting for over 98 % of all enterprises in the region [1]. However, SMEs have long faced difficulties in accessing financing and slow disbursement. According to HKMA estimates, Hong Kong's trade finance gap in 2024 ranged from HKD 311.2 billion to HKD 519.1 billion, representing approximately 3.6% to 5.5% of total trade value [2]. The root cause of this gap largely stems from the inherent limitations of traditional credit models. Traditional bank lending relies heavily not only on tangible collateral such as property and equipment, but also on financial statements and audit records. As a result, many asset light SMEs and startups lacking financial records are unable to obtain credit support due to insufficient collateral and financial documentation. Moreover, traditional loans involve a lengthy process from application to disbursement, making it difficult to meet SMEs' funding needs that are often small in amount, short term, high frequency, and urgent.

Alternative data refers to non-traditional financial data that can reflect the actual operating conditions of enterprises, such as customs declaration data, logistics data, electronic payment records, and so on [1]. Unlike traditional credit records, these data directly reflect the current operational vitality of enterprises, enabling banks to use data driven credit assessments as a substitute for traditional collateral. In Hong Kong, digital banks, leveraging their native digital architecture, have taken the lead in putting this concept into practice. In October 2025, HKMA Chief Executive Eddie Yue explicitly identified "using alternative data to streamline loan processes" as one of the three landmark achievements of bank digitalization [3]. In January 2026, the HKMA officially released the "Project CargoX Proposal Report", outlining three strategic pillars and 20 specific recommendations to enable SMEs to obtain financing based on operational data, replacing the traditional model of physical collateral and historical financial statements [4].

Comparison of Traditional Credit and Alternative Data Credit

The traditional credit model uses collateral to mitigate the information asymmetry between banks and enterprises. However, this model excludes asset light small and medium sized enterprises. A 2022 working paper by the Bank for International Settlements (BIS) points out that collateral requirements are closely related to firm size, and a considerable number of SMEs are rejected due to insufficient

asset base [5]. A World Bank survey shows that among the 164000 firms surveyed, about 89% have a bank account, but less than one third have a bank loan or a credit line [6]. The traditional credit model also faces several problems for SMEs: lack of information transparency, as many SMEs do not have standardized financial records; high operating costs, as manual loan processing is economically unfavorable for small sized loans; and long approval cycles, which typically take weeks to months [7].

A 2020 BIS working paper points out that large technology firms can use massive amounts of data to assess the creditworthiness of enterprises, thereby reducing reliance on collateral in credit markets [8]. In this context, "alternative data" is defined as non-traditional data beyond conventional credit history. In the SME credit scenario, operational data such as customs declaration data, logistics data, and e commerce transaction records constitute the core sources of alternative data. Lee et al. (2026) provide quantitative evidence, found that after incorporating retail transaction data, the credit card approval rate for applicants without credit history increased from 16% to between 31% and 48% [9].

Hong Kong provides a unique institutional environment for the development of alternative data credit in digital banks. In 2022, the HKMA launched the Commercial Data Interchange (CDI), which allows banks, after obtaining enterprise authorization, to obtain alternative data such as customs declarations and logistics data from third party data sources including Tradelink, the Port Community System, and e commerce platforms for credit assessment [10]. In January 2026, the HKMA released the "Project CargoX Proposal Report," explicitly proposing to enable SMEs to "obtain financing based on operational data, replacing the traditional model of physical collateral." As of December 2025, the CDI has facilitated over 82000 loan applications, with total approved credit exceeding HKD 66.4 billion [5].

Result and Discussion

PAO Bank is the first digital bank in Hong Kong to participate in the CDI facility launched by the HKMA, and it is also the first pilot bank to introduce data from the Port Community System [11]. The bank has already taken a leading position in the industry in applying alternative data credit. The following sections provide an in-depth analysis of the bank's alternative data credit practices from three perspectives: operating mechanism, efficiency improvement, and coverage expansion. Figure illustrates the operating mechanism.

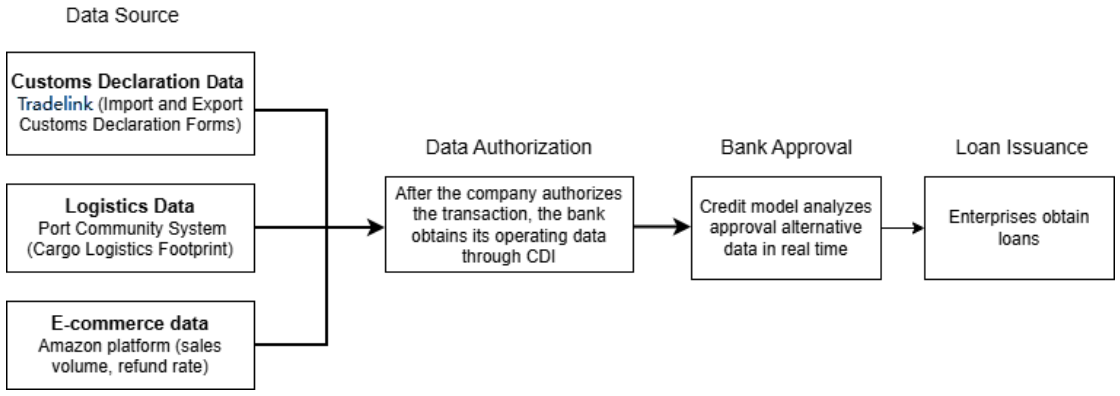


Figure. Flowchart of PAO Bank's alternative data credit mechanism

As shown in Figure 1, Tradelink Electronic Commerce Limited (Tradelink) provides import and export customs declaration data, the Port Community System (PCS) provides real time cargo logistics data, and e commerce platforms such as Amazon provide operational data including sales volume and refund rates. These three types of data together form the foundational sources of alternative data. Then, through the CDI facility launched by the HKMA, enterprises grant one time authorization for banks to access their operational data. After obtaining authorization, the bank uses its credit assessment model to conduct real time analysis of the alternative data and completes the approval process. Finally, the bank proceeds with loan approval and disbursement.

This operating mechanism replaces traditional tangible collateral with real time, transparent operational data. For small and medium sized enterprises, even without traditional collateral and financial records, if they have authentic customs declaration, logistics, or e commerce operational records, they can obtain financing, thereby lowering the financing threshold.

Digital banks have significantly improved efficiency. Under the traditional credit model, banks often take a long time to process loan applications, sometimes as long as several months. A toy company in Hong Kong had to delay its research and development plans and thus missed business opportunities. After authorizing through CDI, PAO Bank obtained the company's operational data such as customs declarations and logistics information, completed the approval process, and enabled the company to obtain a loan within five days, providing sufficient funds to seize market opportunities [12]. In January 2025, the bank also launched a cross-border e commerce revolving loan with a credit amount of up to USD 5 million. After obtaining enterprise authorization, the bank accesses real time data from the enterprise's Amazon platform, including sales volume, inventory levels, refund rates, etc., and then conducts credit assessment. The enterprise will receive the loan funds within one week, with a repayment period of up to six months [13].

Alternative data credit not only improves efficiency but also reaches groups that are excluded under the traditional credit model. According to official disclosures from PAO Bank, approximately 25 % of the approved loan customers were enterprises obtaining a bank loan for the first time as of December 31, 2024. This demonstrates that using operational data as a substitute for collateral can serve enterprises lacking collateral and credit records, which are typically beyond the reach of the traditional credit model. About 8.2 % of the approved customers were startups operating for less than three years, and they obtained unsecured loans, proving that this model can serve enterprises lacking financial history in their early stages [14; 15]. The growth in PAO Bank's loan portfolio further confirms the expansion of coverage. According to PAO Bank's 2025 interim financial report, the bank's total SME loans increased from HKD 3.13 billion on December 30, 2024, to HKD 3.72 billion on June 30, 2025, representing a growth rate of 41 %. This indicates that more SMEs are gaining credit support through the alternative data model, and the coverage scope is continuously expanding.

These results show that using operational data as a substitute for collateral can effectively serve enterprise groups that are difficult to reach under the traditional credit

model, with broad coverage. For SMEs, this approach efficiently addresses capital shortages and the difficulty of obtaining loans.

Conclusion

The practical case of PAO Bank shows that the alternative data credit model has transformed the credit assessment logic of digital banks. Instead of relying on enterprises' financial statements and traditional collateral, banks actively obtain operational data such as customs declarations, logistics, and e commerce activities through the CDI to conduct credit assessment and approval. Digital banking provides a new solution for small and medium-sized enterprise financing, which lowers the financing threshold for small and medium sized enterprises, significantly increases the bank's approval speed, and has a substantive impact on SMEs financing efficiency, effectively addressing the funding needs of SMEs that are often small in amount, short term, high frequency, and urgent. This model is being rapidly promoted, with loan portfolio growing by as much as 41 % in half a year, benefiting a growing number of SMEs. From the perspectives of operating mechanism, efficiency improvement, and coverage expansion, these three aspects together validate the feasibility and inclusive value of alternative data.

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УДК 336.71

ENHANCING FINANCIAL INCLUSION IN RURAL REGIONS THROUGH LIVE LIVESTOCK AS COLLATERAL

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Abstract. Animal husbandry plays an important role in the economy and the well-being of people in countries such as China and Russia. Credit constraints are prominent in pastoral regions specializing in animal husbandry. To address this contradiction, Chinese central bank and relevant authorities have promoted a policy of live livestock mortgage financing, allowing pastoral households to apply for loans using live livestock as collateral. Based on empirical data and academic research from pastoral areas in Inner Mongolia, China, this paper systematically evaluates the effects of this policy from the perspective of individual pastoral households. The findings show that live livestock mortgage loans effectively improve credit availability for households, enabling more households with adequate farming scales to access formal financial services. The core mechanism lies in substituting traditional collateral requirements with the value of live livestock, combined with digital and intelligent supervision technologies that reduce banks' post lending management costs. This study reveals the effectiveness of live livestock collateral loans in alleviating credit constraints on pastoral households and provides empirical evidence for improving financial inclusion in rural regions.

Keywords: animal husbandry, collateral, credit availability, financing, financial inclusion.

ПОВЫШЕНИЕ ФИНАНСОВОЙ ДОСТУПНОСТИ СЕЛЬСКИХ РЕГИОНОВ ЧЕРЕЗ ЗАЛОГ ЖИВОГО СКОТА

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Аннотация. Животноводство играет важную роль в экономике и благосостоянии населения таких стран, как Китай и Россия. Кредитные ограничения особенно проявляются в пастушьих регионах, специализирующихся на животноводстве. Для решения этой проблемы центральный банк Китая и соответствующие ведомства продвигают политику

кредитования под залог живого скота, позволяя пастушьим хозяйствам получать кредиты. На основе эмпирических данных и академических исследований, проведенных в пастушьих районах Внутренней Монголии (Китай), в данной работе систематически оцениваются эффекты этой политики с точки зрения отдельного пастушьего хозяйства. Результаты показывают, что кредиты под залог живого скота эффективно повышают доступность кредита для хозяйств, позволяя большему числу хозяйств с адекватным масштабом производства получить доступ к официальным финансовым услугам. Ключевой механизм заключается в замещении традиционных залоговых требований стоимостью живого скота в сочетании с технологиями цифрового и интеллектуального контроля, которые снижают затраты на последующее управление кредитом. Данное исследование раскрывает эффективность кредитов под залог живого скота в снижении кредитных ограничений для пастушьих хозяйств и предоставляет эмпирические доказательства для повышения финансовой инклюзивности в сельских регионах.

Ключевые слова: животноводство, залог, доступность кредита, финансирование, финансовая инклюзивность.

Animal husbandry occupies an important position in the national economy and the well-being of the people. Pastoral households have long faced the dilemma of "having assets but difficulty obtaining financing". Live livestock account for a very high proportion of household assets, yet financial institutions refuse to accept them as collateral due to their high mobility and difficulty in constant monitoring. As a result, credit constraints are particularly prominent in pastoral regions where animal husbandry is a main part of the regional economy. In typical pastoral areas of Inner Mongolia, live livestock account for more than 85 % of the asset structure of pastoral households, while the proportion of fixed assets such as real estate and equipment recognized by financial institutions is very low. Although land use rights have some value, their mortgage and disposal are restricted. This singularity of asset structure places pastoral households at a disadvantage in the traditional credit system.

Small scale credit loans are usually only 30000 to 50000 yuan, which is far from sufficient to meet the needs of pastoral households for purchasing forage, building sheds and pens, and expanding breeding scales. Once a large loan is involved, banks require eligible collateral, but live livestock are precisely what banks have long refused to accept. The banks' concerns are realistic: live livestock can move, get sick, die, have fluctuating values, and are difficult to monitor continuously. Survey data from China Agricultural University in pastoral areas between 2019 and 2020 confirm this dilemma. Among 446 sample households, the average years of education of pastoral households was only 4.35 years, the average age of household heads was 46 years, and about 21 % of pastoral households faced significant credit constraints [1]. The core contradiction can be summarized as follows: pastoral households' primary asset is live livestock, but financial institutions do not recognize it as collateral. Having assets yet difficulty obtaining financing is precisely the crux of credit constraints in pastoral regions.

To address this contradiction, Chinese central bank and relevant authorities have promoted a policy of live livestock mortgage financing. In December 2025, the

People's Bank of China, Ministry of Agriculture and Rural Affairs, and the National Financial Regulatory Administration jointly issued the " Notice on Properly Carrying Out Mortgage Loan Services for Agricultural Facilities and Live Livestock/Poultry" [2]. This is the first time a systematic design for live livestock mortgage financing has been introduced at the national level. The document addresses previous institutional obstacles from four dimensions: confirming live livestock as eligible collateral; promoting digital means of rights confirmation such as electronic ear tags and biometric identification; handling mortgage registration through the Unified Registration System for Movable Property Financing; and exploring an "agricultural insurance plus financing" model along with risk compensation funds.

Taking the first loan of 900000 yuan in Zhengxiangbai Banner, Inner Mongolia in 2023 as an example [3], the operating procedure includes: value assessment (value of cattle), mortgage registration (handled online through the Unified Registration System for Movable Property), intelligent supervision (real time positioning via electronic ear tags), insurance support (compulsory insurance with claim priority for loan repayment), and loan disbursement. The detailed process is shown in Figure.



Figure. Operating procedure of live livestock collateral loans

The operating procedure of live livestock collateral loans shown in Figure 1 effectively improves loan accessibility. As of the end of September 2024, the outstanding balance of live livestock mortgage loans in Inner Mongolia reached 2 billion yuan. The loan interest rates for farming and pastoral households decreased by 77 basis points year on year, with cumulative interest reductions and concessions amounting to nearly 400 million yuan. Village level credit granting covered 11000 administrative villages, and the coverage rate of agricultural service points reached 99 %. Credit was granted to 1.43 million farming and pastoral households, accounting for 44.4 % of the region's total [4]. Together with land management right mortgage loans (5.2 billion yuan), live livestock mortgage loans constitute the two pillars of property rights mortgage lending in pastoral regions.

Actual implementation shows significant differences in access to loans among pastoral households with different herd sizes. Large scale households with more than 100 head of livestock have sufficient collateral value (100 head valued at approximately 900000 yuan) and standardized management, making them more likely to obtain loans. Medium sized households with 30 to 100 head can partially pass the assessment, but they must meet conditions such as uniform breeds, good health, and willingness to cooperate with supervision. For small households with fewer than 30 head, obtaining a loan is very difficult. The problem is not the creditworthiness or willingness of the pastoral households, but the bank's economic logic: the costs of

assessing small scale livestock, installing ear tags, and continuous monitoring are too high relative to the loan amount.

An empirical study based on 339 large scale breeding households in Shanxi and Inner Mongolia confirms this finding: live livestock mortgage loans significantly promote the income of large-scale breeding households [5]. However, it is worth noting that the study sample itself was limited to "large scale breeding households", meaning that small scale pastoral households were not included in the research scope, which precisely illustrates that they have been overlooked by this policy tool. Pastoral households that obtained loans experienced significant changes in their production and operation behaviors. Empirical results confirm that large scale breeding households that received loans increased their supplementary feeding expenditure by an average of 32%, while unit breeding costs decreased by 9 % [6]. Luo and Li (2025) further revealed the transmission mechanism: the main pathway through which live livestock mortgage loans promote income growth is by encouraging pastoral households to adopt digital and intelligent technologies (electronic ear tags, IoT monitoring). The study also found that policy effects are more significant in contexts where government training is provided, indicating a complementary relationship between human capital investment and financial policy [5].

Despite notable achievements, four boundary issues remain from a micro perspective. First, limited coverage: the primary beneficiaries are households with more than 100 head, while small households are largely unable to access the program. Second, technological barriers: electronic ear tags and mobile apps create new forms of exclusion for elderly pastoral households (average age 46 years) and those with low education levels (average 4.35 years). Third, regional differences in disposal mechanisms: the development of live animal trading markets varies across regions, leading to significant differences in the efficiency of collateral disposal, which affects banks' willingness to lend. Fourth, implementation variability: the effectiveness varies greatly across different banks and even different loan officers, with human capital still playing an excessively large role.

Based on the above analysis, the following findings can be summarized: (a) The policy is significantly effective. The 2025 three department notice resolved institutional obstacles. The 2-billion-yuan loan balance and 77 basis point interest rate reduction in Inner Mongolia, along with the output enhancement effects across 290 prefecture level cities and the income growth of 339 large scale breeding households, all demonstrate that the policy direction is correct [4]. (b) There are clear limitations. Live livestock mortgage loans face scale thresholds, technological barriers, regional disparities, and implementation variability. The policy effectively serves medium sized and larger pastoral households, but the dilemma of "having assets but difficulty obtaining financing" for small scale pastoral households has not truly changed. (c) Effective policies require complementary support. Government training significantly amplifies policy effects, indicating that financial policy needs to work in concert with human capital investment, technical guidance, and grassroots capacity building.

The findings of this paper indicate that policy measures recognizing live livestock as eligible collateral, combined with digital supervision technologies, have effectively alleviated credit constraints for medium sized and larger pastoral

households, significantly improved credit availability in pastoral regions, and hold positive implications for promoting rural economic development and deepening financial inclusion. However, the policy effects are not universally inclusive. Small scale pastoral households face significant difficulties in obtaining loans due to banks' cost benefit considerations; elderly and low education pastoral households encounter barriers in adopting digital technologies; and regional disparities in the efficiency of collateral disposal further constrain the balanced coverage of policy outreach. Pastoral households that obtained loans have directed funds toward productive investment and technological upgrading, achieving improvements in operational efficiency. Moreover, government training significantly amplifies the policy effects, indicating a complementary relationship between human capital investment and financial policy. Overall, live livestock mortgage lending represents a valuable exploration of inclusive finance in pastoral regions. Yet, to truly benefit the vulnerable pastoral households most in need of financial services, further policy refinements are required in areas such as lowering scale thresholds, preserving credit loan channels, and strengthening grassroots complementary support, to develop rural finance toward the genuine goal of financial inclusion.

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УДК 332.1:659.1

PLACE BRANDING AS A TOOL FOR REGIONAL DEVELOPMENT: THE ROLE OF CULTURE AND ART IN CITY PROMOTION

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Abstract. This paper examines place branding as a strategic instrument for regional development, with a focus on the role of cultural resources and art in shaping the identity of Russian cities. The authors analyze key theoretical approaches to territorial branding, review domestic and international practices of culture-driven place promotion, and identify the main barriers to effective branding in Russia. It is shown that a systematic integration of cultural heritage and contemporary art into branding strategy significantly enhances a city's investment attractiveness and fosters the retention of residents.

Keywords: place branding, territorial marketing, regional development, cultural identity, city image, investment attractiveness, urban competitiveness.

БРЕНДИНГ ТЕРРИТОРИЙ КАК ИНСТРУМЕНТ РЕГИОНАЛЬНОГО РАЗВИТИЯ: РОЛЬ КУЛЬТУРЫ И ИСКУССТВА В ПРОДВИЖЕНИИ ГОРОДОВ

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Аннотация. В работе рассматривается брендинг территорий как стратегический инструмент регионального развития с акцентом на роль культурных ресурсов и искусства в формировании идентичности российских городов. Проанализированы ключевые теоретические подходы к территориальному брендингу, рассмотрена отечественная и зарубежная практика культурно-ориентированного продвижения городов, выявлены основные барьеры для эффективного брендинга в России. Показано, что системная интеграция культурного наследия и современного искусства в

брендинговую стратегию существенно повышает инвестиционную привлекательность города и способствует удержанию жителей.

Ключевые слова: брендинг территорий, территориальный маркетинг, региональное развитие, культурная идентичность, имидж города, инвестиционная привлекательность, конкурентоспособность городов.

The competition between territories for human and financial capital has ceased to be an exclusively economic phenomenon – today it unfolds in the plane of images, meanings and emotions. Cities compete not so much with resources as with reputations: how attractive a place looks in the eyes of potential residents, tourists, and investors. In this context, the branding of territories is turning from a marketing tool into a full-fledged strategy for managing the development of the region. Culture and art play a special role in building an attractive image.: they not only form a unique identity of the place, but also create a stable emotional connection between the territory and its audience. Nevertheless, in Russian practice, the potential of the cultural dimension of branding is still used inconsistently and in many ways intuitively, which makes the topic of this work relevant both theoretically and in applied terms.

Territorial branding as an independent discipline took shape at the turn of the XX–XXI centuries. One of the first to systematically comprehend this phenomenon was undertaken by A. P. Pankrukhin, who defined territorial marketing as an activity aimed at identifying and promoting the interests of a territory in order to solve specific problems of its development [1, p. 55]. Later, the concept was developed in the works of D. V. Vizgalov, who distinguished the marketing of the city and branding as its most complex form, requiring systematic management of the identity of the place [2, p. 18]. An international scientific school edited by K. Dinni made a significant contribution to understanding the nature of the territorial brand: the collection of the best world practices shows that the brand of a territory is not limited to a logo or slogan, but is a set of associations connecting a place with certain values and images [3, p. 24]. Russian researchers, in particular, L. V. Kovyneva and A. G. Steinberg – concretized this thesis in relation to Russian realities, showing that in a country with pronounced regional heterogeneity, the brand of the territory is able to reduce population outflow and attract investment, but only if there is political will and coordination of actions of all stakeholders [4].

It is customary to consider the brand of a territory as a multi-level structure that includes functional, emotional and symbolic components. In the work of I. V. Loguntsova and A. S. Zaitseva, devoted to the practice of geobranding administrative centers of the subjects of the Russian Federation, a three-level classification of urban brands is proposed: cities with documented concepts and systemic marketing activity; cities with individual signs of geobranding within a regional or tourist route; cities without signs of systemic branding work [5, p. 165]. According to this content analysis, which covered 83 regions of the Russian Federation, only a small proportion of cities belong to the first group, while the majority either limit themselves to creating a logo or do not take any purposeful actions to create an image.

As a result, the potential of the territory remains undiscovered, and competitive advantages remain unclaimed.

A special place among the resources of territorial branding is occupied by the cultural dimension. Cultural heritage, contemporary art, event activity and creative industries form what is commonly called the cultural identity of a place, a stable set of meanings that distinguish this territory from any other. It is culture that ensures differentiation in the context of the increasing visual and functional homogeneity of the urban environment. It is significant that a number of Russian cities have achieved notable results precisely through culturally oriented branding. In 2008-2012, Perm consistently built the image of the "new cultural capital": the White Nights festival, the PERMM Gallery and the large-scale art project "Little Red Men" significantly changed the perception of the city both in Russia and abroad. Kazan has shaped the image of a multinational and multi-religious center by integrating Tatar culture into the urban identity and event calendar. Uryupinsk, one of the first in Russia to register its own brand "Capital of the Russian Province", relied on irony and self-identification, turning provinciality from a disadvantage into a competitive advantage [5, p. 170].

International experience confirms that cultural branding can radically change the perception of a territory, even in unfavorable starting conditions. The book, edited by K. Dinny, provides an example of Australian Wollongong, an industrial city that, through its emphasis on environmental values and coastal identity, transformed the image of a depressed manufacturing center into an attractive place for living and tourism [3, p. 67]. Barcelona, which actively developed its cultural infrastructure in preparation for the 1992 Olympic Games, established a brand that continues to operate three decades later. In both cases, the key role was played not by a one-time event, but by the systemic integration of cultural meanings into urban politics, architecture, communications, and the daily lives of citizens. This is what distinguishes a sustainable brand from a PR campaign with a limited action horizon.

The mechanism of influence of cultural resources on the branding of a territory is implemented through several interconnected channels. The first is the formation of a local identity: when citizens perceive cultural objects and events as their own, they become natural carriers and translators of the brand. The second channel is the creation of informational occasions: festivals, art objects, theater premieres and architectural projects generate the media presence of the city at the regional, federal and international levels without direct advertising costs. The third is a change in the perception of the quality of the urban environment: the presence of cultural infrastructure increases the attractiveness of the territory for representatives of the "creative class" – qualified specialists, without whom sustainable economic development is impossible. D. V. Vizgalov emphasizes that it is competition for talents, and not for investments in their pure form, that is becoming the main driving force of modern urban marketing [2, p. 42].

Despite the obvious potential of culturally oriented branding, few cities are able to fully realize it in Russian practice. The study by L. V. Kovyneva and A. G. Steinberg revealed a number of systemic barriers: lack of long-term branding strategies, lack of

professional competencies in municipal government, limited financial resources and weak involvement of the local community in the processes of forming the image of the territory [4]. In addition, the Soviet architectural unification, characteristic of many Russian cities, makes the visual appearance of various settlements almost indistinguishable. As a result, branding initiatives are often limited to developing a logo, after which the project actually freezes without receiving a strategic continuation. Another common mistake is trying to "buy" a brand through a one–time major event (championship, forum, exhibition) without further work to maintain the formed image in the public consciousness.

The analysis of successful domestic and foreign cases allows us to formulate a number of conditions under which cultural branding of territories gives a stable result. First of all, strategic consistency is needed: the brand should be consolidated in urban planning documents, architectural policy, tourist navigation system and educational programs. The involvement of citizens is equally important: brands created "from above" without the participation of the local community, as a rule, are rejected and do not take root. Authenticity is of fundamental importance: the most viable brands grow from the real cultural characteristics of a place, rather than being artificially constructed on the model of successful analogues. Finally, cultural branding requires coordination between government authorities, business, the creative community, and civil society – only intersectoral partnerships can provide the resources and legitimacy needed for long-term positioning of the territory.

The analysis shows that branding territories based on cultural resources and art is one of the most promising tools for regional development in the context of increasing competition for human and investment capital. The cultural identity of the city – its history, traditions, and modern artistic practices – forms a unique foundation that cannot be easily copied by competitors and is therefore capable of providing sustainable competitive advantages. In the Russian context, the realization of this potential is hindered by insufficient institutionalization of branding processes, weak intersectoral cooperation, and a short-term planning horizon. Overcoming these barriers involves the formation of professional competencies in the field of territorial marketing at the municipal government level, the development of long-term branding strategies that are organically integrated into the strategies of socio-economic development of regions, as well as the creation of mechanisms for involving citizens and creative communities in the processes of shaping the image of the city. In the future, it is those territories that will be able to transform their cultural identity into a conscious and consistently promoted value that will be in the most advantageous position in competition for resources and attention.

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УДК 7.01:659.1

ADVERTISING DESIGN: HOW VISUAL ELEMENTS INFLUENCE HUMAN PERCEPTION

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Abstract. This article examines the influence of visual elements in advertising design on human perception and the effectiveness of advertising messages. It is demonstrated that the visual component of advertising influences not only the conscious but also the subconscious mind, shaping attitudes toward a product, service, or brand. The conclusion is drawn that advertising design should be understood as a system of visual communication in which aesthetic and psychological elements work together and reinforce one another.

Keywords: advertising, design, visual perception, color, advertising image, psychology, marketing.

ДИЗАЙН РЕКЛАМЫ: КАК ВИЗУАЛЬНЫЕ КОМПОНЕНТЫ ВЛИЯЮТ НА ВОСПРИЯТИЕ ЧЕЛОВЕКА

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Аннотация. В статье рассматривается влияние визуальных компонентов рекламного дизайна на восприятие человека и эффективность рекламного сообщения. Показано, что визуальная составляющая рекламы воздействует не только на сознательном, но и на подсознательном уровне, формируя отношение к товару, услуге или бренду. Делается вывод о том, что дизайн рекламы следует понимать как систему визуальной коммуникации, в которой эстетические и психологические средства работают совместно и усиливают друг друга.

Ключевые слова: реклама, дизайн, визуальное восприятие, цвет, рекламный образ, психология, маркетинг.

In today’s society, advertising is present in virtually every aspect of daily life. Its impact stems not only from the content of the message but also from the way it is visually presented, determining the speed of perception, the emotional response, and the subsequent attitude toward the brand.

Today, design is not just a pretty picture, a visual concept, or a marketing tool; it is the embodiment of the consumer's values, taste, and psychological attitudes. Design is a means of communication between a brand and the consumer through visual imagery, aimed at achieving specific objectives. Design serves as both the "face" of a brand or product and a marketing tool – a tool aimed at boosting sales, helping a company win over its target audience, and compete in the marketplace.

A well-executed design is more than just a pretty wrapper. It is your first point of contact with the customer, a means of communication, and even a tool for influencing decision-making. The sheer volume of advertising reduces people's ability to process information; companies begin to look alike, and sometimes even advertising messages become indistinguishable from one another, turning into nothing more than "white noise."

Domestic and international studies in the psychology of advertising note that an advertising image serves not only an informational function but also suggestive, emotional, and associative functions [1, pp. 32–34]. Not every advertising product that draws a person into a pre-programmed communication process can be classified as artistic or considered a work of art. Undoubtedly, we live in a consumer society where advertising has more influence than art.

To identify the specific influence of design on people, an anonymous online survey was conducted among 121 people aged from 13 to 79. According to the results of the survey, the majority of respondents noted that design influences the perception of a product or service, emotional state, and assessment of product quality:

- 98 % confirmed that design can influence the perception of a product or service;
- 89 % noted that design affects their emotional state;
- 80 % would not use poorly designed websites and apps;
- more than 67 % of respondents associate packaging design with product quality.

The results of the empirical study show that visual design elements have a significant impact on human perception.

Our understanding of the visual impact of advertising is based on research in the field of perceptual psychology, particularly Max Wertheimer's 1912 paper "Experimental Studies of Apparent Motion," which became an influential work that laid the foundation for Gestalt psychology. "The fundamental 'formula' of Gestalt theory might be expressed in this way. There are wholes, the behaviour of which is not determined by that of their individual elements, but where the part-processes are themselves determined by the intrinsic nature of the whole" [2, p. 82]. In other words, this means that people perceive an image as a whole: they do not see a collection of separate details, but rather a structure in which the relationships between elements, balance, and composition are important. This approach is particularly significant for the analysis of advertising, since it is precisely the integrity of the visual image that makes the message clear and expressive.

This idea is further elaborated in "The Consumer Society: Myths and Structures", where J. Baudrillard argues that advertising functions not merely as a means of informing consumers about products, but as a system of signs and symbols that shapes social meanings and patterns of consumption [3]. In this context, visual elements serve as independent vehicles of meaning rather than merely illustrations

accompanying the text. Their effectiveness determines not only the audience's attention but also the degree to which information is retained in memory and transformed into consumer behavior.

When considering design from a psychological perspective, perception is traditionally categorized by color, saturation, shape, volume, depth, style, composition, and typical associations [4].



Figure 1. Itten's color wheel

Color is one of the most powerful visual factors of influence. It can instantly attract attention, evoke an emotional response, and form certain associations with a brand or product. Research on the psychology of color notes that different shades can be perceived as warm or cool, calm or active, reliable or dynamic; at the same time, the meaning of color always depends on context, culture, and product category [5]. Even before the recipient reads and understands the text, the color scheme has already managed to store information at the subconscious level. Color is a means of instant information transfer. It appeals to the senses rather than to human logic.

Designers frequently use a technique that is both simple and effective: the color wheel. One example is Johannes Itten's 12-sector color wheel, which is based on three primary colors: red, yellow, and blue (Figure 1). A color wheel is a way of representing the continuity of color transitions. The sectors of the wheel are colored in various shades, arranged in the order of the spectral colors, and to connect the extreme colors (red and violet), magenta was added, which in turn is not a spectral color [6].

Color in advertising rarely functions in isolation. Therefore, the color scheme must align with the communication objective: to attract attention, inspire trust, emphasize status, create a sense of comfort, or, conversely, prompt immediate action. However, over time, consumers adapt to the constant stream of eye-catching products and do not feel compelled to examine them all. Manufacturers, on the other hand, want to achieve recognition among a wide audience in a very short time. Therefore, an information model is needed that concisely conveys extensive information.

Such a model is the logo (from the Ancient Greek λόγος—word + τύπος—imprint). An important aspect of communication between the manufacturer and the consumer is the encoding and decoding of the information embedded in the logo. It is important to note that the artist addresses a broad audience simultaneously. At the same time, different people may interpret this message in their own way, which raises questions about the integrity and consistency of perception, as well as the universality of the meanings conveyed through the artistic symbol. Consequently, a logo is not a

random symbol; it is shaped by expectations and those aspects of its characteristics that make it justified and logical [7].

For example, a study by E. Yu. Karmalova and M. O. Kryukova, dedicated to the perception of the color schemes of logos in various business sectors, demonstrates that the visual elements of a brand are not perceived by the audience arbitrarily, but through a system of stable associations and expectations. An experiment involving 1,533 respondents revealed that certain colors are perceived as most appropriate for specific types of activities: blue – for legal services and real estate, red – for fitness and the entertainment industry, and orange – for advertising and food delivery. The authors conclude that the effectiveness of visual identity depends on the logo's alignment with consumers established cognitive and cultural perceptions of the brand. Thus, a logo is not a random graphic symbol but a visually coherent system of symbols reflecting the company's expected characteristics [8].

As stated earlier, Gestalt principles are an important tool for graphic designers: understanding how people interpret visual information allows designers to highlight connections between different elements and ensures more effective communication. Branding is entirely based on cognitive psychology. Therefore, a skillfully designed logo can attract the attention of potential customers, strengthen emotional attachment to a product or service, and increase conversion rates and sales.

Thus, the way images, text, logos, and other elements are arranged determines which part the viewer sees first and how their gaze moves across the layout. If the composition is organized logically, the advertising message is conveyed more quickly and easily. An advertisement is effective when it penetrates the consumer's consciousness and influences their psyche. However, this process is quite complex and consists of a number of components that are present in advertising to one degree or another. Factors such as bright contrasting colors, unusual images, moving objects, flashes of light, and large fonts play precisely this role. A higher intensity of the stimulus attracts greater attention. Hence, many note that sound in television commercials is significantly more powerful than in the film itself.



Figure 2. Advertising posters for creams featuring well-groomed women

An advertising image can influence viewers through associations, emotional reactions, and subconscious attitudes. For example, in an advertisement for a skin cream, a charming woman applies it to her face, hands, or feet, while the text

accompanying the commercial promises an incredible sensation of freshness (Figure 2). This is precisely why advertising is often perceived as a means of gentle persuasion, and in some cases, as a form of manipulation.



Figure 3. Ikoyi tobacco with the slogan
“I feel great today! This cigarette is delicious!”

At the same time, it is important to distinguish between manipulation and professional visual communication. All advertising aims to influence the audience’s behavior, but such influence is considered ethically acceptable only if it does not distort information or employ blatantly misleading tactics. The problem arises when visual imagery deliberately substitutes for content, exploits stereotypes, or creates a false impression of a product. For example, after World War II, Japan’s economy grew rapidly, and a mass consumer market emerged. At the same time, aggressive advertising and the number of unscrupulous sales practices surged. After the war, tobacco was advertised extremely aggressively, often linking smoking to health, vitality, and “the good life”. During this period, numerous posters were created featuring photographs of working people and slogans like “I feel great today, and this cigarette tastes delicious!” (Figure 3). From a modern perspective, this seems misleading because the advertising effectively associated smoking with health, energy, and social success.

Another example of manipulative advertising is advertising targeted at children. In the second half of the 20th century, marketing aimed at a child audience evolved into a distinct segment of the advertising industry. Companies actively exploited the characteristics of children’s perception, including heightened emotional receptivity, limited ability to critically evaluate advertising messages, and a tendency to form lasting consumer preferences at an early age. The most common tools of influence became cartoon characters, game elements, collectible prizes, and the integration of advertising into entertainment content. Thus, food manufacturers, particularly McDonald’s and cereal companies, fostered positive associations among children between the brand, emotional pleasure, and a sense of belonging (Figure 4). The practice of using children’s television shows and animated series as a covert form of

promoting toys and related products drew particular criticism, as such advertising has a particularly strong impact on children's developing psyches.



Figure 4. Advertising aimed at children

Advertising based on fear appeal and shame appeal also constitutes a form of manipulation in which a negative emotional state – such as anxiety, fear of social rejection, or feelings of inadequacy – is deliberately induced in the consumer, followed by the presentation of a product as a means of eliminating this threat. Such strategies were most prevalent in the 1930s–1970s amid the emergence of the mass consumer market and relatively weak advertising regulation, particularly in the segments of hygiene products, cosmetics and everyday consumer goods (Figure 5). Despite increased legislative oversight in the second half of the 20th century, elements of fear and shame appeals persist in modern advertising, albeit in a more veiled form, primarily in the beauty industry, where they manifest through the creation of subtle social pressure and idealized standards.



Figure 5. Advertising of personal care products

Overall, the analysis conducted leads to the conclusion that modern advertising constitutes a multi-level communication system in which visual and psychological mechanisms play a key role in shaping consumer behavior. Its effectiveness is determined not only by artistic and design solutions but also by the ability to integrate cognitive patterns of perception, ensuring rapid information processing and the lasting retention of the brand image in memory. At the same time, the development of the digital environment and the increase in information saturation have led to a decrease in

the audience’s attention span, which has heightened the importance of brief, visually dominant, and emotionally charged messages. Additionally, ethical requirements for advertising communication are becoming more complex, aimed at limiting manipulative practices and increasing the transparency of their impact. Thus, advertising operates at the intersection of marketing objectives, psychological mechanisms of perception, and regulatory constraints, making it one of the most complex and dynamically evolving phenomena of contemporary visual culture.

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УДК 336.745

DIGITAL YUAN IN RUSSIA: OPPORTUNITIES, RISKS AND THE FUTURE OF CROSS-BORDER CBDC INTEGRATION IN BILATERAL ECONOMIC COOPERATION

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Abstract. This article examines digital yuan (e-CNY) integration into Russia's financial infrastructure amid bilateral trade dedollarization. Using institutional theory and case-study methodology, it analyzes architectural compatibility, sanctions barriers, and market constraints. While e-CNY reduces transaction costs, its Russian deployment is hindered by absent CBDC interoperability, banking resistance, and geopolitical fragmentation. The study concludes with policy recommendations for phased integration via regulatory harmonization and bilateral protocols.

Keywords: central bank digital currency, e-CNY, digital ruble, Russia–China trade, dedollarization, cross-border payments, financial sanctions, monetary integration.

ЦИФРОВОЙ ЮАНЬ В РОССИИ: ВОЗМОЖНОСТИ, РИСКИ И БУДУЩЕЕ ТРАНСГРАНИЧНОЙ ИНТЕГРАЦИИ CBDC В ДВУСТОРОННЕЕ ЭКОНОМИЧЕСКОЕ СОТРУДНИЧЕСТВО

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Аннотация. В данной статье рассматривается интеграция цифрового юаня (e-CNY) в финансовую инфраструктуру России в условиях дедолларизации двусторонней торговли. Используя институциональную теорию и методологию тематических исследований, автор анализирует совместимость архитектуры, санкционные барьеры и рыночные ограничения. В то время как e-CNY снижает транзакционные издержки, его внедрению в России препятствуют отсутствие функциональной совместимости CBDC, устойчивость банков и геополитическая фрагментация. Исследование завершается рекомендациями по поэтапной интеграции посредством гармонизации нормативно-правовой базы и двусторонних протоколов.

Ключевые слова: цифровая валюта Центрального банка, электронный китайский юань, цифровой рубль, российско-китайская торговля, дедолларизация, трансграничные платежи, финансовые санкции, валютная интеграция.

The global financial architecture is undergoing a structural transformation driven by two concurrent forces: the geopolitical fragmentation of the dollar-centric payment system and the technological maturation of central bank digital currencies. Nowhere is this intersection more pronounced than in the economic relationship between the Russian Federation and the People's Republic of China. Having weathered successive waves of Western sanctions since 2014, and particularly following the comprehensive financial restrictions imposed in 2022, Russia has pursued an aggressive strategy of dedollarization. By 2025, bilateral settlements denominated in Russian rubles and Chinese yuan accounted for approximately 99.1 % of total trade turnover, rendering the bilateral corridor one of the most significant experiments in non-dollar international commerce in the post-Bretton Woods era [1, p. 15]. Within this context, the digital yuan (e-CNY) occupies a position of particular analytical interest. Launched in pilot form in 2020 and having accumulated over $2.3 trillion in transaction volume by late 2025, the e-CNY represents the world's most advanced operational retail CBDC [2, p. 45; 3, p. 8]. Its cross-border variant, operationalized through the Renminbi Digital system and integrated with the Cross-Border Inter-Bank Payments System (CIPS), has already processed transactions equivalent to $90 billion, including flows directed toward the Russian market [4, p 12]. Yet the integration of the e-CNY into Russia's domestic financial infrastructure remains incomplete. Russia does not participate in the Bank for International Settlements' Project mBridge – a multilateral CBDC platform that includes China, the United Arab Emirates, Thailand, and Saudi Arabia – owing to sanctions-related restrictions [5, p. 22]. Consequently, the utilization of the digital yuan in Russia occurs primarily through conventional correspondent banking channels rather than through native CBDC interoperability.

This article seeks to address a critical gap in the existing literature by examining the specific modalities, opportunities, and risks of e-CNY deployment in Russia. Unlike extant studies that treat the digital yuan either as a domestic Chinese phenomenon or as a generic instrument of de-dollarization, this research focuses on the bilateral institutional context. The central research question is formulated as follows: Under what conditions can the digital yuan serve as an effective and sustainable settlement instrument in Russia–China economic relations, and what structural barriers impede its deeper integration?

The theoretical foundations for analyzing bilateral CBDC integration draw primarily from Mundell's theory of optimal currency areas (OCA), as subsequently extended by McKinnon and Kenen [6, p. 657; 7, p. 41]. While the OCA framework was originally developed to assess the viability of monetary unions, its core criteria – factor mobility, openness, fiscal integration, and symmetry of shocks – remain relevant for evaluating the preconditions for deep currency cooperation short of a formal union. Russia and China exhibit high trade openness relative to each other, with bilateral turnover reaching $244.8 billion in 2024, yet significant asymmetries persist in terms of economic structure, regulatory frameworks, and exposure to external shocks. More recently, the literature has shifted toward an institutional perspective, emphasizing the role of payment infrastructure as a determinant of currency internationalization. Farrell and Newman's concept of "weaponized interdependence" is particularly salient here: the dominance of the Society for Worldwide Interbank Financial Telecommunication

(SWIFT) and correspondent banking networks has allowed the United States and its allies to impose extraterritorial sanctions, thereby incentivizing targeted states to develop alternative payment rails [8, p. 42]. The e-CNY and CIPS are frequently analyzed within this strategic framework as instruments of monetary sovereignty.

The empirical literature on the e-CNY is bifurcated between domestic and international analyses. Domestically, scholars have emphasized the People's Bank of China's (PBOC) two-tier architecture, in which the central bank issues digital currency to authorized commercial banks and non-bank payment institutions, which in turn distribute it to end users. This design preserves the existing banking intermediation structure while enabling programmable money, conditional payments, and enhanced monetary policy transmission. Internationally, the focus has centered on Project mBridge and bilateral pilots. The mBridge platform, built on distributed ledger technology (DLT), achieved a cumulative transaction volume of $55 billion by late 2025 and demonstrated the technical feasibility of multi-CBDC wholesale settlements. However, the literature notes that mBridge's governance structure – anchored in the BIS Innovation Hub – effectively excludes sanctioned jurisdictions, creating a bifurcated global CBDC landscape. Russia's exclusion from mBridge has received limited analytical attention, representing a significant lacuna that this article addresses. Parallel to China's e-CNY development, the Central Bank of the Russian Federation (CBR) has advanced its own CBDC agenda. The digital ruble pilot, launched in August 2023 and expanded in 2024–2025, employs an account-based two-tier model conceptually similar to the e-CNY. However, the Russian project has encountered substantial headwinds. Survey data indicate that 51 % of Russian citizens remain unwilling to adopt the digital ruble, while commercial banks have resisted integration due to anticipated cost structures and disintermediation risks [9, p. 15]. The mass-scale launch, originally scheduled for July 2025, has been deferred to September 2026, underscoring the institutional fragility of Russia's CBDC ecosystem [10, p. 28]. The nascent state of the digital ruble creates an asymmetry in bilateral CBDC relations: China possesses a mature, high-volume digital currency infrastructure, while Russia's equivalent remains in pilot phase. This asymmetry has implications for bargaining power, technical standard-setting, and the distribution of seigniorage benefits in the bilateral corridor.

This study employs a qualitative case-study methodology, combining document analysis, comparative institutional analysis, and process tracing. The primary data sources include official reports from the PBOC and CBR, BIS Innovation Hub publications on Project mBridge, SWIFT and CIPS transaction data, and secondary literature on sanctions economics [11, p. 7]. The analytical framework integrates institutional theory – focusing on path dependence, regulatory harmonization, and organizational resistance – with technical analysis of payment system architectures. The case-study approach is justified by the uniqueness of the Russia–China bilateral context: no other major economy pair exhibits comparable levels of dedollarization combined with such divergent stages of CBDC maturity. The study period covers 2020–2026, with particular emphasis on developments following the escalation of sanctions in 2022 and the operationalization of cross-border e-CNY platforms in 2024–2025.

The e-CNY operates on a hybrid architecture that combines centralized ledger technology for wholesale interbank settlements with distributed approaches for retail transactions. At the wholesale level, the PBOC maintains a centralized ledger recording issuance and redemption operations with authorized intermediaries. At the retail level, end-user wallets – managed by commercial banks and licensed payment platforms - facilitate peer-to-peer transfers, merchant payments, and, increasingly, programmable –transactions utilizing smart contracts. For cross-border applications, the PBOC has developed two complementary tracks. The first relies on CIPS, the yuan-denominated alternative to SWIFT, which now supports e-CNY settlement for correspondent banking relationships. The second involves dedicated bilateral platforms, such as the Renminbi Digital system, which enables direct CBDC transfers between authorized financial institutions in partner jurisdictions. The latter has been particularly relevant for Russia, where a subset of Russian banks has obtained access to yuan liquidity through CIPS-connected e-CNY corridors.

Available data indicate that the e-CNY delivers substantial efficiency gains in cross-border contexts. In the China–Indonesia bilateral pilot, the first cross-border transaction was executed approximately 100 times faster than conventional correspondent banking methods, with cost reductions ranging from 75 % to 98 % relative to SWIFT-based transfers [12, p. 18]. Settlement finality is achieved within 7–8 seconds, compared to 2–5 business days for traditional wire transfers. These performance characteristics are theoretically transferable to the Russia–China corridor. However, the realized benefits depend critically on the depth of integration between the e-CNY infrastructure and Russia's domestic banking systems. As of 2025, this integration remains partial: Russian banks primarily receive e-CNY through conventional nostro/vostro accounts denominated in yuan, rather than through native digital currency wallets. The distinction is non-trivial. In the former case, the digital yuan functions as a bookkeeping entry within the traditional banking system; in the latter, it would operate as a tokenized liability of the PBOC held directly by Russian institutions.

The most immediate opportunity for e-CNY integration lies in the reduction of frictions in bilateral trade finance. Russian exporters of hydrocarbons, metals, and agricultural commodities face elevated costs associated with sanctions compliance, intermediary bank fees, and currency conversion spreads. The e-CNY's capacity to bypass SWIFT and settle transactions on a near-real-time basis offers a direct reduction in both explicit costs and counterparty risk. For Russian importers of Chinese manufactured goods, the digital yuan can streamline prepayment and letter-of-credit arrangements, reducing working capital requirements. While the e-CNY does not provide absolute immunity from sanctions – given that participating banks may still be subject to secondary sanctions – it significantly complicates the enforcement of financial restrictions. The combination of CIPS and e-CNY creates a parallel payment architecture that operates outside the direct control of Western correspondent banks. For Russian entities, this represents a second-best alternative to full dollar access, particularly for trade flows that do not involve Western intermediaries or dual-use goods.

The smart contract functionality embedded in the e-CNY protocol opens avenues

for conditional payments tied to trade documentation, customs clearance, or logistics milestones. In the Russia–China context, this could automate settlement upon confirmation of cargo delivery via digital trade corridors, reducing the need for documentary letters of credit and associated banking charges. The pilot program in Tatarstan, where the digital ruble is being tested for targeted social payments, suggests that Russian regulators are receptive to programmable money concepts, creating a potential convergence point with e-CNY capabilities [13, p. 5]. The long-term strategic opportunity lies in establishing a technical and regulatory framework for direct e-CNY – digital ruble interoperability. Both currencies employ two-tier architectures with account-based retail models, suggesting a degree of architectural compatibility. A bilateral bridge – distinct from the BIS-governed mBridge – could enable atomic settlement of Russia – China trades without reliance on third-country infrastructure. Such a system would represent a foundational element of a multipolar financial architecture.

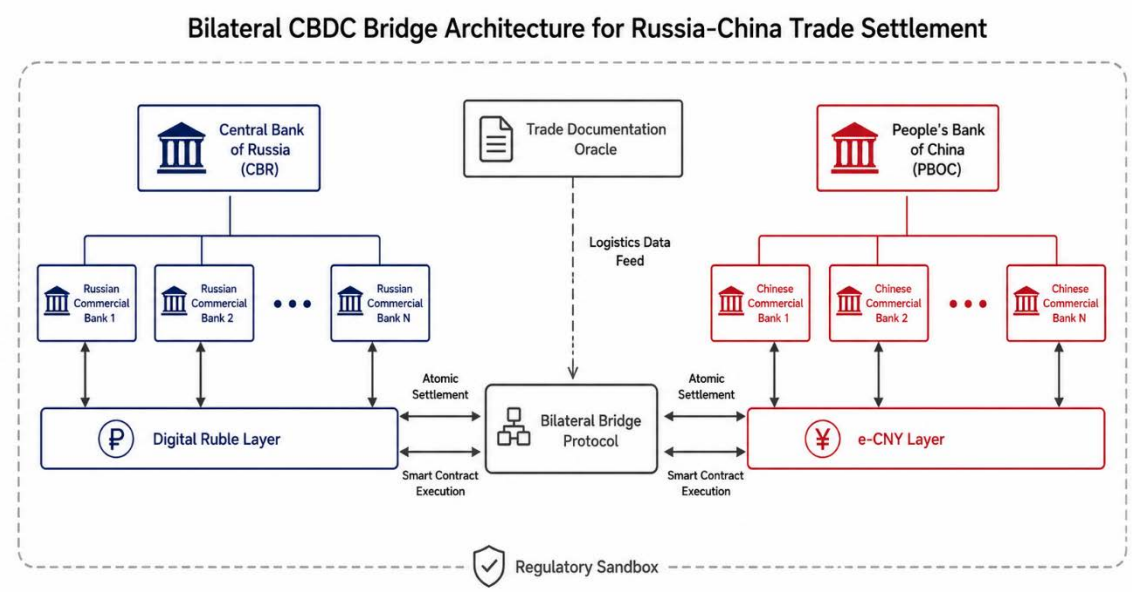


Figure. Bilateral CBDC Bridge Architecture for Russia–China Trade Settlement

Despite these opportunities, significant risks and structural barriers constrain the deeper integration of the digital yuan into Russia's financial infrastructure. Despite architectural similarities, no technical bridge currently connects the e-CNY and digital ruble systems. Russian banks access yuan liquidity through CIPS, which operates as a messaging and settlement system rather than a CBDC interoperability platform. This means that the "digital" aspect of the e-CNY is effectively stripped away at the Russian border: yuan holdings in Russian banks are conventional deposit liabilities, not tokenized central bank money. The absence of native interoperability limits the theoretical benefits of programmability, atomic settlement, and disintermediation.

The exclusion of Russia from Project mBridge is not merely a political inconvenience but a structural constraint. The BIS, as an institution dominated by G10 central banks, cannot extend support to sanctioned jurisdictions without jeopardizing its own institutional legitimacy and legal standing. This exclusion forces Russia and China to pursue bilateral solutions outside established multilateral frameworks,

increasing development costs and reducing network externalities. Moreover, the threat of secondary sanctions continues to loom over financial institutions processing yuan transactions for Russian counterparties. While Chinese banks have demonstrated a higher risk tolerance than their Western counterparts, several major institutions have periodically restricted correspondent services to Russian clients to preserve their dollar-clearing access. This creates uncertainty that undermines the reliability of e-CNY-based settlement channels.

The digital ruble's troubled trajectory casts a shadow over bilateral CBDC prospects. The CBR's pilot has revealed significant institutional resistance: commercial banks fear disintermediation and the operational costs of integrating new infrastructure, while the general public exhibits skepticism toward state-controlled digital money. If the digital ruble fails to achieve critical mass domestically, Russia's leverage in negotiating technical standards for bilateral interoperability will be substantially weakened. The asymmetry in CBDC maturity – China's operational system versus Russia's pilot – risks locking Russia into a subordinate position in which yuan settlement becomes the de facto standard, with limited reciprocal ruble functionality. A fundamental economic risk stems from the structural asymmetry of Russia–China trade. Russia's exports are concentrated in commodities (hydrocarbons, minerals, timber), while China's exports to Russia consist predominantly of manufactured goods and technology [14, p. 10]. The pricing power in commodity markets remains largely dollar-denominated, creating a natural ceiling on yuan invoicing. Russian exporters may accumulate yuan revenues, but the limited depth of Russia's yuan-denominated capital markets constrains their ability to recycle these holdings into productive assets. Without a robust yuan investment ecosystem in Russia, the digital yuan risks becoming a transactional vehicle rather than a store of value, limiting its long-term attractiveness.

Table. Comparative Parameters of Major CBDC Projects Relevant to Russia–China Cooperation

Parameter	e-CNY (China)	Digital Ruble (Russia)	Project mBridge	Digital Euro (EU)
Status (2026)	Operational phase	Pilot (launch 09.2026)	MVP ($55 bn turnover)	Preparation phase
Architecture	Two-tier, hybrid DLT	Two-tier, account-based	Multi-CBDC DLT	Two-tier (planned)
Cumulative volume	$2.3 trillion	~$90 million (pilot)	$55 billion	N/A
Cross-border model	CIPS + bilateral platforms	Prototype with Belarus	5 countries (China, UAE, Saudi Arabia, Thailand, Hong Kong)	Not yet defined
Programmability	Smart contracts, conditional payments	Pilot in Tatarstan (targeted funds)	Smart contracts	Planned
Privacy model	Controlled anonymity	No anonymity (traceable)	Jurisdiction-dependent	High priority
Russia participation	Indirect (via CIPS)	Domestic pilot only	Excluded (sanctions)	Not applicable

The analysis suggests that the integration of the digital yuan into Russia's financial infrastructure is neither a panacea for sanctions evasion nor a straightforward technical upgrade. Rather, it represents a complex institutional adaptation requiring coordinated action across multiple domains. Russian and Chinese regulators should establish a dedicated bilateral working group on CBDC interoperability, tasked with developing technical standards for cross-platform settlement. This group should prioritize the creation of a bilateral bridge mechanism – analogous in function to mBridge but governed exclusively by the CBR and PBOC – capable of atomic swaps between e-CNY and digital ruble liabilities. The Russian banking sector requires targeted incentives to adopt e-CNY infrastructure. These may include tax preferences for institutions processing digital yuan transactions, CBR liquidity support facilities denominated in yuan, and regulatory forbearance during the integration period.

Russia must accelerate the domestic maturation of the digital ruble. Without a credible domestic CBDC counterpart, Russia cannot negotiate bilateral interoperability from a position of parity. The CBR should address public skepticism through transparent communication and pilot programs demonstrating tangible consumer benefits, while engaging commercial banks through revenue-sharing arrangements that mitigate disintermediation fears. Both countries should expand the scope of yuan-denominated investment instruments available to Russian entities. The development of yuan-denominated government bonds, corporate debt, and derivatives markets within Russia would enhance the attractiveness of yuan accumulation and support the transition from transactional to structural currency integration. Within the BRICS framework, Russia and China should advocate for the establishment of a dedicated CBDC cooperation mechanism that includes non-sanctioned emerging markets. Such a mechanism could eventually evolve into a broader multi-CBDC platform, reducing reliance on BIS-governed structures while preserving interoperability with the global financial system.

The digital yuan presents Russia with a dual-edged instrument: a powerful mechanism for reducing transaction costs and enhancing sanctions resilience in bilateral trade, yet one constrained by technical fragmentation, regulatory asymmetry, and the nascent state of Russia's own CBDC ecosystem. The current modality of e-CNY utilization – channeled through CIPS and conventional correspondent banking – captures only a fraction of the potential efficiency gains inherent in tokenized central bank money. For the Russia–China economic partnership to fully realize the benefits of CBDC integration, both nations must move beyond ad hoc bilateral arrangements toward a structured interoperability framework. This requires not merely technical engineering but institutional innovation: the creation of governance mechanisms for a bilateral digital currency bridge, the harmonization of regulatory standards, and the parallel development of the digital ruble as a credible counterpart to the e-CNY.

Ultimately, the digital yuan in Russia is best understood not as an isolated technological adoption but as a strategic node in the broader transformation of the global monetary order. Its success or failure will serve as a bellwether for the viability of CBDC-based economic alliances in an era of geopolitical fragmentation. For policymakers and scholars alike, the Russia–China corridor offers an unparalleled laboratory for observing how digital money reshapes the architecture of international trade – and how states navigate the tension between monetary sovereignty and economic interdependence.

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УДК 005.95/.96

ANALYTICAL REVIEW OF GENERATION Z IN REMOTE AND HYBRID WORK RESEARCH

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Abstract. The paper deals with Generation Z in research on remote and hybrid work. The study combines Google Scholar search result dynamics for 2000-2025 with a thematic analysis of a Scopus records on remote, hybrid and distributed work. The results show growing publication activity after 2020 and a shift toward hybrid formats, employee wellbeing, organisational support, digital tools and work design. The findings may be useful for HR specialists, managers and researchers.

Keywords: Generation Z, distributed work, young employees, organisational support, employee wellbeing, digital workplace, review.

АНАЛИТИЧЕСКИЙ ОБЗОР ИССЛЕДОВАНИЙ ПОКОЛЕНИЯ Z В КОНТЕКСТЕ УДАЛЕННОЙ И ГИБРИДНОЙ РАБОТЫ

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Аннотация. В статье рассматривается, как поколение Z представлено в исследованиях, посвященных удаленной и гибридной работе. В статье объединяется анализ динамики поисковых результатов Google Scholar за 2000-2025 гг. и тематический анализ статей из Scopus по удаленной, гибридной и распределенной работе. Результаты отражают рост публикационной активности после 2020 г. и смещение внимания к гибридным форматам, благополучию сотрудников, организационной поддержке и цифровым инструментам. Результаты могут быть полезны HR-специалистам, руководителям и исследователям.

Ключевые слова: поколение Z, распределенная работа, молодые сотрудники, организационная поддержка, благополучие сотрудников, цифровая рабочая среда, аналитический обзор.

The contemporary world of work is undergoing a large-scale transformation. Digitalisation, global instability and the growth of online communication have changed traditional models of work organisation. One of the most visible outcomes of this process is the spread of remote and hybrid employment formats. In this context, the study of Generation Z becomes particularly important. Generation Z, usually defined

as people born from the late 1990s to the early 2010s, enters the labour market in an environment where digital interaction and flexible work are already common. Its representatives are often associated with technological literacy, interest in work-life balance and the expectation of regular feedback. At the same time, early-career employees may face specific difficulties in remote and hybrid settings, including weaker informal learning, limited face-to-face contact and blurred boundaries between professional and personal life.

According to the Financial University under the Government of the Russian Federation, the labour-force participation rate of young people aged 20-24 in Russia increased in 2024 for the first time since 2019, from 53.2 % to 54.1 %. In March 2025, the number of employed young people in this age group reached 3.6 million [1]. The digital context of early career development is also becoming more intensive. Deloitte reports that 74 % of Gen Zs and millennials use artificial intelligence to some extent in their day-to-day work [2]. These figures show that young employees are becoming more active in the labour market and are entering professional life in technology-mediated environments. However, it remains unclear how fully research on remote and hybrid work reflects the specific position of Generation Z. This creates a research gap as general studies of flexible work formats are developing rapidly, while the generational perspective may still be insufficiently represented.

The aim of this article is to analyse how Generation Z is represented in research on remote and hybrid work and to identify the main research directions that may be used to study young employees in distributed work settings. To achieve this aim, the following objectives were set:

- to analyse Google Scholar search result dynamics for remote and hybrid work in 2000-2025;
- to compare general publication trends with Generation Z-focused search results;
- to describe the Scopus sample and its selection criteria;
- to identify the main thematic areas in recent studies of distributed employment;
- to determine whether Generation Z is a promising focus for further research on new work formats.

The study is based on an analytical review of publications. Two groups of data were used. The first group includes Google Scholar search results collected to trace publication dynamics from 2000 to 2025. Four search combinations were used: management OR organization “hybrid work”, management OR organization “remote work”, “Generation Z” “hybrid work”, and “Generation Z” “remote work”. The results were grouped into two periods: 2000-2019 and 2020-2025. The period after 2020 was analysed by year. The second group of data consists of a Scopus export. The search was conducted using the following title-based query (“remote” OR “distant” OR “hybrid” OR “distributed” AND “work” OR “virtual team” AND “organ*” OR “management”). The sample was limited to open-access publications in the subject areas Business, Management and Accounting and Economics, Econometrics and Finance. Only records published from 2023 to 2025 were included. This selection made it possible to focus on recent management and economic studies of remote, hybrid and distributed work.

The publication dynamics collected through Google Scholar show a clear growth of research interest in remote and hybrid work after 2020. The query management OR organization “remote work” produced 10 results for the period 2000-2019, whereas for 2020-2025 the total number reached 222 results. The query management OR organization “hybrid work” increased from 1 result before 2020 to 67 results in 2020-2025. The generational dimension develops more slowly. The query “Generation Z” “hybrid work” produced 10 results in 2020-2025, while “Generation Z” “remote work” produced 18 results over the same period. These figures indicate that studies of flexible work formats have grown rapidly, whereas the Generation Z perspective remains less developed. The publication dynamics are shown in Figure.

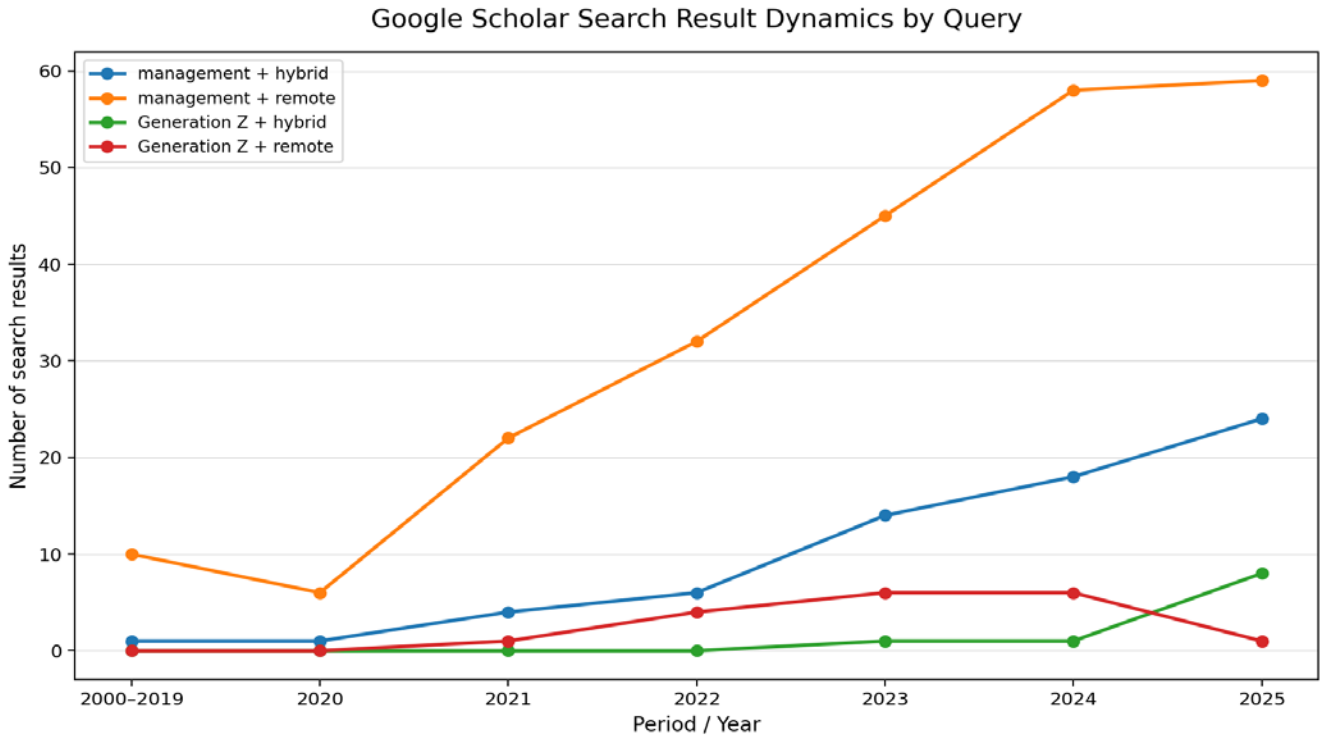


Figure. Google Scholar search result dynamics by query

The data above demonstrate two tendencies. First, remote and hybrid work became established research topics after 2020. Second, the Generation Z perspective is still developing within this broader field. This imbalance is significant for both research and practice. From an academic perspective, it is necessary to understand whether studies of new work formats sufficiently account for the specific needs of young employees. From a management perspective, organisations need evidence-based approaches to onboarding, mentoring, communication, engagement and retention of early-career workers in distributed settings. The next stage of the analysis was based on the Scopus export. The structure of the corpus is presented in Table 2.

Table 2. Selection of Scopus records for thematic analysis

Stage	Documents	Description
Initial Scopus export	36	Records retrieved on remote, hybrid and distributed work
Excluded from thematic interpretation	3	Corrigendum, editorial without analytical content, and one article on hybrid organisations not directly related to work format
Publications used for analysis	33	Articles, reviews, book chapters and one book related to remote work, hybrid work, distributed work, wellbeing, communication, technology adoption and work design

The analysed publications show that research on remote and hybrid work is already a broad interdisciplinary field. It includes studies in management, human resource management, organisational psychology, technology adoption, communication studies and workplace wellbeing. The thematic analysis made it possible to group the most relevant sources into six areas. These areas are presented in Table 3.

Table 3. Results of the analysis

Theme	Description	Most cited papers
Work design and organisational change	Transition to remote and hybrid work, change management, organisational adoption and strategic HRM	Hardwig and Boos [3]; Bonesso et al. [4]; Ferdous et al. [5]
Wellbeing, boundaries and technostress	Work-family interface, technostress, burnout, psychological detachment and work-life boundaries	Huyghebaert-Zouaghi et al. [6]; Harunavamwe and Kanengoni [7]; Whelan et al. [8]
Organisational support and engagement	Perceived organisational support, employee engagement, retention and leadership	Charles et al. [9]; Pham et al. [10]
Communication and teamwork	Internal communication, communication ties and organisational identification	Tröster and Brosi [11]; Beniušis [12]
Digital tools and technology adoption	Digital infrastructure, remote work systems and technology adoption	Ng et al. [13]; Ofosu-Ampong and Acheampong [14]
Diversity and young employees	Management of diverse employees in hybrid models	Yeke and Özveren [15]

The first area concerns work design and organisational change. Hardwig and Boos describe hybrid work as a change-management challenge and identify team effectiveness, cohesion and infrastructure as central issues [3]. Bonesso et al. analyse this format from a strategic HRM perspective and argue that it should be integrated into a coherent system of HR practices rather than treated as an isolated benefit [4]. Ferdous et al. provide a framework that connects organisational adoption of remote work with employee outcomes [5].

The second area includes studies of wellbeing, boundaries and technostress. Huyghebaert-Zouaghi et al. examine work-family interface profiles and show that remote and onsite workers may experience different combinations of conflict, enrichment, engagement and performance [6]. Harunavamwe and Kanengoni analyse the interaction between technostress, perceived organisational support, work-family conflict and engagement in hybrid and virtual settings [7]. Whelan et al. examine burnout in hybrid arrangements through technostress, psychological detachment and organisational support [8].

The third area focuses on organisational support and engagement. Charles et al. show how hybrid work and organisational support shape employee engagement in an IT company [9]. Pham et al. examine perceived organisational support, retention and transformational leadership in a remote work context [10]. These studies suggest that flexible formats are not automatically effective or ineffective. Their outcomes depend on whether employees receive sufficient support, communication, resources and managerial attention.

The fourth theme concerns communication and teamwork. Tröster and Brosi show how hybrid work shapes communication ties and how concerns about relationship loss and organisational identification influence these ties [11]. Beniušis examines internal communication challenges in a public sector organisation implementing hybrid work [12].

The fifth area covers digital tools and technology adoption. Ng et al. use the technology-organisation-environment framework to analyse remote work as a new normal and connect it with job performance, work-life balance and emotional exhaustion [13]. Ofosu-Ampong and Acheampong study the adoption of contactless technologies for remote work after COVID-19 and show that organisational and technological conditions shape implementation [14].

The sixth area concerns diversity and young employees. Yeke and Özveren examine the management of diverse employees in the hybrid work model and show that hybrid arrangements require attention to differences in employee needs, expectations and working styles [15].

The analysis shows that academic discussion is concentrated around five practical problems: work design, employee wellbeing, engagement, communication and the use of digital tools. These directions are relevant to Generation Z because young employees enter the labour market at a stage when organisational models, communication norms and digital management practices are still being reconfigured. Therefore, the selected thematic areas can be used as an analytical framework for studying the adaptation of Generation Z to remote and hybrid work settings. The main research directions are summarized in Table 4.

Table 4. Research directions for studying Generation Z in remote and hybrid work settings

Direction	Main findings from the Scopus corpus	Implications for Generation Z
Work design	Flexible formats require changes in management, coordination and HR	Young employees enter organisations while work models are still changing
Wellbeing and boundaries	Technostress, burnout and blurred boundaries are recurrent themes	Early-career employees need support in self-organisation and digital boundaries
Organisational support	Engagement and retention depend on support, leadership and resources	Generation Z require regular feedback, mentoring, transparent communication
Communication and social ties	Hybrid work changes internal communication and team relationships	Professional socialisation is weaker when informal contact is reduced
Digital workplace	Technology adoption shapes work experience and performance	Young employees are digitally active, but digital guidance is needed

The analytical review shows that remote and hybrid work have become established areas of management research, especially after 2020. However, the generational perspective remains less developed. Google Scholar search dynamics indicate growing interest in Generation Z after 2020, while the Scopus corpus shows that most recent studies still focus on employees, teams and organisations in general.

The Scopus analysis identified five areas that are particularly relevant for further research on Generation Z: work design, wellbeing, organisational support, communication and digital workplace practices. These areas are important because young employees enter the labour market while organisational models and management tools are still being reconfigured.

The study is limited by the use of Google Scholar search results and a Scopus export restricted to open-access publications in business and economics for 2023-2025. Further research may include a larger corpus, surveys of Generation Z employees and interviews with HR specialists responsible for remote and hybrid work policies.

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УДК 621.798

BARRIERS AND OPPORTUNITIES FOR THE IMPLEMENTATION OF INNOVATIVE PACKAGING SYSTEMS IN THE FOOD INDUSTRY: THE ROLE OF GOVERNMENT SUPPORT

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Abstract. Today, new technologies are being actively developed and implemented in the food industry worldwide. Their use is contributing to significant progress in environmental protection. The main impetus for the creation of innovative systems is the inability of traditional packaging to maintain product quality and extend shelf life. This article examines innovative packaging systems, their characteristics and applications, as well as the role of government support in their implementation. The advantages of these technologies are described and barriers to implementation are identified.

Keywords: Food industry, food products, innovative packaging systems, "smart" packaging, "active" packaging, ecology.

БАРЬЕРЫ И ВОЗМОЖНОСТИ ДЛЯ ВНЕДРЕНИЯ ИННОВАЦИОННЫХ СИСТЕМ УПАКОВОК В ПИЩЕВУЮ ОТРАСЛЬ: РОЛЬ ГОСУДАРСТВЕННОЙ ПОДДЕРЖКИ

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Аннотация. Сегодня в мире активно разрабатываются и внедряются новые технологии в пищевую промышленность. Их использование способствует значительному прогрессу в области охраны окружающей среды. Главным стимулом к созданию инновационных систем выступает то, что традиционная упаковка перестала справляться с задачами сохранения качества и продления

сроков годности продукции. В этой статье рассмотрены инновационные системы упаковок, приведена их характеристика и сферы применения, а также роль государственной поддержки в их реализации. Были описаны преимущества данных технологий и выявлены барьеры для внедрения.

Ключевые слова: пищевая промышленность, пищевые продукты, инновационные системы упаковок, «умная» упаковка, «активная» упаковка, экология.

The packaging industry is a global leader due to increased industrial production and rapid scientific and technological advances, particularly in artificial intelligence. The primary functions of packaging are to prevent food spoilage, ensure hygiene, and preserve its quality. Today, packaging is not limited to these basic functions, it must also meet modern requirements, such as environmentally friendly materials, cost-effective packaging and processing, and simplified transportation, warehousing, and handling processes in retail and wholesale environments.

Given the pace of development in this industry, it is safe to assume that within a few years, innovative packaging systems will be used in all offline and marketplace product packaging. This will ensure high quality and product safety.

To preserve the quality of a food product, it is necessary to select packaging that minimizes the negative impact of external (climatic) factors during transportation, storage, and distribution. The following negative external factors alter product quality: atmospheric oxygen, relative humidity, light, and temperature. Each of these factors triggers a specific process that leads to slow spoilage or irreversible changes in the product (Table 1) [1].

Table 1. External factors affecting product quality

External factor	Change in product quality
Air oxygen	During the oxidation process, the color of the product changes, essential oils and vitamins are destroyed, fats become rancid, and proteins are denatured
Relative humidity	Leads to processes of absorption, desorption, and catalysis. In this case, lumps, softening, hydrolytic rancidity of fats, and the presence of microbiological spoilage can be observed in products
Light	The consequences of photodestruction are observed: destruction of vitamins (sensitive to light), discoloration and oxidative rancidity of fats
Temperature	At elevated air temperatures, the rate of chemical reactions changes, which leads to a reduction in shelf life.

In addition to addressing negative external factors, packaging production takes into account principles of easy recycling and reduced toxic impact on the environment. This significantly reduces food waste due to spoilage.

At this stage in the development of the packaging industry, two innovative systems exist: “active” and “smart” packaging. It is worth noting that these technologies are not exactly new, as they were first discussed in the early 1970s in

scientific and professional literature in the United States. These packaging systems are not yet in widespread use, but interest in them among companies and consumers is growing every year.

"Active" packaging is packaging that directly interacts with the product or the environment inside. Special excipients or materials play a key role, affecting the composition and properties of the contents. This type of packaging addresses the impact of external factors on product quality, thereby extending its shelf life.

The components used in "active" packaging include: absorbers of substances (oxygen, moisture, ethylene, taste and odor); emitters (generators) of substances (CO2, preservatives, ethanol); temperature regulators; antimicrobial layers and coatings [2].

Oxygen and moisture absorbers are most often used for packaging bakery and flour confectionery products, cookies, coffee, snacks, fruits and vegetables, dehydrated foods, and some beverages. These substances can include ascorbic acid, powdered iron, silica gel, and other substances that prevent the product from becoming damp.

The most popular generator is the CO_2 generator. It creates a safe environment inside packaging, protecting the product from the growth of microbes and mold. It is used for packaging coffee, fresh fish, nuts, and baked goods; it can be present in the form of iron oxide, calcium oxide, or activated carbon.

Temperature regulators can be used in smart packaging, such as non-woven polymeric materials, various double-walled containers, gaseous hydrofluorocarbon compounds, or ammonium nitrates with water. They are used for packaging ready-to-eat meals, meat, fish, and beverages.

Antimicrobial layers and coatings are packaging elements that prevent the growth of harmful microorganisms. These materials contain silver, copper, or zinc ions. These coatings are most often used in packaging dairy products, eggs, and soft cheeses.

This technology has been widely used in the food industry since the late 1970s. The first company to create a prototype of "active" packaging was the Japanese Mitsubishi Gas Company, which introduced the "Ageless" oxygen absorber to the market. Also, the renowned Swedish chemical company Ciba Speciality Chemical developed special sorbents based on organometallic compounds that act as catalysts to accelerate oxidation reactions.

The use of "active" packaging offers a number of advantages for both manufacturers and consumers. The main ones are a significant increase in product shelf life, preservation of organoleptic properties, and a reduction in food waste (Table 2) [3].

Table 2. Comparison of traditional and "active" packaging

Indicator	Traditional packaging	Active packaging	Improvement
Shelf life of meat	4-6 days	9-13 days	+100-150 %
Expiration date of bread	3-5 days	7-14 days	+140-200 %
Shelf life of nuts	3-6 months	12-18 months	+200-300 %
Losses during storage	40-50 %	15-20 %	-60-70 %
Preservation of vitamins	60-70 %	85-95 %	+25-35 %

While "active" packaging primarily refers to the materials and special substances

used, “smart” packaging places greater emphasis on new developments. “Smart” packaging is equipped with technologies that monitor the product’s condition inside in real time and communicate this information externally. Some people use a different term: “intelligent packaging”.

“Smart” technologies operate using several categories: time-temperature indicators for freshness monitoring (TTI indicators), radio-frequency identification tags (RFID tags), and various QR codes. Each of these options addresses specific challenges, from product quality control throughout the entire supply chain to counterfeit detection and increased consumer loyalty.

Time-Temperature Indicators (TTIs) are small stickers on packaging that clearly show the temperature history of a product. The market for these indicators is estimated at $982.1 million by 2025, and is projected to reach $1.66 billion by 2034.

There are 3 types of indicators used in the food industry, differing in their operating principle: enzymatic, diffusion and polymer (Table 3) [4].

Table 3. Characteristics of TTI indicator types

Type	Operating principle	Application	Peculiarities
Enzymatic	The reaction between enzymes and the substrate changes the pH and color	Perishable foods	High sensitivity
Diffusion	Migration of lactic acid changes the color of the indicator	Fruits, vegetables, dairy products	Irreversible color change
Polymer	Polymerization changes the physical properties of the material	Frozen foods, meat	Durability, fine-tuning to the product

RFID (Radio Frequency Identification) tags are a modern, automated method for identifying products. They consist of an antenna and a microchip and can emit light or transmit data to any reader. They are used to track the location of a product or provide information to consumers about its ingredients, manufacturer, and other details. A major advantage of these tags is the ability to read hundreds of packages at a time, even through layers of packaging material, speeding up scanning and the identification process. Some models can be equipped with integrated sensors for measuring acidity, humidity, temperature, and gas composition inside the package.

QR codes are often applied to the outside of packaging to provide product information, authentication, or consumer engagement. In today’s world, they have become a universal communication tool between consumers and manufacturers.

Some international studies cite the following statistics: approximately 92% of food companies use QR codes on their packaging. Due to their widespread use in the food industry, an updated global standard, IEC ISO 18004:2024, was released in 2024. It defines criteria for the readability and security of the codes.

As mentioned above, smart packaging not only protects and tracks products, but also actively changes consumer perceptions.

Firstly, packaging becomes an expanded source of information and trust. In

addition to important labeling information (ingredients, production date, expiration date, storage method, etc.), packaging can provide information about the product's condition and also serve as an authentication tool. This undoubtedly increases consumer trust in the manufacturer's products.

Secondly, smart packaging is created with the trend toward eco-friendliness and sustainability in mind, using biodegradable sensors and reducing food loss. This enhances the company's reputation by promoting environmental responsibility.

The most striking example of "smart" packaging was the development of special price tags for meat packaging by the small Japanese design firm To-Genkyo. The concept was that the price tags would change color when exposed to ammonia released as the product spoiled, making it easy to determine the freshness of the product on the shelf [5].

Continuing to talk about international developments, it is worth mentioning that in 2025, researchers from Finland's University of Vaasa created a packaging system with functional ink that recognizes and displays the state of a product in real time using artificial intelligence technologies [7].

Scientists have noticed that industries have increasingly adopted sensors to monitor product conditions. The challenges were previously expensive electronics, high production costs, and difficult processing. The technology uses functional inks that change color with temperature or humidity, and artificial intelligence analyzes and detects even the slightest changes with an accuracy approaching that of the human eye.

This indicator has a simple design and is relatively inexpensive. Potential applications include the food and pharmaceutical industries, where monitoring storage conditions is crucial.

Innovative packaging systems are not yet widely used in the Russian Federation. Of the existing digital labeling systems, the "Chestnyy znak" system, which also allows for product tracking, is widely used.

One might assume that the challenging economic situation is to blame. However, the primary reason is the limited information about this new area of the packaging industry.

Over the past 10 years, Russian researchers have made several innovative developments. In 2024, a team from the St. Petersburg State University of Information Technologies, Mechanics, and Optics (ITMO) presented a prototype indicator for "smart" packaging designed for chilled meat, poultry, and fish. The indicator glows under ultraviolet light, but gradually fades when signs of spoilage (for example, increasing hydrogen sulfide levels inside the package) are detected. The researchers plan to synchronize the indicator with a mobile app. The project received 6 million rubles from the Russian Science Foundation.

In November 2022, chemists from St. Petersburg State University created "smart" packaging for fruits and vegetables using rhizomes, seaweed, eucalyptus, and pineapple leaves. The project was implemented in collaboration with scientists from India, Brazil, and South Africa. The researchers noted that the packaging is biodegradable, readily soluble in water, edible, and safe for both adults and children. The packaging will be available for the Russian market in both film and liquid form. The former could partially replace plastic bags, while the liquid form could replace paraffin wax for fruits and vegetables [6].

The advantages of modern innovative packaging solutions are difficult to dispute, because they allow:

1. Increase the shelf life of food products several times without adding preservatives and additives;
2. Reduce the amount of food waste, which in the future will have a positive impact on the environmental situation on the planet;
3. Increase the level of control over the quality and safety of food products;
4. Differentiate products in the market and communicate with consumers as effectively as possible, gaining their loyalty.

The widespread adoption of innovative packaging solutions is possible in the foreseeable future, as it's a matter of time and the pace of research in this area. However, any innovation in any field faces its own implementation challenges.

To identify and analyze barriers to the implementation of innovative packaging systems in the food industry, we used Kaoru Ishikawa's cause-and-effect diagram. This visual tool for analyzing the root causes of specific problems shows the relationship between an effect and all the factors influencing it (Figure).

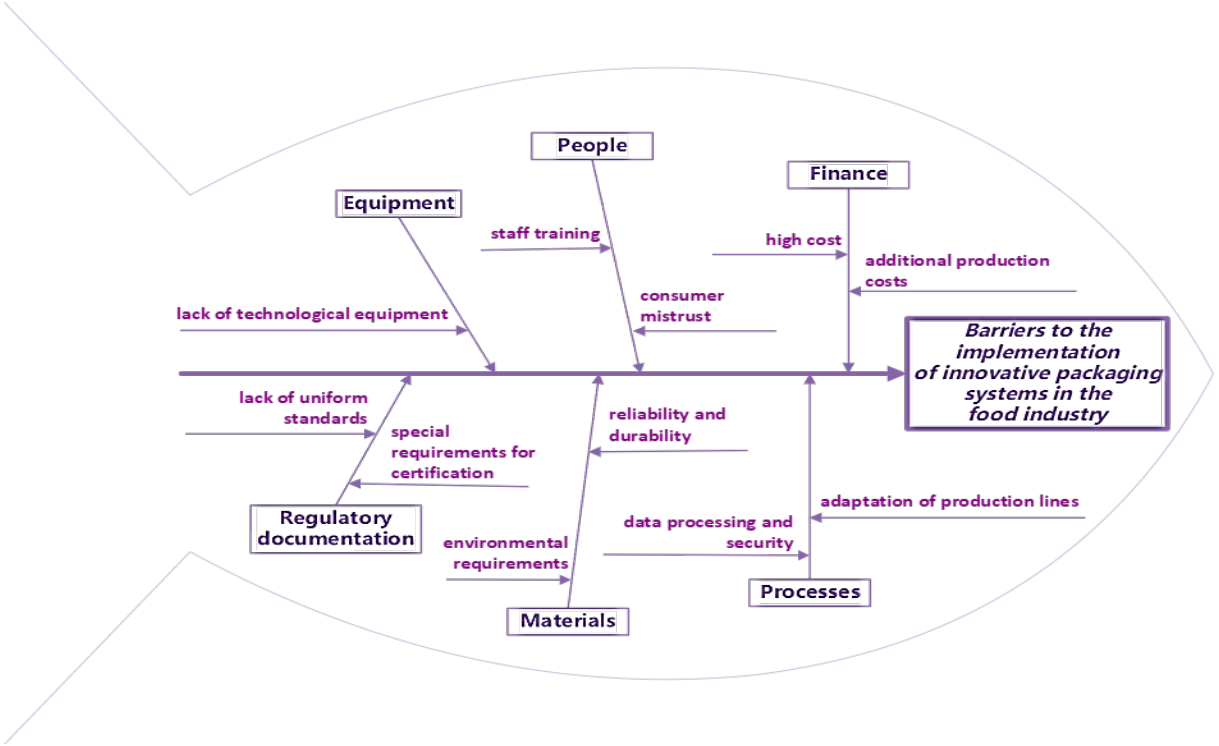


Figure. Analysis of barriers to the implementation of innovative packaging systems in the food industry using Kaoru Ishikawa's cause-and-effect diagram

Several groups of reasons have been identified why the introduction of innovative packaging systems into the food industry may be difficult.

The first is additional financial costs and, as a result, an increase in the cost of the product. For many manufacturers, using traditional packaging is more cost-effective and accessible, especially for small and medium-sized businesses.

Personnel training and process adaptation are crucial aspects. In order to launch a new packaging system, it is necessary to hire or train specialized employees who are fully familiar with all the technological processes.

Innovative food packaging cannot be produced without specialized equipment, which also requires additional financial investment. Not every company, especially in the development stage, can afford such an expense.

A particularly significant barrier to implementation is the lack of global harmonization of standards. The creation of a unified system not only accelerates international exchange and reduces production costs, but also ensures a common approach to product safety. Unlike Russia, foreign countries are actively developing and implementing new regulatory documents and issuing regulations that will serve as the basis for the full implementation of “smart” and “active” packaging.

Thus, in 2024, the EU Regulation (EU) 2025/40 on packaging was introduced, which will contribute to the reduction of packaging waste. According to it, by 2030, all food packaging must be produced for reuse or high-quality recycling; by 2026, packaging in contact with food must contain tracking elements (e.g., unique identifiers or digital passports). In 2024, the FDA supported the initiative to introduce a complete ban on the use of perfluoroalkyl and polyfluoroalkyl substances (PFAS), heavy metals, and other toxic compounds in food packaging by 2025. This measure was introduced in some US states (California, New York, Washington) [8].

The Asia-Pacific region stands out in particular. In 2024, Japan passed the Food Sanitation Law, which requires all catering and food processing establishments to implement a HACCP-based hygiene management system.

In 2025, Singapore’s National Environment Agency (NEA) issued the Plastics Regulation. It requires all packaging to be eco-friendly, compostable, and contain identification tags by 2026.

Russia currently lacks common standards for “smart” or “active” packaging, which hinders scalability. Any packaging solution must undergo testing to confirm that it meets all national certification requirements. Manufacturers can only implement innovative packaging if they can prove its safety and effectiveness. Currently, the primary standards in Russia are GOST 17527-2020 “Packaging. Terms and Definitions” and TR CU 005/2011 and TR CU 021/2011, which regulate the safety of active materials.

Analyzing the identified barriers, we can conclude that government support is critical for the implementation and widespread use of these technologies in the future.

Firstly, in order to conduct more research and implement projects, it is necessary to allocate funds on a permanent basis, as well as provide grant support to interested scientists.

Secondly, create a unified regulatory framework that meets all modern requirements, such as environmental friendliness, safety, and ease of recycling and reuse. This can be achieved through international cooperation with countries actively developing innovative packaging systems, sharing best practices, and implementing joint projects.

Third, it’s important to support environmental initiatives and promote environmental education in society. The more consumers are aware of the importance of caring for nature and resources, the more likely they will be to embrace such technologies and the future transition to sustainable materials.

In conclusion, it should be noted that innovative packaging systems are a truly viable tool for extending the shelf life and storage of products. This is a step into a

future where packaging serves not only as a protective shell but also as a source of important information.

Not only will the government benefit from introducing innovative systems into the food industry, for example, through new business opportunities and waste minimization, but consumers will benefit as well. Such packaging will guarantee safety and ensure the highest quality of goods, thereby significantly improving the quality of life. With active government support, traditional materials will gradually be phased out, giving way to more technologically advanced alternatives.

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УДК 331.45

OCCUPATIONAL HEALTH AND SAFETY IN THE CRUSHING DEPARTMENT OF ANOF-3 KIROVSK BRANCH OF JSC APATIT

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Abstract. The article focuses on occupational safety in the crushing department of the ANOF-3 processing plant of JSC “Apatit”. It examines the main hazardous and harmful production factors, personnel requirements, types of safety briefings, and personal protective equipment. Special attention is given to organizational and technical measures aimed at risk reduction, including equipment modernization, employee training, and compliance with regulations. The importance of a comprehensive safety approach for preventing injuries and improving production efficiency is emphasized.

Keywords: occupational safety, crushing department, industrial safety, hazardous factors, personal protective equipment, safety briefing, production risks, workplace safety, processing plant.

ТЕХНИКА БЕЗОПАСНОСТИ И ОХРАНА ТРУДА В ДРОБИЛЬНОМ ОТДЕЛЕНИИ АНОФ-3 АО «АПАТИТ»

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Аннотация. Статья посвящена обеспечению охраны труда в дробильном отделении обогатительной фабрики АНОФ-3 КФ АО «Апатит». Рассмотрены основные опасные и вредные производственные факторы, требования к персоналу, виды инструктажей и средства индивидуальной защиты. Особое внимание уделено организационным и техническим мерам снижения рисков, включая модернизацию оборудования, обучение работников и соблюдение нормативных требований. Подчеркивается значимость комплексного подхода к безопасности для предотвращения травматизма и повышения эффективности производства.

Ключевые слова: охрана труда, дробильное отделение, промышленная безопасность, вредные факторы, средства индивидуальной защиты, инструктаж, производственные риски, безопасность труда, обогатительная фабрика.

The crushing department belongs to high-risk industrial units; the technological process is carried out with crushers, conveyors, and auxiliary equipment under conditions of high noise, dust, and vibration loads. The process includes coarse crushing (Figure 1), grinding, screening, and subsequent refining of the feedstock in order to obtain material of the required size and uniformity. At the Benefication Plant for the production of apatite-nepheline concentrate (ANOF-3), which is part of Kirovsk Branch of JSC“Apatit” (part of the PhosAgro group of companies), occupational safety in crushing department is carried out in accordance with the occupational health and safety instruction for the crusher operator job title, OSIaP №001/8-2025 [1].



Figure 1. Type of used crusher KKD-1500/180 on ANOF-3

The following hazardous and harmful factors may occur here: moving and rotating parts of equipment, falling pieces of ore, high noise levels (up to 65–70 dBA), dust dissemination in the air, vibration, increased voltage in electrical installations, slippery floors and height differences, as well as work at height during maintenance of mechanisms [2, pp. 12-15]. Crushers and related units must be equipped with reliable protective guards, housing covers, and aspiration systems for capture of dust.

The main objective of the occupational safety system is to ensure safe working conditions, prevent industrial injuries and occupational diseases, and comply with industrial safety requirements. The correct organization of crushing, proper allocation of responsibilities, and regular maintenance contribute to stable operation and profit for the national economy.

Work in the crushing department is classified as “high risk”, therefore special requirements are imposed on personnel. In accordance with labor legislation, only persons over 18 years of age are allowed to work [3, p. 265]. All employees must undergo mandatory preliminary medical examination (upon employment) and regular periodic examinations to determine their susceptibility to harmful factors [3, p. 220]. Before starting work, introductory and primary safety instructions must be carried out:

introductory – for newly hired employees before entering the workplace, primary – at the workplace before independent work.

In addition, personnel must be trained in safe working methods and have a confirmed electrical safety qualification group if their duties involve electrical equipment. Employment and permission for independent work are granted only after fulfilling these requirements.

There are several types of occupational safety instruction, according to Government Decree RF №2464 [4, pp. 8-22]:

- Introductory is carried out before employees begin their duties;
- Primary is carried out before starting work;
- Repeated is carried out once a year for all employees, regardless of qualification, work experience, or nature of duties;
- Unscheduled is carried out when job responsibilities change, after an industrial accident, or at the request of the federal labor inspectorate;
- Targeted is carried out before performing work not related to main duties (for example, accident elimination) and before high-risk operations.

Employees must comply with safety instructions, use personal protective equipment, and immediately report equipment malfunctions or emergency situations to their supervisor.

All employees of the crushing department must be provided with personal protective equipment (PPE), which the employer is obliged to issue in accordance with labor legislation [3, pp. 221].

The following PPE is issued to a crushing department worker: protective helmet; cotton work suit (jacket and trousers); work mittens and gloves; protective goggles or face shield; dust respirator; protective earmuffs or earplugs [5]. (Figure 2)



Figure 2. Personal protective equipment

When working outdoors in winter, warm protective clothing (felt boots, insulated jacket) is provided. All PPE must meet established standards and be replaced when worn out.

According to safety requirements, a worker in the crushing department is prohibited from:

- Cleaning or repairing operating equipment;
- Being in the area of moving mechanisms;
- Removing protective housing covers;
- Overloading crushers beyond the determined limit.
- In addition, the worker in the crushing department must:
- Ensure evenly distributed feedstock supply;
- Control noise and vibration levels;
- Maintain cleanliness at the workplace;
- Keep a safe distance from moving parts of equipment [3, p. 215].

In case of an accident or hazardous situation, the worker must immediately stop the equipment (press the emergency stop) and report to management. Access to the dangerous zone must be restricted (install barriers, post warning signs), and first aid must be provided if necessary. Further actions are carried out in accordance with the local emergency response plan and evacuation instructions.

In all cases, the worker must act in strict compliance with occupational safety regulations and training programs. After an incident, repeated instruction of the injured and other employees is conducted, the causes of the accident are analyzed, and preventive measures are adjusted. Compliance with these rules is the key to preventing injuries and occupational diseases in the crushing department.

Ensuring safe working conditions in the crushing department is a complex and multifaceted task that can only be successfully addressed through a comprehensive and systematic approach. Such an approach involves not only modern technical equipment but also a well-organized system of measures aimed at minimizing occupational risks and preventing accidents.

First and foremost, the technical component plays a crucial role. The use of modern crushing equipment get with automation systems, remote control, and emergency protection significantly reduces the level of risk for workers. Dust suppression systems, ventilation, and noise insulation are also of great importance, as they ensure compliance with sanitary and hygienic standards and reduce the impact of harmful factors on the human body. Regular maintenance, diagnostics, and timely repair of equipment are essential elements of the safety system.

Equally important is the strict organization of work. Clear regulation of production processes, development and adherence to occupational safety instructions, and control over the execution of technological operations all contribute to maintaining discipline and reducing the likelihood of errors. An important aspect is also the rational distribution of responsibilities among employees, compliance with work and rest schedules, and control over personnel authorization for high-risk tasks.

Special attention is given to personnel training and development. Regular safety briefings, training in safe work methods, professional development, and assessment of knowledge in occupational safety requirements help to build strong safety habits.

Practical training for emergency situations enhances personnel readiness to respond quickly and appropriately to unforeseen circumstances.

At the same time, personal responsibility of each employee remains a key factor. Awareness of the importance of safety compliance, careful attention to one's own health and the health of colleagues, and strict adherence to established rules form the foundation of a strong safety culture within the enterprise.

The implementation of these measures at the ANOF-3 Processing Plant demonstrates a high level of occupational safety management. The enterprise shows a consistent commitment to reducing industrial risks through the introduction of modern technologies, improvement of management practices, and enhancement of production culture.

Continuous improvement of the safety system, the adoption of innovative solutions, and systematic efforts to prevent injuries and occupational diseases not only ensure worker protection but also increase overall operational efficiency. As a result, the enterprise achieves stable, reliable, and safe long-term performance.

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УДК 55.3179

THERMOPHYSICAL PROPERTIES OF PEAT SOILS

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Abstract. This paper examines the thermophysical properties of peat soils, which are determined by the low thermal conductivity of particles and high moisture content, which slows down freezing and thawing processes. Approaches to assessing heat transfer, including steady-state and non-steady-state measurement methods, are analyzed. D. I. Fedorovich's experimental method, using a simplified calorimeter, is described, allowing the thermophysical properties of samples to be determined at average temperatures. It is demonstrated that moisture content is a comprehensive indicator that summarizes the thermophysical properties of peat soils.

Keywords: thermophysical properties of peat soils, non-stationary measurement methods, frozen soils, degree of humidity, moisture migration in soils, Fedorovich calorimetry method, thawing and freezing of peat soils, experimental determination of thermophysical characteristics.

ТЕПЛОФИЗИЧЕСКИЕ СВОЙСТВА ТОРФЯНЫХ ГРУНТОВ

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Аннотация. В работе рассмотрены теплофизические свойства торфяных грунтов, обусловленные низкой теплопроводностью частиц и высоким влагосодержанием, что приводит к замедлению процессов промерзания и оттаивания. Проанализированы подходы к оценке теплопередачи, включая стационарные и нестационарные методы измерений. Описана экспериментальная методика Д. И. Федоровича с использованием упрощенного калориметра, позволившая определить теплофизические характеристики образцов при средних температурах. Обосновано, что степень влажности является комплексным показателем, обобщающим теплофизические свойства торфяных грунтов.

Ключевые слова: теплофизические свойства торфяных грунтов, нестационарные методы измерений, мерзлые грунты, степень влажности, миграция влаги в грунтах, метод калориметрирования Федоровича, оттаивание и промерзание торфяных грунтов, экспериментальное определение теплофизических характеристик.

The specific thermophysical properties of peat soils, due to the low thermal conductivity of their particles and high moisture content, lead to significant differences in heat transfer compared to mineral soils [1, 2, 3]. This is manifested in the slowing of thawing and freezing processes, changes in the temperature gradient with depth, and the approach of zero annual temperature amplitudes to the surface. To accurately determine the estimated depths of seasonal thaw, predict the temperature regime of foundations made of frozen peat soils, estimate the rate and maximum values of thaw depth during engineering preparation of a site, and solve other engineering problems, it is necessary to consider the thermophysical characteristics of peat [4, 5].

The primary method of heat transfer in solids is conduction; however, in soils, this process is complicated by mass transfer, convection of liquids and gases, and moisture movement [1, 3]. Measuring mass transfer characteristics in soils presents significant difficulties, so in practice, equations based solely on conductive thermal conductivity theory are used, which do not account for mass transfer effects. In thermal calculations, the soil medium is typically considered quasi-homogeneous, with averaged effective values of thermophysical properties.

The approach to assessing heat transfer we are discussing is also applicable to peat soils; however, their high water content requires special consideration. This is because the thermal conductivity, thermal diffusivity, and heat transfer coefficient of water significantly exceed those of solid soil particles, especially peat [3]. Consequently, as the moisture content of peat soils increases, all their effective thermophysical parameters increase faster than those of mineral soils.

The quantitative values of thermophysical characteristics are largely determined by the chosen measurement method. Two main approaches can be identified in soil thermal property research [2]. The first is based on the principles of a steady-state thermal regime, in which the temperature difference remains constant throughout the experiment. The second approach utilizes the principles of transient thermal conditions, where temperature gradients vary and depend on the experimental conditions.

Experimental determination of the thermophysical properties of wet thawed soils is complicated by temperature gradients, which initiate significant moisture migration in the direction of the heat flow, leading to measurement errors [1]. This effect, combined with the difficulty of maintaining a constant heat source temperature when using steady-state methods, significantly limits their applicability for studying the thermophysical properties of wet thawed soils.

Moisture migration also occurs during transient thermal processes, being directly proportional to temperature gradients. However, for methods based on transient thermal conditions, the influence of this factor is reduced due to the relatively short duration of the experiment [2].

Optimal conditions for determining the thermophysical properties of wet thawed soils are achieved using methods based on transient thermal conditions. At the same time, for frozen soils at temperatures significantly below the water phase transition temperature, both steady-state and non-steady-state approaches are applicable [4]. However, in the field of intense phase transformations, both methods face methodological difficulties. This is due to the fact that the significant release of latent heat of crystallization leads to dynamic changes in the soil’s thermophysical properties,

which hinders their direct and accurate experimental determination [1].

To summarize the above, it should be noted that for achieving the goals of a comprehensive study of the thermophysical properties of peat soils, methods based on non-steady-state heat flow are the most appropriate. For soils, these are probe methods and methods of regular thermal regime [2]. The key advantage of probe methods is their applicability in the field; however, they are characterized by significant time expenditures for measurements, which entails errors in the final results. The method for complex thermophysical studies of samples using calorimetry, developed by D. I. Fedorovich [6], was chosen as a method based on the theory of a regular thermal regime for soils.

During the experiments to determine the thermophysical properties of soils, a simplified calorimeter with kerosene as the calorimetric fluid was used. The initial temperature of the kerosene was constant: 18-20 °C for thawed soils and 6-7 °C for frozen soils, which ensured the absence of intense phase transitions.

Preparation of soil samples, both thawed and frozen, included their collection in a ring, placement in brass boxes (4 cm in diameter and height), and then storing them for at least 20 hours. Thawed samples were stored at 0 °C in melting ice, while frozen samples were stored at -21.2 °C in a cryohydrate mixture of salt and ice.

To determine the thermophysical properties of the soil, its temperature was calculated. The change in temperature of the calorimetric fluid was experimentally recorded. Based on the principle of heat balance for the liquid-soil system, it was found that the rates of temperature change of the liquid and the soil sample coincide over time. This means that if the liquid temperature changes by a certain percentage of the total change over a given period of time, the soil sample temperature will change by the same percentage over the same period. Knowing the initial and final temperatures of the sample, its temperature can be plotted as a function of time. Integrating this dependence yields the average temperature at which the thermophysical properties were determined. For the given temperature gradients, the average temperature was –10 °C for frozen soils and +14 °C for thawed soils.

To understand how thermophysical characteristics depend on physical properties, we need to identify the key parameters that describe these properties collectively.

The key factors determining heat transfer in soil are its mechanical composition, porosity, and pore size and shape. These characteristics directly influence the importance of convective and radiative heat transfer. According to research [7], the radiative component of heat transfer in soils is less than 1 %, and convection is activated only in pores thicker than 10 mm at a temperature gradient exceeding 0.3 °C. In narrow layers (less than 5 mm), convection is virtually absent, even with significant temperature differences (up to 100 °C). With a pore radius of 3 mm, the convective share of the heat flow is only 0.13 %. Considering that in peat, with the exception of the moss-peat cover, the pores usually do not exceed 3-5 mm, it can be concluded that under normal temperature conditions, radiant thermal conductivity and convection in peat and other fine-grained soils do not require consideration.

The porosity coefficient measures the influence of porosity on thermophysical properties, providing a quantitative assessment without taking into account individual

pore characteristics (size and shape). However, since the porosity coefficient is directly dependent on the bulk density of the soil and the bulk density of its skeleton, these particle compaction indices can also be used for assessment.

Thus, as with mineral soils, for peat soils, moisture content and bulk density of the skeleton are fundamental physical parameters determining their thermophysical properties. For mineral soils in the frozen and thawed states, graphical and empirical relationships have been established between the thermophysical properties of the soil and moisture content and the total density of the soil, or moisture content and density of the dry soil.

When conducting practical calculations, the use of analytical relationships between thermophysical characteristics and a single parameter significantly simplifies the task. This parameter is intended to summarize all physical properties that influence heat transfer in soil. In the case of peat, in addition to moisture content, the key typological indicator is the degree of decomposition, which determines its mechanical composition, porosity, and pore size. However, for generalization purposes, the total moisture capacity parameter is more practical. It is a complex indicator of the soil's physical properties, dependent on its density and bulk density, and demonstrates a strong correlation with the degree of decomposition.

Moisture content and total moisture capacity are key indicators of peat soils, directly affecting their thermophysical properties. Both parameters reflect the degree of water saturation. Total moisture capacity is a fixed value for a given soil, while moisture content can vary from completely devoid of water to saturation. The ratio of these two quantities, expressed as the degree of moisture (Wc/Wn), combines them. Substituting into this ratio the dependence of total moisture capacity on the porosity and density of water and soil, we obtain the formula:

$$\frac{W_c}{W_n} = \frac{W_c * p_w}{p_w(p - p_d)},$$

where W_c – soil moisture content, %;

W_n – total soil water capacity, %;

ρ_w – water density, g/cm³;

ρ – soil density (bulk density), g/cm³;

ρ_d – dry soil density (bulk density of the skeleton), g/cm³.

This moisture content thus describes the proportional relationship of all components of the soil complex that determine its thermophysical properties. Consequently, the moisture content is a complex indicator that summarizes the thermophysical characteristics of peat soils. Experimental data confirm this: the thermophysical parameters of peat soils, presented as a function of their water saturation, fit onto a single generalized curve. For mineral soils containing plant residues, the thermophysical properties can be described as a function of two complex variables: moisture content and peat content.

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УДК 620.9

ORGANIZING AN ASMAE IN THE OPERATIONAL AND TECHNOLOGICAL MANAGEMENT SYSTEM

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Abstract. The problem under consideration is particularly significant in the operating conditions of 6-10 kV distribution networks, where the significant length of transmission lines and the geographic remoteness of facilities and power consumers complicate the rapid identification and resolution of emergency situations. The implementation and operation of automated metering systems (ASMAE) in the electric power system and networks enables the use of telemetry information for the prompt localization of emergency areas. Consequently, electrical equipment downtime is reduced, and the economic costs associated with power outages are lowered power consumers.

Keywords: ASMAE, short circuit, fault, recloser, electrical device, energy conservation.

ОРГАНИЗАЦИЯ АСКУЭ В СИСТЕМЕ ОПЕРАТИВНО-ТЕХНОЛОГИЧЕСКИХ УПРАВЛЕНИЙ

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Аннотация. Наибольшую значимость рассматриваемая проблема приобретает в условиях эксплуатации распределительных сетей класса напряжения 6-10 кВ, где фактор значительной протяженности линий электропередачи и географическая удаленность объектов и электроприемников обуславливает сложность оперативного поиска и устранения аварийных ситуаций. Внедрение и эксплуатация АСКУЭ в электроэнергетической системе и сетях обеспечивают использование телеметрической информации для оперативной локализации аварийных участков. Как следствие, сокращается время простоя электрооборудования и снижаются экономические издержки, связанные с перерывами в электроснабжении электроприемников.

Ключевые слова: АСКУЭ, короткое замыкание, неисправность, реклоузер, электрический аппарат, электросбережение.

Russia’s energy system is a unified complex that plays a strategic role in the country’s economy. It comprises power plants (generating facilities), the grid (substations and high-voltage lines), and end consumers of electricity, spread across a vast territory. Given the country’s vast geography, Russia has developed and

effectively operates a multi-tiered generation system, including various types of power plants: nuclear, hydroelectric, thermal, and others. It ensures an uninterrupted supply of electricity to various consumers. Today, this type of energy is the most economically advantageous due to its low cost and high profitability, while at the same time it has a unique ability to be converted into other types of energy [1].

Modern, civilized energy trading is impossible without automated electricity metering, which minimizes human intervention in the measurement, collection, and processing of data. This approach ensures the reliability, accuracy, efficiency, and flexibility of metering, allowing for adaptation to various tariff systems for both suppliers and consumers. This approach ensures the reliability, accuracy, efficiency, and flexibility of metering, allowing for adaptation to various tariff systems for both suppliers and consumers. To achieve these objectives, both electricity suppliers and consumers are implementing automated energy consumption monitoring and metering systems (ASMAE) at their facilities [2].

Ensuring the reliability and quality of electricity supply to various consumers is the primary task of operational management in modern electric power systems and networks [3]. Electricity meters play a key role in the energy industry, ensuring accurate measurement of electricity consumption. This allows distribution companies to accurately bill consumers. However, electricity theft by individuals, businesses, and organizations, as well as damage to power supply systems, lead to significant financial losses and reduced energy system efficiency.

To achieve these objectives, automated metering systems ASMAE are being implemented in power systems. These systems not only provide commercial metering and energy consumption control but also monitor the current state of electrical networks in real time. The authors' works [2] examine the potential of using automated metering systems to address operational and technological management issues in electric power systems. The most important function of the automated metering system (ASMAE) within operational management is monitoring electrical power quality indicators. This is achieved by monitoring key network parameters: voltage, current, and identifying harmonic distortions and phase load asymmetries. This information becomes critical for diagnosing various types of transients, short circuits, and electrical substations (ES) failures. For example, in the case of single-phase ground faults, the system allows for the recording of characteristic signs of a fault: a sharp asymmetry of currents and voltage imbalance in the electrical network [4].

Rapid data collection from electricity meters enables the timely detection of abnormal electrical grid conditions, precise location of the incident, and targeted action to resolve it as quickly as possible. The implementation and active use of an automated metering system significantly reduces response times to emergency situations and minimizes their consequences. Ultimately, this leads to increased power supply reliability and enhanced security of the entire energy infrastructure [5-9].

The aim of this study is to investigate the role of automated power metering systems (ASMAE) in operational dispatch control systems and for fault detection on high-voltage overhead lines. The focus is on analyzing how data on voltage imbalances and other network parameters can be used to improve the effectiveness of emergency

response in electric power systems and networks.

Let’s consider practical developments in organizing an automated metering system (ASMAE) in the operational and technological control system of power supply networks, which include the following stages:

1. Preparatory stage. At this stage, existing power supply systems for typical facilities are studied and analyzed, electrical equipment is selected based on the specifics of the facility, and agreed upon with the customer. Based on customer requirements, design and estimate documentation is developed in AutoCAD or Kompas 3D programs in accordance with industrial safety requirements [3]. All structural details of the technical documentation for the facility’s power supply system are then agreed upon with the customer. Another method is to improve the existing power supply design for such facilities.

2. Coordination and design. After all design revisions have been clarified with the client, the project is approved by the energy supply, water, gas, and environmental authorities. Particular attention is paid to determining the installation locations of equipment: meters, current transformers, concentrators, modems, and other electrical devices.

3. Installation and commissioning. After approval by all regulatory authorities, installation work is carried out, including the installation of modern electronic metering devices, grounding them, and remote reading capabilities. During installation, communication via wired or wireless lines can be established, with dedicated internet channels using standard signal transmission protocols. Tariff data is separated using combiners with internal memory for data storage, and backup power is provided for the equipment. After commissioning and testing of the communications system for functionality, including emergency modes, the entire system is tested for protection against unauthorized access and data breaches.

4. Commissioning and Maintenance. This is performed by the service organization through a test run of the system. If any transmission errors are detected, the system is optimized and ultimately launched into permanent operation. The primary tasks during commissioning of this system include software configuration and connecting remote workstations for operational management. A maintenance and warranty agreement is then drawn up, specifying the frequency of system maintenance.

5. Establishment of data processing centers. When operating this system, a large number of signals or information are received from remote locations. To store and subsequently process these signals, data processing centers equipped with modern computing hardware and software are created. The server equipment must be provided with a stable power supply and grounding for all components.

6. System Operation. To ensure successful operation of the installed system, regular scheduled preventive maintenance (SPM) must be conducted. Plans must be drawn up for SPM, routine repairs, and major equipment overhauls to replace outdated, non-standard lines and equipment. The dispatch service provides prompt response to emergency situations and restores system functionality.

To locate the location of a single-phase short circuit in 6-35 kV district electrical networks, the production department of Neftekamsk Electrical Networks (PD NEN) of Bashkirenergo LLC uses the following technical devices: *LineTroll 110Eμ, IKZ-33*

TN3, VECTOR indicators and reclosers.

The *LineTroll 110Eμ* high-voltage overhead line fault indicator with an integrated radio transmitter is designed for local fault indication. It transmits a signal to the pole housing the collector (*CmT-115C*), which interfaces with the *SCADA RTU* terminal for remote monitoring [4]. The device is designed to detect external fault conditions in distribution networks, including phase-to-phase short circuits and phase-to-ground faults. Activation occurs when the short-circuit current reaches the threshold required for reliable detection. Indicators are placed at strategic points along the high-voltage line. When a fault is detected, all indicators installed on the faulty phase(s) between the supply substation and the fault location will operate. Indicators located beyond the fault location or on the undamaged phase(s) will not operate.

The short circuit indicators (*SCI-33 TN3)* indicator set is designed to determine the direction of fault location search on overhead lines (*OHL*) of 6-10 kV distribution power grids [1]. The fault location direction is determined by analyzing the locations of *SCI-33TN3* indicator sets that have and have not recorded a fault. A fault is recorded in a set when a short-circuit current, or zero-sequence current, flows in one or more phases of the lines. The *SCI-33* indicators measure instantaneous current and voltage values, calculate the current and voltage amplitude values, compare the obtained values with the set values, and then, if necessary, transmit all these characteristics to the information collection and transmission unit (*ICTU-3TN3*) unit (data collection and transmission unit). The *ICTU-3TN3* data collection and transmission unit is mounted directly on the pole (Figure 1).

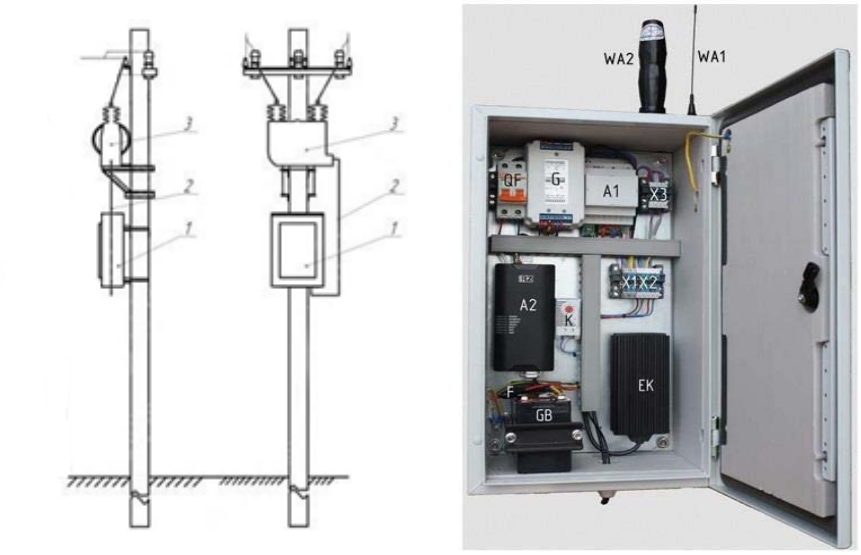


Figure 1. Installation of the data collection and transmission unit:
1 – ICTU- unit; *2* – cable; *3* – high-voltage single-phase transformer

The portable digital indicator “Vector” (Figure 2) is designed to determine the location of a single-phase ground fault (SPF) in overhead power lines (OPL) with a voltage of 6-35 kV.

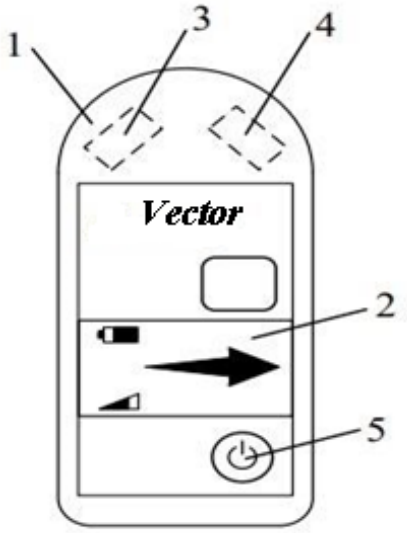


Figure 2. The Vector device

When passing along the route past the location of a single-phase ground fault (SPF), the arrow on the indicator display smoothly turns (Figure 3), all the time pointing to the location of the SPF.

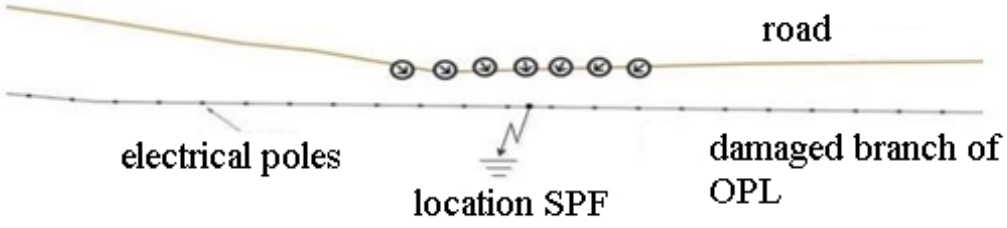


Figure 3. Determining the location of the SPF

The Vector indicator allows you to find a fault in high-voltage overhead lines, even if it is not visually recognizable.

Modern high-voltage devices include reclosers, designed for the automatic protection and automation of overhead power lines. Their primary function is to automatically disconnect the faulty section of the line from one feeder to another in the event of a short circuit, and then automatically reconnect it if the fault is short-lived. This allows reclosers to significantly improve power supply reliability and minimize power outages, especially in remote or hard-to-reach areas.

When high-voltage fuse f. "A" at transformer substation (TS) TS-6(10)/0.4 kV burned out, a control summary of data from the metering device with the automated system for commercial accounting of power consumption (ASMAE) located at this TS was performed. According to the survey data, the phase voltage was U_{A0} = 78.1 V, U_{B0} = 161.12 V, U_{C0} = 232.68 V (Figure 4).

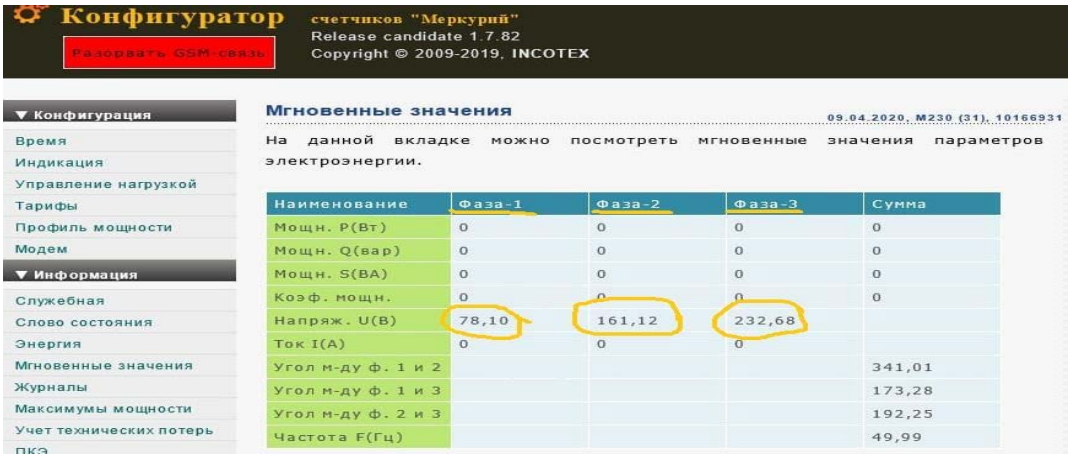


Figure 4. Instantaneous values when a high-voltage fuse blows at TS-6(10)/0.4 kV

Voltage measurements taken directly at the transformer substation showed the following values: U_{A0} = 78 V, U_{B0} = 160 V, U_{C0} = 232 V.

The values after replacing the damaged fuse were shown in Figure 5.



Figure 5. On-screen display of electrical energy parameter values indicating that the voltage complies with the standard

The display of the main electrical parameters is shown in Figure 6.

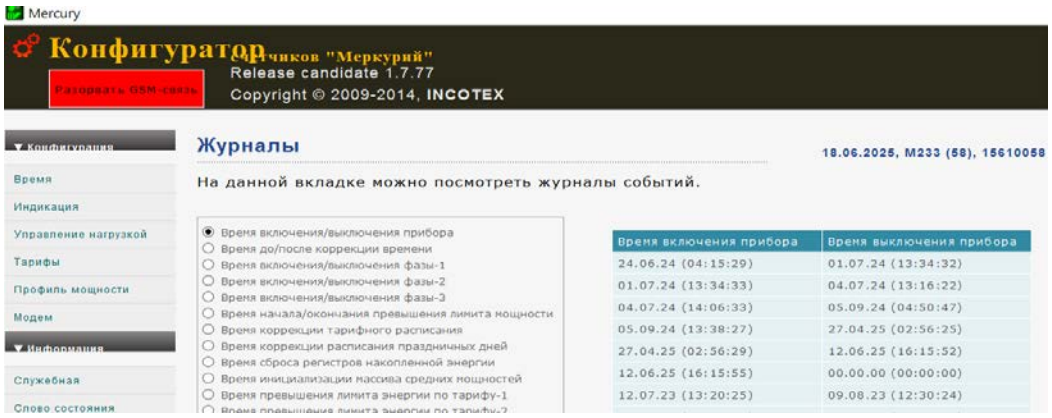


Figure 6. Display of electrical parameters in the event log

Let’s consider a case where a break in the loop occurs at a disconnect switch located at the beginning or on a section of a high-voltage line. A diagram of a 6 kV overhead line with a break in the loop at 2-sectional disconnector (2SD-1) is shown in Figure 7.

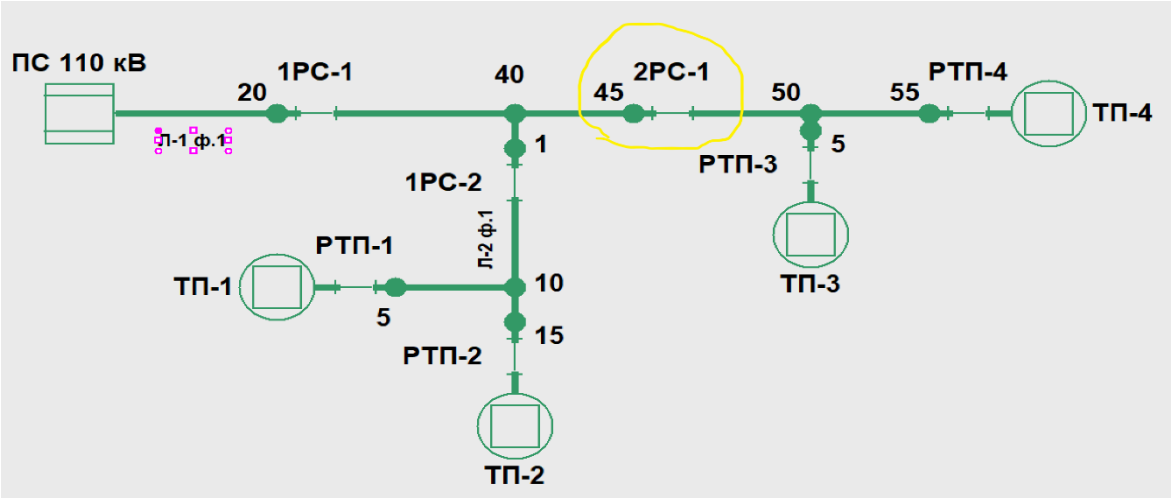


Figure 7. Overhead power lines (OPL) - 6(10)/0.4 kV with a break in the loop on the 2-sectional disconnector (SD)

Upon receipt of a complaint from consumers about low voltage or missing phase from TS-4, we carry out diagnostics using the metering device located at this TS and the nearest TS-3. This confirms the absence of one phase, say phase "B", while the voltage is U_{A0} = 220 V, U_{B0} = 70 V, U_{C0} = 150 V. To determine a more precise break location, we perform a control query of TS-1, where the voltage is normal U_{A0} = 222 V, U_{B0} = 223 V, U_{C0} = 222 V. Based on the polled results, we determine that the break is located in the section from support No. 40 to support No. 50 of VL-10 L-1 phase 1 of the electrical substation (ES) 110 kV. The diagram of the 6 kV *OPL* with an open circuit at 1PD-2 is shown in Figure 8.

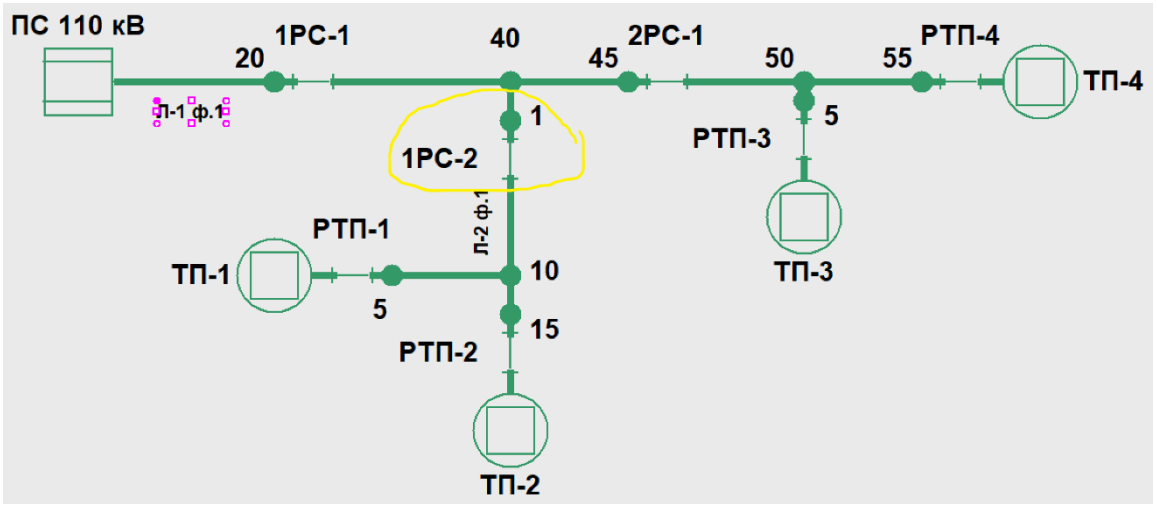


Figure 8. OPL- 6(10)/0.4 kV with a break in the loop on 1 sectionalizing disconnector

When consumers complain about low voltage or missing phases from TS-1, we conduct diagnostics using the metering device located at this TS and the nearest TS-2. This confirms the absence of one phase, let's say phase "B", while the voltage is U_{A0} = 220 V, U_{B0} = 70 V, U_{C0} = 150 V. To determine the exact location of the break, we query the metering device at TS-3, where the voltage is normal: U_{A0} = 222 V, U_{B0} = 223 V, U_{C0} = 222 V. Based on the diagnostic results, we determine the location of the break on the section OPL-10 L-2 phase 1 of the ES -110 kV.

These examples demonstrate that with such a diagnostic system and electrical equipment, it is possible to determine the location of damage before the crew arrives on site, without leaving the duty station, which significantly reduces the downtime of electricity consumers.

It should be noted that as of January 1, 2026, 82 % of 6(10) kV transformer substations in the NES PO of Bashkirenergo LLC are equipped with metering devices with the ASMAE system and the "Configurator" software packages for "Mercury" meters and the "Energomera" admintools are used.

Thus, we can conclude that the implementation of an automated metering system allows:

- instantaneous fault location;
- troubleshooting 4-5 hours faster;
- savings of over 2 million rubles per year by reducing downtime alone;
- reducing labor costs and increasing the reliability of power supply to consumers.

Therefore, installing an automated metering system is not only technologically feasible but also economically advantageous, especially for 6-10/0.4 kV distribution networks. In addition to metering consumption, this system provides operational monitoring of the network's condition and allows for the localization of any AMR-related incidents without physically visiting all transformer substations:

- a signal is received about an emergency;
- the location of the failure (substation, feeder, network section) is precisely determined;
- the repair crew immediately heads directly to the site of the failure, rather than spending hours driving around all the areas.

Thus, the use of fault indicators, Configurator software, Mercury smart meters, and reclosers eliminates unnecessary manipulation of circuit breakers and disconnectors when troubleshooting short-circuit faults on high-voltage overhead lines. This reduces wear and tear, as frequent switching operations negatively impact the electrical life of distribution devices.

The implementation of an automated metering system (ASMAE) is an effective tool for improving energy efficiency, reducing costs, and fostering a culture of rational energy consumption at both industrial enterprises and residential consumers. The resulting developments ensure high reliability, accurate metering, and operational dispatch control in power supply networks for electrical consumers in large and complex areas.

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УДК 621.391

DEVELOPMENT AND TESTING OF DIGITAL FILTERING ALGORITHMS FOR ELECTROCARDIOGRAPHY IN MATLAB

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Abstract. This paper examines digital filtering methods for electrocardiogram (ECS) signals aimed at suppressing baseline drift and myographic artifacts. Three approaches are implemented and compared using the MATLAB environment. Recommendations are provided for selecting algorithms based on accuracy and processing latency requirements.

Keywords: electrocardiography, digital filtering, MATLAB, signal quality assessment, noise immunity.

РАЗРАБОТКА И ТЕСТИРОВАНИЕ АЛГОРИТМОВ ЦИФРОВОЙ ФИЛЬТРАЦИИ ЭЛЕКТРОКАРДИОГРАФИИ В СРЕДЕ MATLAB

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Аннотация. В работе исследуются методы цифровой фильтрации электрокардиосигналов (ЭКС), направленные на подавление дрейфа нулевой линии и миографических артефактов. С использованием среды MATLAB реализованы и сопоставлены три подхода. Сформулированы рекомендации по выбору алгоритмов в зависимости от требований к точности и задержке обработки.

Ключевые слова: электрокардиография, цифровая фильтрация, MATLAB, оценка качества сигнала, помехоустойчивость.

Cardiovascular diseases (CVD) remain the leading cause of death and disability worldwide, creating a high demand for continuous cardiac monitoring and early diagnosis systems. In recent years, wearable telemedicine sensors have become widespread, but most commercially available foreign-made solutions are characterized

by high costs, proprietary hardware and software platforms, and limited availability for widespread implementation in the Russian healthcare system. Therefore, in this study, we developed a domestic hardware and software system for remote cardiac monitoring, focused on accessibility, open architecture, and adaptability to Russian clinical practice [1].

The core of the proposed system is the recording and analysis of the electrocardiogram (ECG) [2], which offers high diagnostic value, is noninvasive, and has low data acquisition costs. However, during outpatient and telemedicine use, the ECG is subject to intense interference of various origins: low-frequency baseline drift, power line interference and its harmonics and pulsed interference caused by electrode movement or changes in electrode-to-skin resistance. Incorrect suppression of these distortions leads to errors in the automatic detection of morphological elements, false positives in arrhythmia diagnostic algorithms, and reduced clinical reliability of remote monitoring. Therefore, the development of computationally robust digital ECG filtering algorithms is becoming a critical step in the creation of reliable domestic telemedicine devices [3].

Modern approaches to ECG cleaning fall into three main groups: linear frequency-selective filters, nonlinear and adaptive methods, and methods based on wavelet transforms and machine learning [4]. Despite the widespread use of ready-made solutions, the problem of selecting the optimal algorithm remains relevant due to the conflict between signal recovery quality, computational load, processing latency, and the ability to operate in real time on domestic microcontrollers.

The aim of this work is to develop, implement software in the MATLAB [5] environment, and comparatively test three algorithms for digital ECG filtering using standard signal quality metrics and publicly available reference recordings, which will allow the formation of scientifically based recommendations for the implementation of the selected methods in the developed domestic telemedicine system.

To test the digital filtering algorithms, we used our own dataset of electrocardiogram signals, presented in text format (.txt). The data organized line by line: each line of the file corresponds to one 60-second ECG recording. The total sample size was 120 recordings, providing sufficient statistical power for comparative analysis. The signals were imported into the MATLAB environment using the importdata function, followed by amplitude normalization and checking for missing values. When gaps or filling artifacts were detected, linear interpolation was applied to sections no longer than 50 ms.

All algorithms were developed taking into account the requirements for embedded telemedicine platforms: minimal processing latency, resistance to motion artifacts, and the ability to be subsequently transferred to microcontroller code. Software implementations in MATLAB are provided below.

The first implemented approach is based on a cascade structure of three sequentially connected recursive units. The first stage uses a second-order Butterworth high-pass filter with a cutoff frequency of 0.5 Hz, designed to suppress low-frequency baseline drift caused by changes in electrode contact resistance and respiratory movements. Next, the signal passes through a type 2 Chebyshev notch filter with a center frequency of 50 Hz and a quality factor of Q = 35, providing deep suppression of power-line interference without significantly affecting the useful ECG spectrum. A fourth-order Butterworth low-pass filter completes the cascade with a cutoff frequency

of 40 Hz, smoothing high-frequency myographic artifacts and quantization noise. To eliminate phase distortions, critical for analyzing cardiac cycle time intervals, filtering is performed in zero-phase-shift mode using the bidirectional filtfilt procedure [5].

The second algorithm is a nonlinear adaptive median filtering method designed to effectively suppress impulse noise and motion artifacts. The method is based on a sliding median filter window, the width of which dynamically changes from 5 to 15 samples depending on the local signal dispersion. When recording sharp spikes, the window expands to enhance smoothing, and in stable regions, it narrows to preserve the steepness of QRS complex fronts. Additionally, to eliminate residual low-frequency drift, a polynomial baseline subtraction step is applied using a third-degree approximating polynomial in a 1-second sliding window. This combination of nonlinear filtering and parametric correction ensures high immunity to non-stationary interference typical of ambulatory monitoring [4].

The third approach is based on wavelet analysis methods, enabling joint frequency-time localization of the signal. The original ECG signal is decomposed into six levels using the Daubechies-4 (db4) orthogonal basis, optimally matched to the morphology of cardiac complexes. High-frequency detail coefficients of levels 1 and 2, which predominantly contain noise, are subject to strict thresholding according to the universal Vishanathan-Huber rule. Level 6 approximation coefficients, corresponding to frequencies below 0.5 Hz, are forced to zero to completely remove baseline drift. The purified signal is reconstructed using the inverse discrete wavelet transform, which ensures the preservation of diagnostically significant transients while significantly improving the signal-to-noise ratio.

To quantitatively evaluate the effectiveness of the developed filtering algorithms, a set of metrics characterizing both the quality of signal recovery and the computational complexity of the methods was used. The signal-to-noise ratio was chosen as the primary indicator of noise immunity.

To characterize the accuracy of reproducing the amplitude-temporal parameters of the cardiac cycle, we used the root-mean-square error, calculated as the root-mean-square difference between the original and filtered signals. The root-mean-square error is sensitive to local distortions in the waveform morphology and allows us to identify algorithms that cause undesirable smoothing of steep QRS complex fronts or ST segment deformation.

Additionally, the linear statistical relationship between the signals was assessed using the Pearson correlation coefficient. A coefficient value close to one indicates a high similarity between the filtered waveform and the reference recording, which is critical for automated diagnostics based on the analysis of morphological features.

Visual analysis of the oscillograms showed that the cascaded IIR structure effectively suppresses network noise and drift, but leaves minor spikes in the T-wave region in the presence of myographic activity. Adaptive median filtering copes better with impulse noise, but results in smoothing of the QRS complex fronts with a window width greater than 9 samples. The wavelet method demonstrates the highest accuracy in morphology reconstruction, including preservation of the P-wave amplitude and the steepness of the ascending R-branch, but is sensitive to the choice of basis and decomposition level.

The advantage of wavelet filtering is its localization in both frequency and time, allowing for selective removal of interference without distorting transients. However,

the computational complexity of the method limits its use in portable monitors and telemedicine systems with stringent power consumption requirements.

Cascaded IIR filtering, despite its moderate SNR, ensures stable quality with minimal latency and a predictable phase response. This approach is suitable for embedded systems and real-time arrhythmia detection algorithms. Adaptive median filtering occupies an intermediate position and is recommended for recordings dominated by impulse noise.

Limitations of the study include the use of data at a single sampling rate and the lack of testing on recordings with a high degree of signal and noise spectral overlap. Future plans include integrating the algorithms with neural network anomaly detectors and implementing hardware acceleration using FPGAs [6].

This paper develops and compares three digital ECG filtering algorithms using MATLAB. It was found that wavelet thresholding based on db4 provides the best signal reconstruction quality but requires significant computational resources. The cascaded IIR structure demonstrated an optimal balance between accuracy, processing speed, and ease of implementation, making it preferable for real-time monitoring systems. The results can be used in the design of ECG processing software modules for medical devices and research platforms.

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УДК 004.6, 658.5:004

ADVANTAGES AND DISADVANTAGES OF USING BIG DATA IN MANUFACTURING

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Abstract. The integration of Big Data tools into contemporary industrial operations is investigated against the backdrop of the broader transition toward Industry 4.0. A conceptual grounding is provided by examining five defining attributes: scale, speed of generation, format diversity, reliability, and economic worth. A real-world illustration is explored in depth, detailing the installation of an AI-driven visual inspection system at the RVK FOOD bakery in Samara, Russia. Drawing on recent academic publications and sector-specific reports, the paper highlights several primary benefits, namely gains in process efficiency, condition-based equipment servicing, full-spectrum product inspection, streamlined logistics networks, and the construction of virtual replicas of physical assets. In parallel, a number of implementation hurdles are catalogued, such as steep infrastructure expenses, the difficulty of connecting with older machinery, amplified exposure to digital attacks, scarcity of cross-disciplinary personnel, and persistent data integrity problems.

Keywords: Big Data, large data, industrial production, digital transformation, Industry 4.0, process optimization, machine learning, video analytics, digital twin.

ПРЕИМУЩЕСТВА И НЕДОСТАТКИ ИСПОЛЬЗОВАНИЯ BIG DATA НА ПРОИЗВОДСТВЕ

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Аннотация. Предметом рассмотрения выступает внедрение технологий больших данных (Big Data) в современные производственные процессы, осуществляемое в условиях разворачивающейся парадигмы Индустрии 4.0. Теоретический базис концепции раскрывается через описание пяти стержневых характеристик: объем, быстрота поступления, многообразие форм, достоверность и полезность. В качестве детальной иллюстрации приведен практический кейс запуска системы видеоаналитики на российском пищевом

предприятии – заводе RVK FOOD в Самаре. Опираясь на актуальные научные источники и прикладные исследования, автор выделяет такие ключевые достоинства, как рост операционной результативности, предупредительное техобслуживание, всесторонний контроль качества, оптимизация логистических цепочек и разработка цифровых двойников. Параллельно систематизированы основные препятствия: значительная стоимость инфраструктуры, трудности сопряжения с устаревшим оборудованием, усиление киберугроз, нехватка специалистов смешанного профиля и проблемы низкого качества исходных сведений.

Ключевые слова: Big Data, большие данные, промышленное производство, цифровая трансформация, Индустрия 4.0, оптимизация процессов, машинное обучение, видеоаналитика, цифровой двойник.

Manufacturing is changing faster than ever before. We are now in the era of Industry 4.0, a term made famous by Klaus Schwab in his 2016 book. The big idea is simple yet deeply impactful: the physical world of machines and factories is merging with the digital world of computers and the internet. This creates smart factories where everything is connected. A newer idea building on this is the Industrial Metaverse, which aims to create a shared virtual space where people and machines work together seamlessly, using real-time data from the real factory floor [1].

In this new world, one thing has become more valuable than almost anything else: data. Every single day, a modern factory creates a flood of information. Thousands of sensors measure things like temperature, pressure, and vibration. Tracking systems follow every item from raw material to finished product. All of this information – measured in terabytes, which is thousands of gigabytes – is a goldmine. It contains hidden clues about how to make the factory run better, faster, and cheaper. The winners in this new world will be the companies that are best at using this data to make smart decisions. Big Data technology is the tool that makes this possible. It helps us find patterns and useful information in this huge, messy pile of numbers, pictures, and text. The market for Big Data in manufacturing is expected to grow by over 21 billion US dollars by 2029, with an impressive yearly growth rate of 26.4 % [2]. This shows that businesses truly believe in its power. This journey is not easy. Along with the great promise come real challenges that every company must deal with.

To understand the pros and cons, we first need a clear, simple definition. The term "Big Data" was created in the late 2000s. It does not just mean "a lot of data." It describes data that is so huge, so fast, and so varied that normal computer software simply cannot handle it. We need a new generation of powerful, flexible tools.

When describing the Big Data, people often use the “Five Vs” which is an easy way to remember its key features. The first “V” is Volume, which is the sheer amount of data, like all the measurements from every sensor in a factory over several years. The second is Velocity, the speed at which data is created and needs to be processed, often in real-time from a production line. The third is Variety, referring to all the different types of data, from neat rows in a spreadsheet to messy video footage and written maintenance reports. Two more Vs are crucial for practical use. Veracity is about how much we can trust the data; if the sensors are broken or the data is full of errors, it is useless. And finally, Value, which is the most important of all, because if

you cannot turn the data into something that saves money, improves quality, or makes better decisions, then there is no point in collecting it. In manufacturing, the five Vs are a daily reality. The goal is to turn a fast and messy river of data into a reliable source of real value.

Big Data is not just a fancy tech term; it brings real, practical improvements to the factory floor. Several advantages are changing the way things are made.

The biggest and most immediate win is better overall efficiency. Old-school control systems are great at keeping one setting, like a constant temperature, at a specific level. But they cannot see the bigger picture – how many different things slowly change over time and affect each other. Big Data, combined with machine learning, can do exactly this. It constantly looks at years of past and present data, spots the hidden patterns that cause waste or slowdowns, and suggests the perfect settings for the machines. This leads directly to the next big advantage: predictive maintenance. The old ways of fixing machines are to either wait for them to break (which is expensive and chaotic) or to replace parts on a fixed schedule, even if they are still in perfect condition (which is wasteful). Predictive maintenance uses Big Data to listen to the machines. By analyzing real-time data like vibration, temperature, and oil quality, the software can detect the earliest, tiniest signs that a part is starting to wear out. It can then send an alert days or weeks before a breakdown. This allows the repair to be planned for a quiet time, preventing a costly sudden stop of the whole production line.

A third major advantage is product quality control. In industries like food or medicine, one mistake can be very damaging. Old quality checks often mean looking at a few finished products at the end of the line. With Big Data, you can check every single product at every single step. A perfect real-world example is the RVK FOOD factory in Samara, Russia. They make around 400,000 frozen pastries – like croissants and puff pastries – every day. Before, workers manually logged how many boxes of each pastry type were loaded onto trucks. This would sometimes lead to human errors, like a box marked "puffs" actually being full of "tongues." This would only be found much later, causing problems with their customers. To fix this, Beeline's Big Data & AI team, which has over 200 experts and has completed over a thousand such projects, installed a smart video system [3]. A camera network and a neural network now automatically identify the code on each pallet, count them, and send the correct information directly to the company's main computer system. As Pavel Shuvalov, the factory's Production Director, said, before the system, finding an error meant manually watching hours of security camera video. Now, the system catches mistakes in real-time, saving his team from awkward conversations with their business partners [4].

Looking beyond the factory walls, Big Data also makes the supply chain smarter. A factory’s efficiency is directly tied to its suppliers and customers. Big Data can connect information from store checkouts, warehouse levels, delivery routes, and even weather forecasts to predict exactly how much product will be needed and when. This reduces the need for huge, expensive stockpiles of raw materials and unsold goods. Finally, the most advanced use of Big Data is the "digital twin." This is a living computer model of a real machine, a production line, or even the entire factory. It is constantly updated with live data. This lets engineers run tests and try out "what if" scenarios in complete safety, without risking a single real product. Groundbreaking

research has proven the power of this idea. A digital twin system was tested in a real factory for a full year. The results were amazing: it reduced the time to switch a production line to a new product by 37 %, cut total costs by 14.6 %, and made the factory able to react to market changes 42 % faster, leading to a direct 11 % increase in profit [5]. These numbers show that digital twins are a serious business strategy.

For all its potential, the road to using Big Data is full of potholes. If companies ignore these problems, they end up with expensive tech that never really works. There are several big challenges that need a clear plan.

The number one problem is cost. Big Data needs a lot of very powerful, specialized computers and software to store and process the information. This costs a huge amount of money to set up and to keep running. For a very large company, this might be a normal IT budget item, but for a small or medium-sized business, it is often simply too expensive. A second major problem is getting the new Big Data tools to work with the old systems that are already on the factory floor. A factory is like a technology museum: you might have a brand-new, high-tech robot working next to a controller from the 1990s. These old machines were never designed to share data with a modern cloud server. Making them all speak the same language is a massively complex technical puzzle. Research on the Industrial Metaverse points out that this lack of compatibility is a "strategic bottleneck," and no single software platform currently exists that can solve all these connection problems at once [1].

When connected to the internet, old isolated machines create a serious new risk: cybersecurity. A smart factory is a vulnerable factory. Hackers no longer just try to steal data; they can try to cause physical damage. A cyber-attack could fool a control system into over-pressurizing a tank or overheating a chemical reactor, leading to a real-world disaster. Protecting the factory’s secret recipes, unique processes, and data becomes as important as locking the physical doors.

Another huge challenge is finding the right people. You cannot just buy Big Data tools and plug them in. You need a rare type of expert: a "hybrid" professional. You need a data scientist who understands not just code, but also chemistry or mechanics. You need an engineer who is comfortable working with artificial intelligence. These people are very hard to find and very expensive to hire. There is also a human challenge of culture. A highly experienced machine operator, who knows their equipment by sound and feel after 25 years, may not trust an AI recommendation that contradicts their gut feeling. Bridging this gap between technical possibility and human trust is one of the hardest jobs of all [1].

Finally, there is the boring but deadly problem of bad data and the ethical problem of privacy. The saying "garbage in, garbage out" is the golden rule of Big Data. If the information you feed into the system is full of mistakes – like broken sensors, missing numbers, or clocks that are not synchronized – then the brilliant insights that the system spits out will be completely wrong. Up to 80% of a data project's time is often spent just cleaning and fixing the raw data, which is unexciting but absolutely critical work. On top of this, using cameras and trackers to monitor everything on the factory floor can feel like a surveillance state for workers. There is a fine line between ensuring quality and safety and destroying the trust and privacy of your employees. It is a management challenge that technology alone cannot solve.

The future direction is clear. The Big Data market in manufacturing is booming

[2]. The success story at RVK FOOD shows that even a non-tech company like a bakery can use AI and video cameras to fix a real business problem and get a quick payback [4]. The research on digital twins proves that combining Big Data with smart models can lead to enormous efficiency gains [5]. The final conclusion is a balanced one. For large, high-tech factories, the advantages of using Big Data are already too great to ignore. They can afford the cost and complexity, and the payoff in efficiency, quality, and predictive maintenance makes it a smart investment. But for smaller companies, the challenges of cost, complexity, and finding the right people are still very high. The most important lesson is that Big Data is not a magic wand. It is a powerful but demanding tool. True success comes not from just buying the fanciest software, but from a careful strategy that focuses on cleaning your data, building trust with your people, and solving specific, practical business problems.

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При написании статьи были применены технологии искусственного интеллекта.

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УДК 004.8:519.876:658.5

THE APPLICATION OF ARTIFICIAL INTELLIGENCE TO OPTIMISE THE DEVELOPMENT OF MATHEMATICAL MODELS IN MANUFACTURING

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Abstract. This paper discusses how artificial intelligence can be used to make the development of mathematical models in manufacturing faster and more efficient. Traditional modeling approaches are often slow and require significant expert involvement. In this study, modern AI techniques such as symbolic regression, neural networks, and hybrid models are analyzed. It is shown that these approaches help reduce development time, improve prediction accuracy, and lower the cost of industrial experiments.

Keywords: artificial intelligence, mathematical modeling, manufacturing, machine learning, neural networks, optimization.

ПРИМЕНЕНИЕ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА ДЛЯ ОПТИМИЗАЦИИ РАЗРАБОТКИ МАТЕМАТИЧЕСКИХ МОДЕЛЕЙ В ПРОМЫШЛЕННОМ ПРОИЗВОДСТВЕ

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Аннотация. В данной работе рассматривается возможность использования искусственного интеллекта для ускорения и повышения эффективности разработки математических моделей в производстве. Традиционные подходы к моделированию зачастую являются медленными и требуют значительного участия экспертов. В исследовании анализируются современные методы ИИ, такие как символьная регрессия, нейронные сети и гибридные модели. Показано, что эти подходы помогают сократить время разработки, повысить точность прогнозирования и снизить затраты на промышленные эксперименты.

Ключевые слова: искусственный интеллект, математическое моделирование, производство, машинное обучение, нейронные сети, оптимизация.

Industrial enterprises are constantly required to improve product quality while simultaneously reducing production costs and optimizing resource usage. One of the most important tools for achieving these goals is the use of mathematical models, which allow engineers to predict system behavior and choose optimal operating conditions.

However, creating such models using classical methods is a difficult and time-consuming process. It often requires deep knowledge of physics, mathematics, and the specific technological process. At the same time, modern production systems generate large volumes of data through sensors and monitoring systems. This creates an opportunity to apply data-driven approaches based on artificial intelligence.

In recent years, AI methods have increasingly been used to simplify and accelerate the modeling process by automatically identifying patterns in data and reducing the need for manual analysis [1].

The classical approach to building mathematical models typically includes several steps: analyzing the process, constructing equations, estimating parameters, and validating the model.

Each of these stages can be associated with serious difficulties. For example, deriving equations requires expert-level understanding of the system, while parameter estimation often depends on expensive and time-consuming experiments.

In addition, traditional models may lose accuracy when operating conditions change. This makes them less flexible and requires repeated adjustments [2].

As a result, the main disadvantages of classical modeling can be summarized as follows:

1) reducing the need for manual analysis
2) long development time;
3) dependence on highly qualified specialists;
4) difficulty in describing complex nonlinear processes;
5) limited adaptability to new conditions.

One of the promising AI-based approaches is symbolic regression. Unlike traditional regression methods, it does not rely on a predefined model structure. Instead, it searches for both the structure of the equation and its parameters at the same time.

This is usually achieved using evolutionary algorithms that generate many candidate formulas and gradually improve them. Over multiple iterations, the algorithm selects the best-performing expressions based on how well they fit the data [3].

This approach has several important advantages. First, it eliminates the need to manually define the form of the model. Second, it can reveal hidden relationships that may not be obvious to a human expert. Finally, the result is an explicit mathematical expression, which makes the model easier to interpret compared to neural networks [4].

Neural networks are another widely used tool for modeling industrial processes. Their main strength lies in their ability to approximate complex and nonlinear dependencies.

In practice, different types of neural networks are used depending on the task. For example: feedforward networks are suitable for predicting output variables based on input parameters, recurrent networks (such as LSTM) are effective for processes that evolve over time.

Despite their high accuracy, neural networks have some limitations. In particular, they are often difficult to interpret, and their performance may decrease when applied to data that differ significantly from the training set [5].

To overcome the limitations of purely physical or purely data-driven models, hybrid approaches have been developed. These models combine domain knowledge with machine learning techniques.

For instance, a physical model can be used to describe the main structure of the process, while a neural network is responsible for correcting errors or estimating unknown parameters.

Such a combination allows researchers to achieve both accuracy and interpretability. As a result, hybrid models are becoming increasingly popular in modern industrial applications [6].

Artificial intelligence methods are already being applied in various areas of manufacturing. They are used for process optimization, quality control, and prediction of system behavior.

For example, symbolic regression can be applied to derive relationships between process parameters and product characteristics. Neural networks are often used for defect prediction and process monitoring. Hybrid models are especially useful in complex systems where both physical laws and experimental data must be considered.

These applications demonstrate that AI is not just a theoretical concept but a practical tool that provides measurable benefits in industrial environments.

Several important trends can be identified in the development of AI-based modeling:

1) automation of model development (AutoML) Systems that can automatically select algorithms and tune parameters;

2) integration of physical knowledge and AI Wider adoption of hybrid and physics-informed models;

3) digital twins Creation of real-time models synchronized with actual equipment;

4) these trends indicate that the role of artificial intelligence in industrial modeling will continue to grow [7].

The traditional approach to developing mathematical models has a number of significant limitations, including high complexity, long development time, and low flexibility.

Artificial intelligence offers new ways to address these challenges. Symbolic regression allows automatic discovery of mathematical relationships, neural networks can model complex dependencies, and hybrid approaches combine the advantages of both methods.

As a result, the use of AI makes it possible to develop models faster, improve their accuracy, and reduce the cost of implementation. This makes artificial intelligence an important tool for the future of industrial systems.

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УДК 504.3.054

SMOG FORMATION, ENVIRONMENTAL IMPACT AND MITIGATION MEASURES: THE CASE OF SAINT PETERSBURG

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Abstract. The paper considers the impact of smog on the environment and human health. The conditions for the occurrence of primary and secondary smog have been determined, a set of technological, legislative and infrastructure solutions has been proposed. Based on the analysis of data for 2019-2024, it was found that in St. Petersburg the main contribution to air pollution is made by vehicles (67.3 %), which determines the specifics of the necessary measures to improve the environmental situation in the metropolis.

Keywords: smog, air pollution, primary smog, secondary smog, environment, human health, Saint Petersburg.

ФОРМИРОВАНИЕ СМОГА, ЕГО ЭКОЛОГИЧЕСКИЕ ПОСЛЕДСТВИЯ И МЕРЫ СНИЖЕНИЯ ЗАГРЯЗНЕНИЯ ВОЗДУХА НА ПРИМЕРЕ САНКТ-ПЕТЕРБУРГА

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Аннотация. В работе рассматривается воздействие смога на окружающую среду и здоровье человека. Определены условия возникновения первичного и вторичного смога, предложен комплекс технологических, законодательных и инфраструктурных решений. На основе анализа данных за 2019–2024 гг. установлено, что в Санкт-Петербурге основной причиной загрязнения воздуха является автотранспорт (67,3 %), что определяет специфику необходимых мер по улучшению экологической обстановки в мегаполисе.

Ключевые слова: смог, загрязнение воздуха, первичный смог, вторичный смог, окружающая среда, здоровье человека, Санкт-Петербург.

1. Definition of “smog” and its causes

The term “smog” was first used by Dr. Henry Antoine de Voeux. In 1905, the scientist prepared for the Congress of Public Health an article “Fog and Smoke”, dedicated to the haze that enveloped London and was a mixture of water vapour and coal combustion products – sulphur dioxide.

Smog is excessive air pollution with harmful substances, mainly microparticles, released as a result of industrial production, transportation, and heat-generating facilities under certain weather conditions.

According to the World Health Organization, air pollution causes around 7 million premature deaths annually, which makes the smog problem one of the most acute in urban ecology.

The main cause of smog formation is air pollution and the inability to disperse suspended particles within the boundaries of large cities and industrial centres. This process can occur in any climatic and natural conditions, but it is most pronounced in areas that are protected from winds by natural barriers such as mountains, hills, and elevated regions. Smog reaches its highest concentration during the cool morning hours, and by noon, when the surface of the earth warms up, the suspended particles gradually dissipate, rising with the air currents. Under normal conditions, the air temperature increases with altitude, but during an anomaly, the upper layers of the air masses remain warm enough to prevent this process, stopping the vertical circulation of the air. As a result, the polluted air remains stationary, creating a hazy veil.

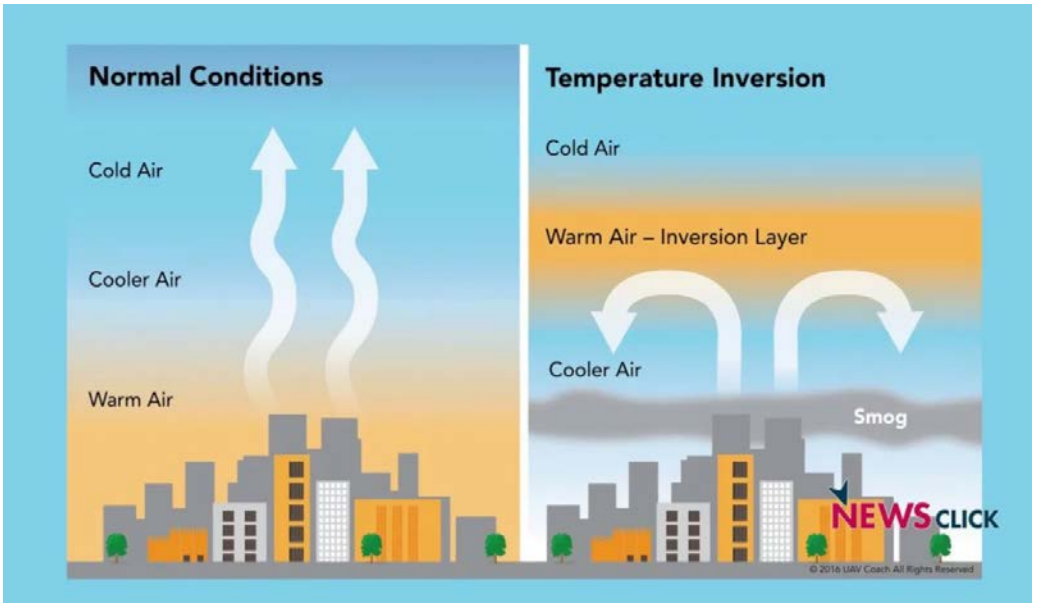


Figure 1. Smog formation due to temperature inversion

2. Types of smog

2.1. Primary smog (London type) [1, p. 220]

Primary smog is a visible air pollution – a thick mixture of smoke, fog and dust with a high concentration of primary pollutants. Londoners call it “pea soup” because of its characteristic black and yellow colour.

Primary smog is called “London type” for a reason. Firstly, the term «smog» was introduced by London doctor Henry Antoine de Voeux in connection with the London

situation. Secondly, a vivid historical example is the Great Smog of London in December 1952. It lasted about five days and was caused by frost, calm weather, temperature inversion, and mass coal burning. The environmental disaster led to an increase in deaths, with initial reports of 4,000 deaths, later revised to 12,000. Thousands of people suffered from respiratory and cardiovascular diseases. Transportation came to a standstill, and performances and movie screenings were cancelled en masse. This disaster led to the enactment of the Clean Air Act in 1956, which restricted the burning of dirty fuels in urban areas. The Clean Air Act introduced smoke control areas and promoted the transition to smokeless fuels in urban areas. British power plants were urgently converted to use alternative fuels. Citizens were provided with subsidies to convert their home coal stoves.

It most often occurs in autumn and winter, when high humidity and low temperatures occur, when calm or light winds, combined with temperature inversion, do not allow pollutants to disperse.

Air humidity plays a key role in the formation of smog, especially the primary type. High humidity (70-80 %) promotes the transition of gaseous pollutants into the liquid phase - fog droplets, which serve as micro-reactors in which dissolved gases enter into chemical reactions. Fog droplets also retain products, preventing them from dispersing. High humidity also promotes the swelling of hygroscopic particles (sulphates, nitrates, soot), which leads to an increase in their size and mass. Such particles remain suspended in the near-surface layer for a longer time and scatter light more strongly, which leads to a decrease in visibility.

At low humidity (less than 40 %), gaseous pollutants oxidise more slowly, and small particles aggregate less. Therefore, primary smog is typical for wet and cold weather in autumn and winter.

The main sources of pollution are coal-fired thermal power plants, boiler houses, household stoves, and industrial enterprises that burn sulfur-containing fuels such as coal and fuel oil.

Primary smog includes sulphur dioxide (SO_2), particulate matter (soot, ash, and dust), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x), and polycyclic aromatic hydrocarbons (PAHs). In modern air quality monitoring, particulate matter is commonly classified as PM_{10} and $PM_{2.5}$. These fine particles are especially important from a health perspective because they can penetrate deep into the respiratory system and contribute to respiratory and cardiovascular diseases. This type of pollution is formed by burning fuel that contains sulphur dioxide (SO_2).

Primary smog is formed by burning fuel that contains sulphur dioxide (SO_2). sulphur dioxide is then oxidised by ozone to sulphur trioxide (SO_3), which reacts with moist air to form sulphuricacid (H_2SO_4). Eventually, tiny droplets of sulphuricacid mix with fog, soot, and dust, forming a dense haze.

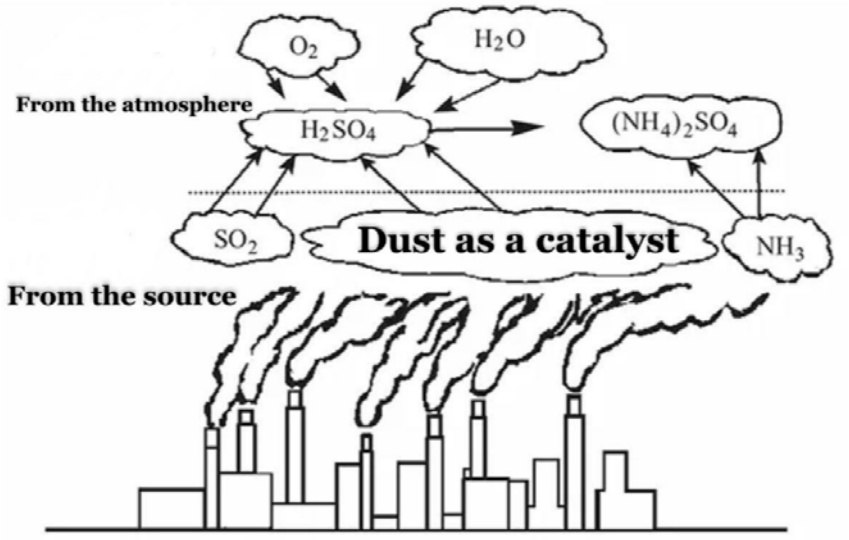


Figure 2. Primary smog formation scheme

This smog can be easily recognized by its dense, opaque, yellowish-grey or black-and-yellow colour , along with a pungent sulphur smell, burning eyes, and a scratchy throat. This phenomenon also significantly reduces visibility.

2.2. Secondary smog (photochemical, Los Angeles type) [2, p. 10]

Secondary smog is fundamentally different from primary smog, as it is not directly produced from emissions, but rather results from complex chemical reactions triggered by solar radiation. This type of smog is most commonly found in large cities with heavy traffic and sunny weather conditions.

Photochemical smog is also known as “Los Angeles type” for a reason. In 1943, residents of Los Angeles experienced a sudden decrease in visibility and irritation of their mucous membranes. The symptoms were not similar to those caused by regular smoke or fog. At that time, people realized that this was a new phenomenon. Scientists studied the composition of the air and described the mechanism of the photochemical reactions that took place in it. This problem was the most typical and acute for Los Angeles, which is why this type of smog was called “Los Angeles type”.

The key condition for its formation is intense ultraviolet radiation, which triggers photochemical reactions in the atmosphere.

The source of the initial substances for these reactions is the exhaust gases of cars, emissions from industrial enterprises and power plants. Nitrogen oxides (NO, NO_2) and volatile organic compounds (VOCs) - hydrocarbons, aldehydes and other substances evaporating from fuel, paints and solvents - enter the air.

Nitrogen oxides form ozone under the influence of ultraviolet radiation, and hydrocarbons break down into various radicals.

Ground-level ozone (O_3) is a key secondary pollutant of photochemical smog. It is not emitted directly from industrial stacks or vehicle exhaust systems, but forms in the atmosphere through reactions between nitrogen oxides (NOx) and volatile organic compounds (VOCs) in the presence of sunlight. Therefore, its concentration can be considered one of the main indicators of photochemical smog.

The products of photochemical reactions accumulate in the air, especially during bright sunlight during the day. In the evening, when solar activity decreases, the reactions slow down, but the accumulated pollutants remain in the atmosphere.

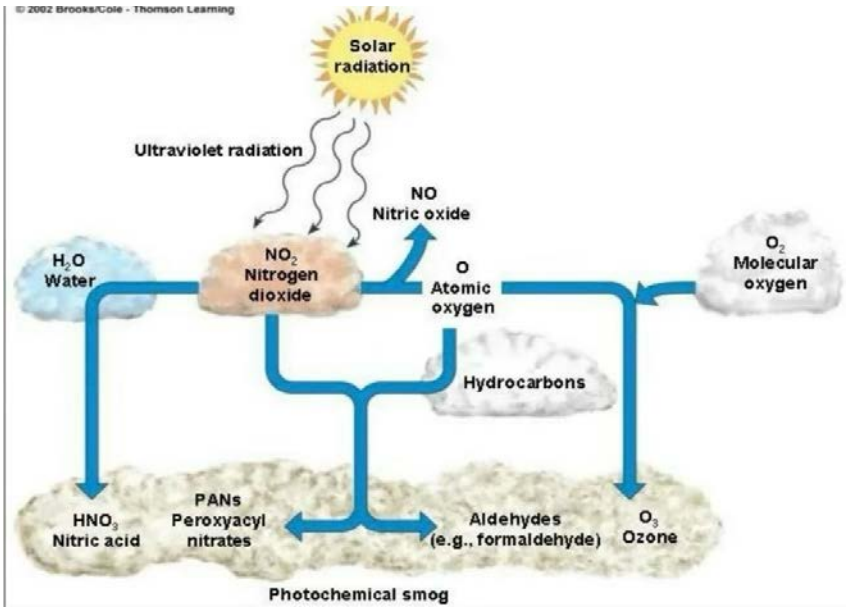


Figure 3. Secondary smog formation scheme

Secondary smog appears as a light blue or brownish haze (the brown colour is caused by nitrogen dioxide). Visibility is reduced, but not as severely as in primary smog. There is often a strong odor due to the presence of ozone and aldehydes in the air.

This type of smog also causes acid rain, the destruction of polymers and rubber products.

3. The impact of smog on the environment

The two main types of smog are interconnected, although they differ in their formation mechanisms and dominant pollutants. Both forms of air pollution have a negative impact on the environment and human health. Particles contained in London-type smog may provide surfaces for further atmospheric reactions, which links combustion-related pollution with photochemical processes.

The soot that makes up primary smog settles on the soil and water bodies. It increases acidity and accumulates carcinogens, which reduces crop yields and inhibits root systems. In water bodies, it leads to the poisoning of aquatic organisms and slows down the photosynthesis of phytoplankton. Primary smog is also dangerous for humans. It causes persistent coughing and allergies, and prolonged exposure can lead to the development of chronic respiratory and cardiovascular diseases [3, p. 115].

Ozone, which is a component of secondary smog, is a strong oxidising agent. Even at low concentrations, it causes leaf necrosis, premature aging, and a sharp decline in forest ecosystems. At high concentrations, it destroys chlorophyll and disrupts photosynthesis. It also contributes to the formation of acid rain, which leads to the acidification of soils and water bodies. Secondary smog also has an impact on human health. It causes watery eyes and irritation of the mucous membranes. At higher

concentrations, it causes respiratory edema and leads to the development of respiratory diseases [4, p. 96].

Saint Petersburg is a historical city with many architectural monuments and heritage buildings. Acid precipitation has a devastating effect on them, especially if the structure is made of marble or limestone. Therefore, air pollution and acid precipitation are particularly relevant for Saint Petersburg, as they may damage historical buildings, marble, limestone, paints, coatings and polymers.

Some pollutants associated with smog formation, such as black carbon, ozone precursors and carbon dioxide, may also contribute to climate-related effects. However, smog should primarily be considered as a problem of urban air quality, public health and ecosystem damage.

4. Ways to solve the problem

4.1. Legislative measures

To improve air quality, several key legislative instruments are identified:

- Setting air quality standards and maximum permissible emissions for industrial facilities, transportation, and other sources of pollution, which include requirements for gas purification, restrictions on the use of high-emission fuels, and monitoring compliance with environmental standards.
- The introduction of adverse weather conditions (AWCs), in which it is recommended that enterprises reduce their emissions by 15-60 % or even completely stop them when there is a calm, temperature inversion, or other conditions that prevent the dispersion of emissions.
- Adoption of international agreements obliging countries to reduce greenhouse gas and pollutant emissions. The Convention on Long-Range Transboundary Air Pollution (1979) and its protocols oblige countries to reduce emissions of sulphur dioxide, nitrogen oxides, ammonia, and VOCs. Russia has a Low-Emission Strategy for Socio-Economic Development until 2050, which aims to reduce emissions to 70% of 1990 levels by 2030.
- Economic instruments include fees for negative environmental impact and tax incentives. Fees for negative environmental impact are based on the principle that the higher the emissions, the higher the fees. Tax incentives encourage the use of clean technologies.

4.2. Technological measures

Modern technological solutions aimed at reducing industrial and transport emissions include [5, p. 120-180]:

- One of the long-term solutions is the transition to cleaner energy sources. The replacement of coal-fired power plants with solar, wind or geothermal energy reduces direct emissions of sulphur dioxide, soot and nitrogen oxides from power generation. However, this measure requires large investment and cannot be implemented immediately.
- Another important direction is the modernisation of industrial plants and the use of gas purification systems. For example, wet limestone scrubbers are used to remove sulphur dioxide from flue gases. In this process, gases pass through a limestone slurry, and the reaction product can be used to produce gypsum. Such systems can remove up to 90–95 % of sulphur dioxide, although they consume energy and may generate wastewater.

– Transport emissions can be reduced by using modern exhaust gas treatment systems. In petrol engines, three-way catalytic converters reduce nitrogen oxides to nitrogen and oxidise carbon monoxide and unburned hydrocarbons to carbon dioxide and water vapour. Diesel engines usually require a more complex system, including oxidation catalysts, particulate filters and selective catalytic reduction systems.

– Industrial combustion processes also need to be controlled. The formation of nitrogen oxides can be reduced by optimising combustion conditions, using staged combustion, low-NO_x burners and selective catalytic reduction. These methods are effective, but their implementation may be limited by the cost of catalysts and the need for regular maintenance.

4.3. Public measures

Social and public initiatives play an important role in reducing the environmental footprint of cities [6, p. 123]:

– Informing the public about air quality and preventive measures through special applications and SMS (alerts about periods of high pollution, recommendations to limit outdoor activities). On days of high pollution, it is recommended to limit outdoor activities, use masks and respirators, and avoid ventilating rooms.

– Reduced electricity consumption reduces the load on coal- and fuel-oil-fired power plants and associated emissions.

– Support for environmental initiatives. Participation in actions aimed at reducing air pollution.

– Refusal to burn garbage and leaves in residential areas. Burning leaves and plastic releases dioxins, furans, PAHs, and soot, which drastically worsen air quality and contribute to smog formation. The alternative is composting the foliage in the adjoining territories.

4.4. Infrastructure solutions

Long-term improvement of the urban environment requires the following infrastructure changes [7, p. 218]:

– Creation of traffic systems that reduce traffic jams. For example, traffic light systems with adaptive control, dedicated lanes for public transport, the organisation of “green waves” (a system of synchronized traffic lights on the highway, which is organized in such a way that a car moving at the recommended speed passes through successive intersections without stopping at a red light) reduce the time that cars spend in traffic jams, and therefore reduce emissions from idling engines.

– Development of public transport, bicycle and pedestrian networks. Popularization of using public transport, bicycles and walking instead of private cars.

– Urban greening and creation of forest parks. Plants absorb pollutants and contribute to improving air quality. In addition, green spaces reduce the temperature of urban air, which reduces the rate of photochemical reactions in secondary smog. However, some trees, such as poplar, release biogenic VOCs, which can increase the formation of ozone under certain conditions.

– Using sprinklers to deposit dust and smog particles on roads.

4.5. Prioritization of mitigation measures for St. Petersburg

Given the transport-dominated emission profile (67.3 %) and the northern maritime climate of Saint Petersburg, the following matrix summarizes the feasibility and impact of key interventions.

Table 1. Prioritization matrix of air pollution mitigation measures for Saint Petersburg

Measure	Environmental effectiveness	Implementation cost	Timeframe	Relevance to SPb
Expansion of electric public transport	High	High	3–5 years	Very high
Low-emission zones in the city center	High	Low	1–2 years	High
Adaptive traffic control & “green waves”	Medium	Low	1–2 years	High
Industrial flue gas scrubbers	High	Very High	5–7 years	Medium
Strategic urban greening (low-VOC species)	Medium	Low	2–4 years	Medium

Note: The ratings are based on the authors’ qualitative assessment of the emission structure of Saint Petersburg and the expected feasibility of the proposed measures.

5. Dynamics of emissions of polluting substances into the atmospheric air of Saint Petersburg

Table 2. Dynamics of emissions of polluting substances into the atmospheric air of Saint Petersburg

Indicator	2019	2024	Change
Emissions from motor vehicles, thousand tons	134,0	140,2	+6,2 thousand tons/ +4,6 %
Emissions from stationary sources, thousand tons	66,9	66,9	No change
Total emissions from stationary and mobile sources, thousand tons	202,0	208,4	+6,4 thousand tons/ +3,2 %
Share of motor transport in total emissions	66,3 %	67,3 %	+1 %
Air pollution level	Low	Low	Increased in 2020–2023; low again in 2024

Source: Compiled by the authors based on the Territorial Observation System (2019) and the Socioeconomic Development Strategy of St. Petersburg (2024)

A comparison of official data for 2019 and 2024 shows that the total amount of pollutants emitted into the atmospheric air of St. Petersburg increased from 202.0 to 208.4 thousand tons, or approximately 3.2 %. The main contributor to air pollution is motor transport, which accounted for 67.3 % of the total emissions in 2024. This confirms the relevance of considering secondary or photochemical smog, as road transport is one of the main sources of nitrogen oxides and volatile organic compounds that participate in photochemical reactions to form secondary pollutants.

6. Conclusion

The analysis of data for 2019–2024 shows that total air pollutant emissions in Saint Petersburg increased by 3.2 %, while the share of motor vehicles reached 67.3 % in 2024. This indicates that road transport remains the dominant source of urban air pollution and makes photochemical, or secondary, smog a relevant risk for the city, especially during periods of high solar radiation and weak pollutant dispersion. In colder months, primary smog associated with sulphur dioxide and particulate matter may also occur under temperature inversion and calm wind conditions.

The impact of smog on Saint Petersburg is not limited to public health risks, such as respiratory and cardiovascular diseases. Air pollution and acid precipitation may also accelerate the deterioration of historical façades made of marble, limestone and other stone materials.

Based on the proposed prioritisation matrix, the most relevant short- and medium-term measures include low-emission zones in the city centre, adaptive traffic control systems, strategic urban greening with low-VOC tree species and the gradual expansion of electric public transport. During unfavourable meteorological conditions, prompt public notification, temporary restrictions on private vehicle use and reduced industrial loads remain necessary operational responses.

The limitation of this study is that it relies on aggregated emission data and does not include ground-level concentrations of PM2.5, ozone or nitrogen dioxide. Further research should include seasonal monitoring data and comparison with similar northern European cities.

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При написании статьи были применены технологии искусственного интеллекта.

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УДК 66.095.132

ESTERS OF HERBARUMIN I AND STAGONOLIDE K: SYNTHESIS AND EVALUATION OF THEIR BIOLOGICAL ACTIVITY

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Abstract. This article discusses methods for synthesizing nonenolide esters. Herbarumin I and stagonolide K, both isolated from the fungal strain *Stagonospora cirsii* S-47, were used as starting compounds. The biological activity of the resulting compounds and the correlation between the length of the acid residue and the properties exhibited are also examined.

Keywords: esterification, esters, Steglich, herbarumin I, stagonolide K, bioactivity.

СЛОЖНЫЕ ЭФИРЫ ГЕРБАРУМИНА I И СТАГОНОЛИДА K: СИНТЕЗ И ОЦЕНКА ИХ БИОЛОГИЧЕСКОЙ АКТИВНОСТИ

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Аннотация. В статье обсуждаются методы синтеза сложных эфиров ноненолидов. В качестве исходных соединений использовались гербарумин I и стагонолид K, выделенные из штамма гриба *Stagonospora cirsii* S-47. Также рассматривается биологическая активность полученных соединений и корреляция между длиной кислотного остатка и проявляемыми свойствами.

Ключевые слова: этерификация, сложные эфиры, Стеглих, гербарумин I, стагонолид K, биологическая активность.

Introduction

The existing herbicides have high toxicity and negatively impact the environment, therefore, exploring the synthetically modified derivatives of natural

compounds which demonstrate a wide spectrum of biological activity is of particular interest. As such natural compounds, esters have attracted researchers' attention, because they show activity in a wide range of interactions with organisms, react or stop enzymes, participate in the regulation of plant growth, are used for effective drug delivery to target tissues as prodrugs [1]. Their derivatives exhibit their properties due to the structure of the hydroxyl and carboxyl group donor. Thus, by using acids and alcohols with different carbon chain structures in synthesis, one can develop a theory for future synthesis [2].

Therefore, the aim of our work is to synthesize ester derivatives of herbarumin I (**1**) and stagonolide K **2**, evaluate their biological activity and evaluate the correlation of the herbicidal properties of the compounds depending on the length of the acid residue in the ester group.

Materials and Methods

The phytopathogenic fungus *Stagonospora cirsii* S-47 was used as a source of the starting compounds. The nonenolides it produces exhibit diverse structures and biological activities.

For submerged cultivation of *S. cirsii* S-47, a YMG medium consisting of glucose, maltose extract, and yeast extract was used. Cultivation was carried out for 7 days at 24°C. Upon completion, the culture fluid was filtered and then extracted with ethyl acetate.

Primary separation of the extract was performed by column chromatography on normal-phase silica gel. Elution was carried out sequentially with hexane-ethyl acetate systems.

Final purification of individual compounds from the obtained fractions was performed by preparative high-performance liquid chromatography (HPLC) using a chromatographic system consisting of a pump (Quaternaty Gradient Module 2545), detector (UV/Visible Detector 2489), and fraction collector (Fraction Collector III, Waters, USA). Purification was performed on an XBridge Prep C18 column with 5 μm particle size, column dimensions 19 × 150 mm (Waters, USA), elution with acetonitrile: 0.1 % aqueous formic acid in a ratio of 35:65 at 20°C, flow rate 24 ml/min, Rt 7.86 min, detection 190 and 234 nm.

The preparation of formates, valerates, and pelargonates of compounds **1** and **2** was carried out by the Steglich esterification method using dicyclohexylcarbodiimide (DCC) and 4-N,N-dimethylaminopyridine (DMAP), using dichloromethane as a solvent [3]. Since one of the reaction products is stable and solid dicyclohexylurea (DCU), this allows for complete conversion of nonedolides and acids [4].

The process was carried out according to the following methodology (Figure 1). A weighed sample of nonenolide was dissolved in dichloromethane to obtain a solution with a concentration of 10 mg/mL. The carboxylic acid and a mixture of DCC and DMAP were then sequentially added. The ratio of nonenolide, acid, dicyclohexylcarbodiimide, and catalyst was 20:40:40:1, respectively. The mixture was stirred for 4 hours at room temperature, evaporated, and redissolved in cold diethyl ether and after it was then filtered through a syringe filter to remove the solid DCU. The resulting mixture was separated by column chromatography, eluting with hexane

and ethyl acetate. Fractions enriched in the reaction products were further purified using a high-performance liquid chromatography.

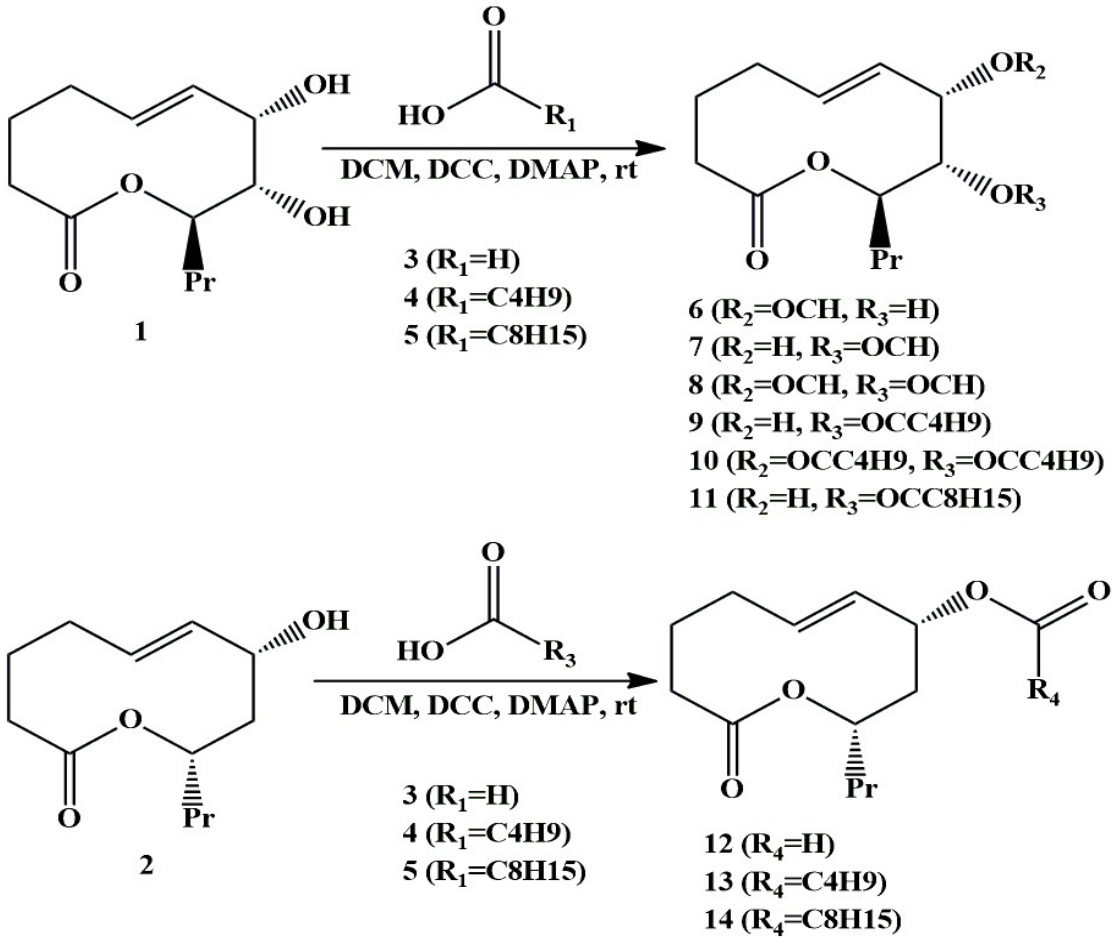


Figure 1. Este rification of herbarumin I (**1**) and stagonolide K **2** according to the Steglich method

Acylation of alcohols with carboxylic acid anhydrides is a nucleophilic addition mechanism followed by acid elimination. This method is used primarily to obtain esters that are difficult or impossible to obtain by esterification reactions [5].

Acetate derivatives of compounds **1** and **2** were obtained using the following procedure: a sample of nonenolide was dissolved in pyridine, after that acetic anhydride was added, further this mixture was stirred for 5 hours at room temperature (Figure 2). After the reaction was completed, 10 % hydrochloric acid was added to the solution, which was then transferred and extracted three times with ethyl acetate. The organic layer was washed with water until the washings were neutral. The resulting mixture was cleaned by column chromatography, using an eluent consisting of hexane and ethyl acetate. Fractions enriched in the reaction products were further purified using a high-performance liquid chromatograph.

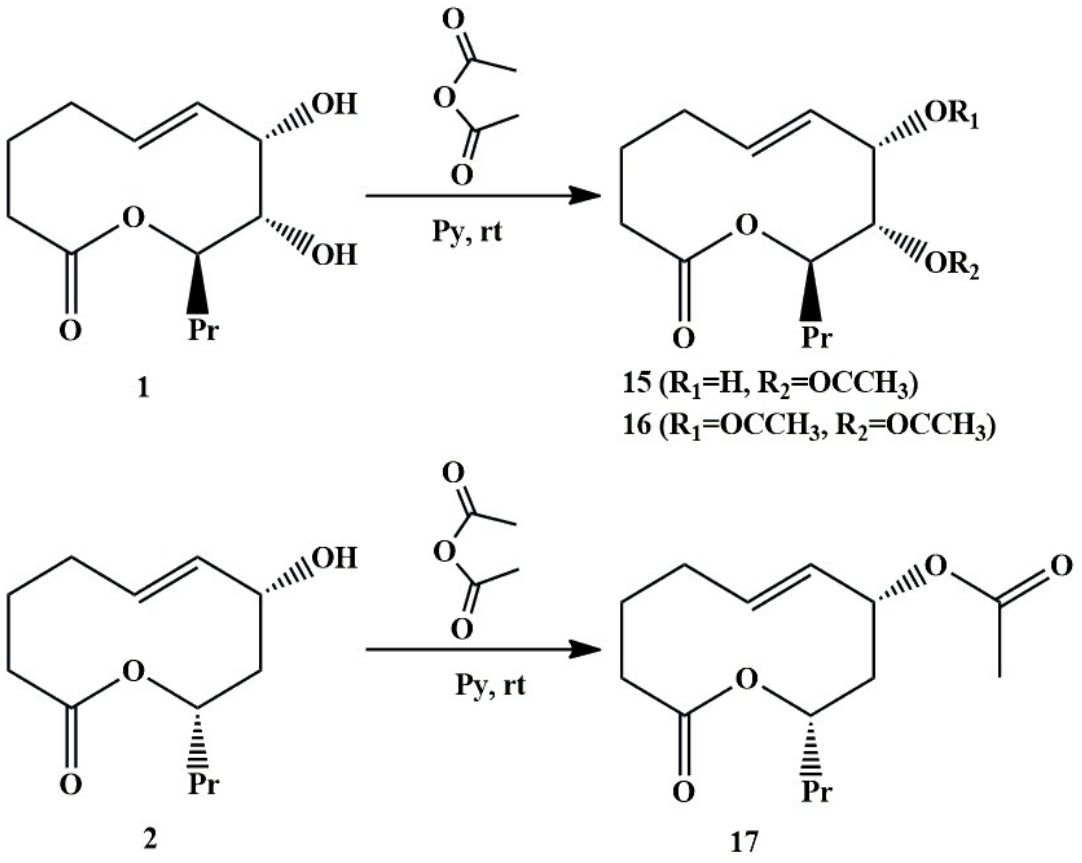


Figure 2. Acylation of herbarumin I (**1**) and stagonolide K **2** with acetic anhydride

The structure of the obtained compounds was confirmed using ^{1}H, ^{13}C NMR and correlation spectroscopy.

(7S, 8S, 9R)-7-formioxy-8-hydroxy-9-propyl-nonane-9 olide (**6**). Product **6** was obtained as a colorless oil (30.27 mg load of **1**; 22.3% yield); ^{1}H NMR (400 MHz, CDCl3): 0.94 (t, 3H, 3J 7.4 Hz, CH3-12), 1.26-1.43 (m, 2H, CH2 11), 1.49-1.59 (m, 1H, H-4a), 1.72-1.79 (m, 1H, H-3a), 1.79-1.85 (m, 1H, H-4b), 1.86 1.93 (m, 1H, H-3b), 1.94-1.99 (m, 1H, H-10a), 2.00-2.07 (m, 1H, H-2a), 2.08-2.13 (m, 1H, OH-8), 2.34-2.40 (m, 2H, H-2b, H-10b), 3.76-3.81 (m, 1H, H-8), 5.20 (dd, 1H, 2J 5.54 Hz, 2J 2.9 Hz, H-9), 5.38-5.45 (m, 1H, H-5), 5.58 (d, 2J 15.7 Hz, 1H, H-6), 5.68 5.73 (m, 1H, H-7), 8.28 (s, 1H, H-13); ^{13}C NMR (100 MHz, CDCl3): δC 13.94 (C-12), 17.64 (C 11), 24.46 (C-3), 33.41 (C-10), 33.70 (C-4), 34.54 (C-2), 70.41 (C-9), 72.31 (C-8), 74.66 (C-7), 125.29 (C-5), 126.33 (C-6), 160.72 (C 13), 175.02 (C-1).

(7S, 8S, 9R)-7-hydroxy-8-formioxy-9-propyl-nonane-9 olide (**7**). Product **7** was obtained as a colorless oil (30.27 mg load of **1**; 22.4% yield); ^{1}H NMR (400 MHz, CDCl3): 0.91 (t, 3H, 3J 7.4 Hz, CH3-12), 1.26-1.40 (m, 2H, CH2 11), 1.46-1.53 (m, 1H, H-10a), 1.54-1.61 (m, 1H, H-10b), 1.62-1.64 (m, 1H, H-3a), 1.74-1.80 (m, 1H, H-3b), 1.87-1.96 (m, 1H, H-4a), 1.97-2.02 (m, 1H, H-2a), 2.20-2.22 (m, 1H, OH-7), 2.34-2.39 (ddd, 2J 14.1 Hz, 2J 5.8 Hz, 2J 2.3 Hz, 1H, H-2b), 2.42-2.46 (m, 1H, H-4b), 4.49 (d, 2J 7.9 Hz, 1H, H-7), 5.01 (dd, 2J 10.25 Hz, 2J 1.2 Hz, 1H, H-8), 5.36 (td, 3J 9.8 Hz, 2J 3.1 Hz, 1H, H-9), 5.60-5.65 (m, 2H, H-5, H-6), 8.16 (s, 1H, H 13); ^{13}C NMR (100 MHz, CDCl3): δC 13.77 (C-12), 17.67 (C 11), 24.52 (C-3), 33.08 (C-10), 33.35 (C-4),

34.36 (C-2), 67.25 (C-9), 71.03 (C-7), 74.17 (C-8), 126.07 (C-5), 129.65 (C-6), 159.72 (C 13), 175.92 (C-1).

(7S, 8S, 9R)-7,8-diformioxy-9-propyl-nonane-9 olide (**8**). Product **8** was obtained as a colorless oil (30.27 mg load of **1**; 20.1% yield); ^{1}H NMR (400 MHz, CDCl3): 0.92 (t, 3H, 3J 7.4 Hz, CH3-12), 1.29-1.36 (m, 2H, CH2 11), 1.40-1.49 (m, 1H, H-4a), 1.54-1.59 (m, 1H, H-4b), 1.74-1.81 (m, 1H, H-3a), 1.85 1.96 (m, 1H, H-3b), 1.97-2.10 (m, 2H, CH2-2), 2.36-2.42 (m, 2H, CH2-10), 5.10 (d, 1H, 10.3 Hz, H-7), 5.45 (td, 3J 9.7 Hz, 2J 2.9 Hz, 1H H-8), 5.50 (dq, 2J 10.8 Hz, 4J 2.1 Hz, 1H, H-9), 5.60 (d, 2J 15.7 Hz, 1H, H-5), 5.83 (s, 1H, H-6), 8.03 (s, 1H, H-13), 8.22 (s, 1H, H-14); ^{13}C NMR (100 MHz, CDCl3): δC 13.82 (C-12), 17.44 (C 11), 24.34 (C-3), 33.21 (C 4), 33.34 (C-10), 34.43 (C-2), 68.15 (C-8), 70.65 (C-9), 71.51 (C-7), 125.63 (C-5), 126.21 (C-6), 159.48 (C-14), 159.84 (C-13), 174.83 (C-1).

(7S, 8S, 9R)-7-hydroxy-8-nonanooxy-9-propyl-nonane-9 olid (**11**). Product **11** was obtained as a colorless oil (29.92 mg load of **1**; 41.6% yield); ^{1}H NMR (400 MHz, CDCl3): 0.85-0.95 (m, 6H, CH3-12, CH3-21), 1.21-1.41 (m, 12H, CH2-20, CH2-18, CH2-17, CH2-16, CH2-19, CH2-11), 1.43-1.57 (m, 2H, H-4), 1.61 1.70 (m, 2H, H-15), 1.71-1.80 (m, 1H, H-3a), 1.84-1.94 (m, 1H, H-3b), 1.95-2.09 (m, 2H, H-2b, H-10a), 2.14 (s, 1H, OH-7), 2.30-2.46 (m, 4H, H-10b, H-14, H-2b), 4.43 (s, 1H, H-9), 4.88 (dd, 1H, 2J 10.1, 2J 2 Hz, H-8), 5.33 (td, 3J 9.44 Hz, 2J 3.0 Hz, 1H, H-7), 5.54-5.65 (m, 2H, H-6, H-5); ^{13}C NMR (100 MHz, CDCl3): δC 13.81 (C-12), 14.06 (C-21), 17.68 (C 11), 22.62 (C 20), 24.53 (C-3), 24.96 (C-15), 29.10 (C-16), 29.11 (C-18), 29.19 (C-17), 31.78 (C-19), 33.19 (C-4), 33.36 (C-2), 34.40 (C-10), 34.42 (C-14), 67.58 (C-7), 71.15 (C-9), 74.40 (C-8), 125.63 (C-5), 130.10 (C-6), 172.68 (C-13), 175.90 (C-1).

(7R, 9R)-7-formioxy-9-propyl-nonane-9 olide (**12**). Product **12** was obtained as a colorless oil (29.94 mg load of **2**; 54.1% yield); ^{1}H NMR (400 MHz, CDCl3): 0.92 (t, 3H, 3J 7.3 Hz, CH3-12), 1.25-1.39 (m, 2H, CH2 11), 1.41-1.61 (m, 2H, H-10), 1.80-1.84 (m, 1H, H-3a), 1.84-1.91 (m, 2H, H-8), 1.91 1.97 (m, 1H, H-4a), 1.98-2.02 (m, 1H, H-2a), 2.03-2.09 (m, 1H, H-4b), 2.29- 2.42 (m, 2H, H-3b, H-2b), 5.13 (m, 1H, H-9), 5.27 (td, 3J 10.1 Hz, 2J 4.3 Hz, 1H, H-7), 5.43-5.52 (m, 1H, 3J 15.6, 1.2 Hz, H 5), 5.58-5.71 (m, 1H, H-6) 7.98 (s, 1H, H-13); ^{13}C NMR (100 MHz, CDCl3): δC 13.80 (C-12), 18.25 (C 11), 26.11 (C-3), 33.45 (C 4), 34.58 (C-2), 37.63 (C-10), 38.68 (C-8), 70.47 (C-9), 74.39 (C-7), 130.99 (C-5), 133.9 (C-6), 160.05 (C-1), 175.37 (C-13).

(7R, 9R)-7-pentanooxy-9-propyl-nonane-9 olide (**13**). Product **13** was obtained as a colorless oil (30.02 mg load of **2**; 77% yield); ^{1}H NMR (400 MHz, CDCl3): 0.93 (t, 6H, 3J 7.3 Hz, CH3-12, CH3-17), 1.27-1.38 (m, 4H, CH2-11, CH2-16), 1.40-1.54 (m, 2H, H-10), 1.54-1.63 (m, 2H, H-15), 1.72-1.83 (m, 2H, H-8a, H-3a), 1.84-1.90 (m, 1H, H-8b), 1.91-1.97 (m, 1H, H-4a), 1.97-2.08 (m, 2H, H-2a, H-4b), 2.26 (t, 3H, 3J 7.7 Hz, H-3b, H-14), 2.29- 2.39 (m, 1H, H-2b), 5.07 5.12 (m, 1H, H-9), 5.15 (td, 3J 10.2 Hz, 2J 3.8 Hz, 1H, H-7), 5.36-5.48 (dd, 1H, 2J 15.4, 2 J 9.5 Hz, H 5), 5.56-5.66 (m, 1H, H-6); ^{13}C NMR (100 MHz, CDCl3): δC 13.72 (C-12), 13.81 (C-17), 18.26 (C 11), 22.23 (C 16), 26.16 (C-3), 26.97 (C-15), 33.52 (C-4), 34.31 (C-14), 34.61 (C-2), 37.68 (C-10), 38.75 (C-8), 70.69 (C-9), 74.30 (C-7), 131.61 (C-5), 133.19 (C-6), 172.76 (C-13), 175.37 (C-1).

(7R, 9R)-7-nonanoxy-9-propyl-nonane-9 olide (**14**). Product **14** was obtained as a colorless oil (30.07 mg load of **2**; 81% yield); ^{1}H NMR (400 MHz, CDCl3): 0.85-0.94 (m, 6H, CH3-12, CH3-21), 1.22-1.37 (m, 12H, CH2-20, CH2-18, CH2-17, CH2-16, CH2-19, CH2-11), 1.39-1.48 (m, 1H, H-10a), 1.48-1.54 (m, 1H, H-10b), 1.55-1.63 (m, 2H, H-15), 1.72-1.78 (m, 1H, H-8a), 1.79-1.83 (m, 1H, H-3a),1.84-1.90 (m, 1H, H-8b), 1.91-1.96 (m, 1H, H-4a), 1.97-2.08 (m, 2H, H 4b, H-3b), 2.24 (t, 2H, 3J 7.5 Hz, H-14), 2.30- 2.38 (m, 2H, H-2), 5.07-5.12 (m, 1H, H 9), 5.15 (td, 3J 10.3 Hz, 2J 3.7 Hz, 1H, H-7), 5.36-5.48 (dd, 1H, 2J 15.4, 2J 9.4 Hz, H 5), 5.56-5.65 (m, 1H, H-6); ^{13}C NMR (100 MHz, CDCl3): δC 13.81 (C-12), 14.09 (C-21), 18.26 (C 11), 22.64 (C 20), 24.90 (C-15), 26.16 (C-3), 29.09 (C-18), 29.10 (C-17), 29.19 (C-16), 31.79 (C-19), 33.52 (C-4), 34.59 (C-14), 34.61 (C-2), 37.68 (C-10), 38.76 (C-8), 70.69 (C-9), 74.28 (C-7), 131.61 (C-5), 133.17 (C-6), 172.77 (C-13), 175.38 (C-1).

(7S, 8S, 9R)-7-hydroxy-8-acetoxy-9-propyl-nonane-9 olide (**15**). Product **15** was obtained as a colorless oil (31.58 mg load of **1**; 34.8% yield); ^{1}H NMR (400 MHz, CDCl3): 0.91 (t, 3H, 3J 7.2 Hz, CH3-12), 1.25-1.41 (m, 2H, CH2 11), 1.43-1.57 (m, 2H, CH2-10), 1.71-1.80 (m, 1H, H-3a), 1.81-2.13 (m, 3H, H-3b, H 4a, H-2a), 2.15 (s, 3H, CH3-14), 2.31-2.39 (m, 1H, H-2b),2.40-2.46 (m, 1H, H-4b), 4.45 (s, 1H, H-7), 4.88 (dd, 1H, 2J 10.1 Hz, 2J 2 Hz, H-8), 5.29-5.36 (td, 1H, 3J 9.9 Hz, 2 J 2,6 Hz, H-5), 5.52-5.67 (m, 2H, H-6, H-9), 5.65-5.71 (m, 1H, OH-7); ^{13}C NMR (100 MHz, CDCl3): δC 13.79 (C-12), 17.73 (C 11), 21.10 (C-14), 24.54 (C-3), 33.17 (C-10), 33.35 (C-4), 34.38 (C-2), 67.55 (C-9), 71.12 (C-7), 74.74 (C-8), 125.71 (C-5), 130.04 (C-6), 169.95 (C 13), 175.94 (C-1).

(7S, 8S, 9R)-7,8-diacetoxy-9-propyl-nonane-9 olide (**16**). Product **16** was obtained as a colorless oil (31.58 mg load of **1**; 25.3% yield); ^{1}H NMR (400 MHz, CDCl3): 0.91 (t, 3H, 3J 7.2 Hz, CH3-12), 1.25-1.47 (m, 3H, CH2 11, H 10a), 1.49-1.60 (m, 1H, H-10b), 1.71-1.79 (m, 1H, H-3a), 1.81-2.04 (m, 5H, H 4a, H 3b, H-2a), 2.05 (s, 1H, CH3-16), 2.19 (s, 3H, CH3-14), 2.32-2.42 (m, 2H, H-2b, H-4b), 4.92 (dd, 1H, 3 J 2.4, 10.1 Hz, H-8), 5.34-5.47 (m, 2H, H-5, H-9), 5.59 (dd, 1H, 3 J 15.6, 1.2 Hz, H 6), 5.65-5.71 (m, 1H, H-7); ^{13}C NMR (100 MHz, CDCl3): δC 13.92 (C-12), 17.52 (C 11), 20.82 (C-16), 20.89 (C 14), 24.37 (C-3), 33.35 (C-4, C-10), 34.48 (C-2), 68.52 (C-9), 70.96 (C-7), 72.32 (C-8), 125.25 (C-5), 126.87 (C-6), 169.73 (C-15), 170.11 (C 13), 174.83 (C-1).

(7R, 9R)-7-acetoxy-9-propyl-nonane-9 olide (**17**). Product **17** was obtained as a colorless oil (29 mg load of **2**; 66.2% yield); ^{1}H NMR (400 MHz, CDCl3): 0.89 (t, 3H, 3J 7.2 Hz, CH3-12), 1.23-1.37 (m, 2H, CH2 11), 1.28-1.58 (m, 2H, H-10), 1.71-1.82 (m, 2H, H-3), 1.83-1.9 (dq, 1H, 2J 13,6 Hz, 4J 1,7 Hz, H-4a), 1.93-2.08 (m, 5H, CH3-14, H-2), 2.25-2.37 (m, 2H, H-4b, H-2b), 5.04 5.17 (m, 3H, H-8, H-7, H-9), 5.38-5.41 (m, 1H, H-6), 5.52-567 (tt, 3J 10,6 Hz, 3J 4.3 Hz, 1H, H-5); ^{13}C NMR (100 MHz, CDCl3): δC 13.76 (C-12), 18.22 (C 11), 21.30 (C-14), 26.12 (C 3), 33.47 (C-4), 34.57 (C-2), 37.62 (C-10), 38.72 (C-8), 70.162 (C-9), 74.43 (C-7), 131.50 (C-6), 133.27 (C-5), 169.87 (C 13), 175.30 (C-1).

Biological activity testing included a standard set of bioassays, which includes assessment of phytotoxic and antimicrobial activity, acute toxicity to *Paramecium caudatum* and caterpillars *Galleria mellonella*, and inhibition of seed germination.

Bioassays using the *P. caudatum* culture and *G. mellonella* caterpillars can be considered as an acute toxicological assessment. The freshwater ciliate *P. caudatum* is a commonly used test for acute toxicity of wastewater, industrial waste extracts, drilling fluids, and feed [6-7].

The caterpillars of the greater wax moth (*Galleria mellonella*) have been proposed for some time as an inexpensive and easy-to-work-with alternative to the traditional model object in toxicological studies – rodents [8].

To assess the phytotoxic effects of individual compounds, the *Sonchus arvensis* leaf disc puncture assay was used. The sample to be analyzed was first dissolved in a small amount of ethanol, then diluted with water to a target concentration of 2 mg/ml. 1 centimeter diameter cuttings from 3-5-week-old plants were placed in a humid chamber, punctured in the center with a dissecting needle, and 10 μl of the solution was applied to the puncture site. The diameter of necrosis on the sow thistle leaf discs was measured after 48 hours of incubation at 24°C under alternating artificial light (12 hours per day). A 5% ethanol solution was used as a control.

Antimicrobial activity was assessed using the paper disk method at a concentration of 100 μg/disk against *Bacillus subtilis*, *Escherichia coli*, and *Candida albicans*. The diameter of the bacterial growth inhibition zone was measured after 24 hours of incubation at 30°C. Acetone was used as a control.

Acute toxicity to the *Paramecium caudatum* was assessed at a concentration of 100 μg/ml. For this purpose, 500 μl of the paramecium culture (approximately 100 cells/ml) were added to the wells of a 24-well plate. 5 μl of the test substances dissolved in DMSO were added to the paramecium suspension. Paramecium survival was analyzed at 3, 30, and 180 minutes after the start of the experiment. 5% DMSO was used as a control.

Acute toxicity to greater wax moth caterpillars was assessed using the injection method. Ten caterpillars were used for each treatment, and 10 μl of the test substances dissolved in 5% DMSO were injected through the pseudopod of the third pair using an insulin syringe. The caterpillars were placed in a Petri dish with artificial food and incubated at 30°C for two weeks. 5% DMSO was used as a control.

Inhibition of *Lactuca sativa* seed germination was assessed at a concentration of 100 μg/ml. *L. sativa* seeds were sterilized, rinsed with bleach for 1 min, then rinsed with water, and dried. One milliliter of 0.6% aqueous molten agar was added to the wells of a 24-well plate. Fifty microliters of the test substances were added to the solidified agar, and the solvent was allowed to evaporate passively. Five seeds were then placed per well on the agar and incubated in an incubator at 24°C. After three days, seeds with a radicle protruding through the seed coat were considered germinated. The seedling length (from root to shoot) of germinated seeds was measured after freezing. Seeds that did not germinate were not included in the seedling length measurement. Acetone was used as a control.

Results and Discussion

The phytopathogenic fungus *S. cirsii* S-47 produces nonenolides with diverse structures and biological activities. The titers of herbarumin I (**1**) and stagonolides K **2**, A, and J isolated from the fungal culture are 500 mg/kg, 85, 40, and 35 mg/L,

respectively, opening up broad possibilities for the production of semisynthetic derivatives.

Esterification of herbarumin I (**1**) and stagonolide K **2** was carried out with formic acid **3**, valeric acid **4** and pelargonic acid **5** using DCC and DMAP, which are used in esterification according to the Steglich method.

Acylation of herbarumin I (1) and stagonolide K 2 with acetic anhydride in a pyridine solution was successfully accomplished.

The most pronounced phytotoxic activity against *Sonchus arvensis* was demonstrated by **1**, **2**, **6**, **7**, **12**, **15** and **17** with the formation of necrotic spots with a diameter of 4.5 mm, 2.7 mm, 2.4 mm, 2.6 mm, 2.7 mm, 3 mm, and 3.3 mm, respectively (Figure 3).

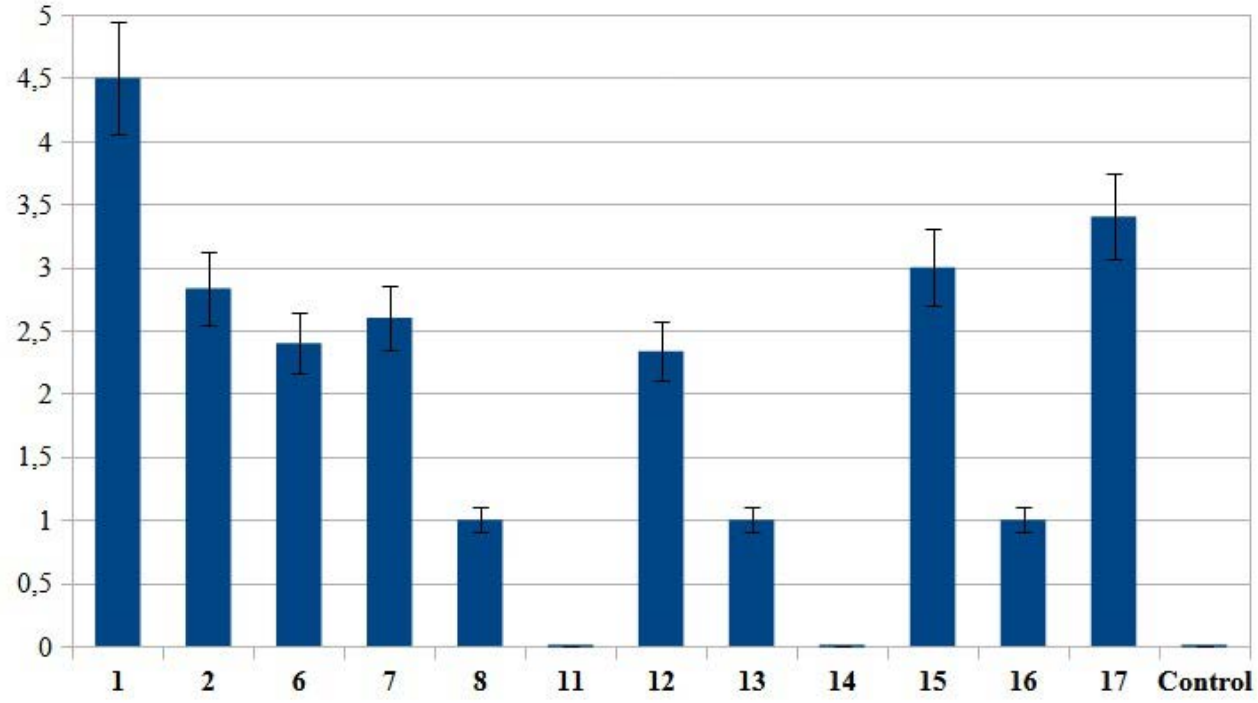


Figure 3. Diameters of necrosis on disc notches of *Sonchus arvensis* treated with the obtained compounds

None of the compounds showed antimicrobial activity against all strains tested.

Compound **13** showed acute toxicity towards the *Paramecium caudatum* 180 minutes after the start of the experiment, but no compound showed significant activity towards the caterpillars of the *Galleria mellonella*.

Compounds **15** and **16** showed the best activity in inhibiting the germination of *Lactuca sativa* seeds (Figure 4).

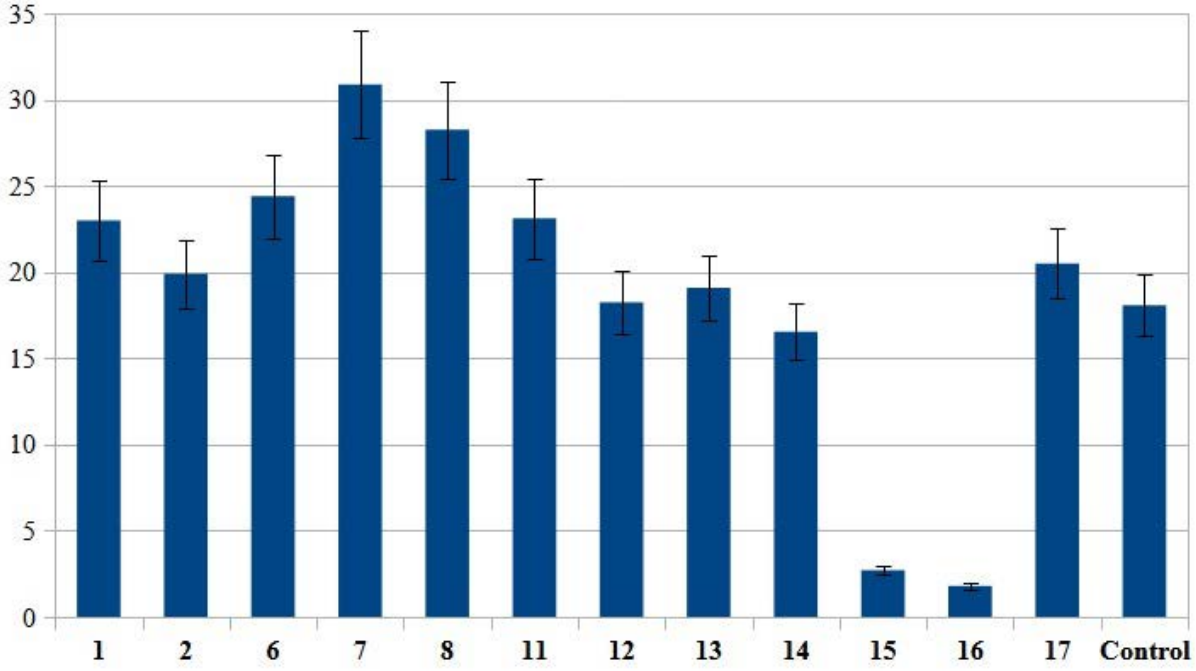


Figure 4. Root length of *Lactuca sativa* seedlings treated with the obtained compounds

Thus, compound **15** exhibited high activity across the entire range of bioassays, with the exception of acute toxicity. Compounds **1**, **2**, **7**, **12**, **13**, and **14** exhibited moderate activity, while compounds **6**, **8**, **11**, and **17** exhibited virtually no activity.

Conclusion

During the study, herbarumin I (**1**) and stagonolide K **2** were isolated from the culture medium of the fungus *Stagonospora cirsii* S-47. Their variously substituted esters were then synthesized by esterification with formic, valeric, and pelargonic acids and acylation with acetic anhydride. The structures of the resulting compounds were determined using ^{1}H, ^{13}C NMR, and correlation spectroscopy.

An assessment of the biological activity of the compounds revealed that formates and acetates of herbarumin I (**1**) and stagonolide K **2** exhibited moderate phytotoxic activity, while herbarumin I (**1**) acetates demonstrated high activity in inhibiting seed germination. Furthermore, the obtained stagonolide K **2** valerate, in addition to moderate phytotoxic properties, demonstrated toxic activity against the *Paramecium caudatum*. A correlation was established between the various herbicidal properties and the structure of the acid involved in the esterification reaction; esters of acids with short and medium carbon chain lengths demonstrated the greatest activity.

Funding

The work was carried out with the financial support of the state program FGEU 2025-0011.

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УДК 004.896:004.032.26

GRAPH NEURAL NETWORKS FOR DYNAMIC WAREHOUSE REPRESENTATION WITH VARIABLE RACK GEOMETRY IN DECISION-MAKING TASKS OF A MOBILE ROBOT

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Abstract. The paper proposes an approach to dynamic warehouse representation based on graph neural networks for mobile robot decision-making under conditions of continuously changing shelf layouts. To describe the current state of the warehouse, a graph model is used in which vertices correspond to storage cells and order picking points, while edges represent route accessibility for robot movement. A graph neural network is applied to analyze the spatial structure and select the optimal movement direction while taking real-time environmental changes into account. The proposed approach is aimed at ensuring stable order picking in unstructured warehouse environments without the need for warehouse reconstruction.

Keywords: graph neural network, dynamic warehouse, mobile robot, decision-making, e-commerce.

ПРИМЕНЕНИЕ ГРАФОВЫХ НЕЙРОННЫХ СЕТЕЙ ДЛЯ ДИНАМИЧЕСКОГО ПРЕДСТАВЛЕНИЯ СКЛАДА С ПЕРЕМЕННОЙ ГЕОМЕТРИЕЙ СТЕЛЛАЖЕЙ В ЗАДАЧАХ ПРИНЯТИЯ РЕШЕНИЙ МОБИЛЬНЫМ РОБОТОМ

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Аннотация. В работе предложен подход к динамическому представлению склада на основе графовых нейронных сетей для принятия решений мобильным роботом в условиях постоянно меняющегося расположения стеллажей. Для описания текущего состояния склада используется модель графа, где вершины соответствуют ячейкам хранения и точкам комплектации заказов, ребра отражают доступность проезда по маршруту. Для анализа структуры пространства и выбора оптимального направления движения применяется графовая нейронная сеть, позволяющая учитывать изменения среды в режиме реального времени. Подход ориентирован на устойчивую комплектацию заказов в неструктурированных складах без переоборудования помещений.

Ключевые слова: графовая нейросеть, динамический склад, мобильный робот, принятие решений, электронная коммерция.

Introduction. Russian e-commerce continues to grow rapidly: online retail volume increased by 28 % in 2025 [1]. This growth coincides with a logistics labour deficit of approximately one million vacancies [2], pushing fulfilment centres towards intensive automation. The Russian robotics market reached 10.3 billion rubles by the end of 2024, while domestic production of industrial robots increased 4.5 times [3]. Demand for warehouse mobile robots has therefore shifted from experimental pilots to operational priority.

A defining feature of typical Russian e-commerce warehouses is the variable geometry of rack systems. Layouts change frequently in response to seasonal SKU mixes, promotional campaigns, and physical reorganization of storage zones. Foreign robotic platforms typically rely on grid-based maps with fixed rack coordinates and floor markings, and their direct deployment in domestic facilities requires costly retrofitting [4]. Conventional occupancy grids and pre-built floorplans become outdated within hours after a layout change, leading to navigation failures and increased intervention rates.

Graph neural networks (GNNs) offer a principled alternative. By representing the warehouse as an attributed graph rather than a metric grid, the system encodes topological relations that remain meaningful even when rack positions shift. The seminal work of Li et al. demonstrated that GNNs can be trained for decentralized multi-robot path planning by exchanging local features along graph edges [5]. Subsequent attention-based extensions, in particular MAGAT, introduced message-dependent attention enabling each agent to weight neighbours selectively [6]. More recently, hierarchical GNN policies coupled with classical optimization have improved throughput on congested warehouse benchmarks by up to 10 % over the 2024 winning baselines [7].

The aim of this paper is to formulate a method of dynamic warehouse representation by a graph neural network in which the rack layout is treated not as a fixed map but as a time-varying graph, and to specify the integration of this representation into the decision-making loop of a mobile warehouse robot. Unlike previous studies of the author dedicated to adaptive trajectory planning, multimodal vision, and discrete route optimization, the present work shifts the centre of attention from metric path computation to topological reasoning over a mutable graph.

1. Limitations of metric maps in dynamic warehouses. Conventional autonomous mobile robot stacks rely on simultaneous localization and mapping algorithms such as Gmapping, Cartographer, or RTAB-Map [8]. These methods produce metric occupancy grids that are well suited for static or slowly changing environments. However, modern Russian e-commerce warehouses violate this assumption: pallets are added and removed on hourly cycles, mezzanines are reconfigured for short campaigns, and shelf reflectivity changes when products are unboxed. Wireless network instability and human operators sharing aisles add further sources of nondeterminism [4].

In a metric representation, every layout change requires either full remapping or manual map editing, which is incompatible with continuous warehouse operations. Even when remapping is performed, the metric map encodes geometry but not the semantics of warehouse operation, namely which cells contain target products, which passages currently allow safe passing of two robots, or which dock has free pickup capacity. These semantic relations are inherently relational and are naturally expressed as a graph.

2. Dynamic graph representation of the warehouse. The proposed representation defines the warehouse as a time-indexed attributed graph $G(t) = (V(t), E(t), X(t))$. The vertex set $V(t)$ contains four classes of nodes: storage cells, aisle segments, intersections, and pickup or dispatch stations. Each node carries a feature vector $x_v(t)$ including occupancy state, current accessibility, target priority within the running order, and a category embedding produced by the perception subsystem. The edge set $E(t)$ encodes spatial reachability between adjacent nodes, with edge attributes describing current passage width, observed traffic density, and recent reliability, the latter computed as a moving average of completed transitions over the last operational window.

Graph reconstruction is performed online from on-board sensor data without external infrastructure. Object detection on RGB and depth streams identifies racks, pallets, and dynamic obstacles; the result is consolidated into a topological skeleton by a graph extraction module. When a rack is moved, the corresponding nodes are not deleted; instead, their attributes are updated and a new edge configuration is induced. This persistent identity of nodes across reconfigurations is essential, since it allows the policy to reuse experience accumulated before the layout change rather than treating the warehouse as a fresh environment.

A natural concern is that pairwise edges may be insufficient when several robots simultaneously affect the same passage. Recent literature addresses this through hypergraph neural networks, which model higher-order group interactions among multiple agents and obstacles [9]. The proposed framework reserves an extension to hypergraph layers for future fleet operation, while the present specification remains within standard pairwise GNNs to keep the architecture deployable on embedded hardware.

3. Graph attention layer for decision-making. Decision-making over the dynamic graph is performed by a graph attention network. Each node aggregates information from its neighbours through learned attention coefficients, allowing the robot to weight nearby aisles more heavily when their reliability is high and to discount passages that have recently caused recovery events. The architecture follows the message-aware graph attention principle of MAGAT [6], in which attention coefficients are computed from the messages themselves rather than from static node features only, providing greater sensitivity to transient warehouse conditions.

The output layer of the network produces, for each candidate target node, an expected utility under the current order context. The robot selects the node with maximum expected utility and delegates the metric trajectory between the current node and the target to the underlying motion planner previously developed by the author. In this way, the GNN does not replace metric planning; it provides a topological controller

above it. This separation is consistent with hybrid architectures combining global guidance with local navigation, where attentive graph networks have been shown to outperform purely reactive baselines such as NH-ORCA and GA3C-CADRL in dynamic multi-agent scenarios [10].

Training is performed by reinforcement learning with imitation pretraining. An expert policy generated offline by classical centralized planners on synthetic warehouse layouts provides demonstrations, after which the GNN policy is fine-tuned through reward signals that penalize collisions, recovery events, and missed deadlines while rewarding completed pickup tasks. This combination follows the practice of recent GNN-based multi-agent pickup-and-delivery systems, in which a GNN policy trained with reinforcement learning outputs an agent distribution over an aggregated warehouse graph and is then refined by lightweight optimization [7].

4. Comparison with international and domestic analogues. International warehouse automation platforms developed by leading vendors typically rely on centralized fleet managers operating over fixed warehouse models with floor markings, structured aisles, and instrumented racks [4]. Such infrastructure is absent in many Russian e-commerce facilities, especially those operated by small and medium fulfilment providers. The proposed dynamic graph representation removes this requirement: the graph is constructed from on-board sensors, and changes to rack geometry are absorbed by attribute updates rather than by external recalibration.

Domestic developments in mobile warehouse robotics, including platforms for sorting and pallet transport, currently focus on metric SLAM and rule-based dispatch [11]. Russian academic work on graph-based environment description has explored interpretable navigation, where the global terrain is encoded as a graph of regions linked by described transitions [12]. The present contribution combines this topological tradition with modern learning-based aggregation, producing a representation that is at the same time interpretable for warehouse operators and trainable from operational data.

Recent industrial trends in Russia confirm the relevance of the approach. By 2030, warehouse robotization is expected to grow under conditions of permanent labour deficit and rising lease costs, with a shift towards solutions that operate in existing facilities rather than purpose-built automated storages [13]. A representation that tolerates layout change is therefore aligned with the structural direction of the domestic market.

5. Expected outcomes and verification plan. Verification of the proposed approach follows three quantitative criteria. The first is the success rate of order-picking missions executed under randomized rack reconfiguration scenarios in simulation; the GNN policy is expected to maintain stable performance where grid-based baselines exhibit substantial degradation. The second is the mean intervention rate per kilometre, measured during deployment in a partner warehouse with periodic layout changes. The third is the average mission duration, since topological reasoning is hypothesized to reduce wasted excursions when familiar passages become temporarily blocked.

The verification environment combines a physically based simulator with a digital twin of a representative Russian warehouse, in which both rack positions and

shelf attributes are randomized between training episodes. Warehouse digital twins, including those developed for layout optimization in Russian fulfilment centres, demonstrate the practical feasibility of such testbeds [13]. Comparison baselines include a classical metric planner with periodic remapping and a uniform-aggregation GNN policy of the type proposed in earlier multi-robot path planning work [5]. According to industry estimates of warehouse robotization in Russia, an effectively integrated decision-making system should permit a throughput growth of 40–60 % while reducing the demand for temporary picking personnel under peak load [13].

Conclusion.

The paper has formulated a graph neural network approach to dynamic warehouse representation for decision-making by a mobile robot under variable rack geometry. The warehouse is encoded as a time-indexed attributed graph; a graph attention layer aggregates topological context; and a learned policy selects target nodes adapted to layout changes, while metric trajectory generation is delegated to a lower-level planner. Unlike previous work by the author, which treated trajectory planning, perception, and discrete route optimization as parallel subsystems, the present contribution introduces a unifying topological controller that absorbs warehouse change without facility retrofitting. Further research will focus on hypergraph extensions for multi-robot fleets and on quantitative validation in a real Russian fulfilment centre.

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УДК 004.056.5

APPLICATION OF MACHINE LEARNING METHODS FOR ANOMALY DETECTION IN NETWORK TRAFFIC

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Abstract. This paper presents an analytical comparative study of machine learning methods applied to the problem of anomaly detection in network traffic. The research examines supervised approaches – Random Forest, Support Vector Machine, and XGBoost – alongside unsupervised techniques such as Isolation Forest and LSTM-autoencoder, evaluated on the NSL-KDD and CICIDS2017 benchmark datasets. The study demonstrates that hybrid two-stage pipelines, combining unsupervised anomaly flagging with supervised attack classification, achieve the best trade-off between detection rate and false-positive reduction.

Keywords: anomaly detection, network traffic, machine learning, intrusion detection system, Random Forest, Isolation Forest, NSL-KDD, CICIDS2017, cybersecurity, unsupervised learning.

ПРИМЕНЕНИЕ МЕТОДОВ МАШИННОГО ОБУЧЕНИЯ ДЛЯ ОБНАРУЖЕНИЯ АНОМАЛИЙ В СЕТЕВОМ ТРАФИКЕ

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Аннотация. В статье представлено аналитическое сравнительное исследование методов машинного обучения, применяемых для решения задачи обнаружения аномалий в сетевом трафике. Рассматриваются методы с учителем – случайный лес (Random Forest), метод опорных векторов, XGBoost, и методы без учителя, в частности Isolation Forest и LSTM-автоэнкодер, оцениваемые на эталонных наборах данных NSL-KDD и CICIDS2017. Показано, что гибридные двухэтапные конвейеры, сочетающие беспризнаковое выявление аномалий с классификацией атак с учителем, обеспечивают наилучший баланс между точностью обнаружения и снижением уровня ложных срабатываний.

Ключевые слова: обнаружение аномалий, сетевой трафик, машинное обучение, система обнаружения вторжений, случайный лес, Isolation Forest, NSL-KDD, CICIDS2017, кибербезопасность, обучение без учителя.

The rapid growth of computer networks and the proliferation of internet-connected devices have significantly increased the attack surface available to malicious actors [1, p. 78659]. Modern enterprise infrastructure generates enormous volumes of network traffic on a daily basis, and detecting hostile activity within this stream manually is no longer feasible. Intrusion Detection Systems (IDS) represent the primary line of automated defense; however, traditional signature-based methods are unable to detect novel attack patterns that have not been previously encountered [1, p. 78658]. This limitation has motivated a sustained body of research into anomaly-based detection, where a model learns a representation of normal traffic and flags deviations as potential intrusions. Machine learning (ML) has become the dominant framework for constructing such models due to its ability to derive complex decision boundaries from high-dimensional data.

The objective of this paper is to compare the most commonly used ML methods for network-traffic anomaly detection, evaluate their performance on established benchmark datasets, and determine the conditions under which each method is most effective. The study is based on peer-reviewed publications from 2021 to 2024 and uses the NSL-KDD and CICIDS2017 datasets as the main evaluation benchmarks, as these are the most widely cited corpora in the field for reproducible experimentation [2, p. 5340]. Both datasets contain labeled records of network connections with a large number of traffic-level features, allowing a controlled comparison of methods under consistent experimental conditions.

Network-traffic anomaly detection can be formulated as a binary or multi-class classification problem, where each observed flow must be assigned to a normal category or one of several attack types – Denial of Service (DoS), Distributed DoS (DDoS), probe, Remote-to-Local (R2L), User-to-Root (U2R) [3, p. 440]. The main challenges are the extreme class imbalance typical of real network environments, where attack flows may represent less than 1 % of total traffic, and the high dimensionality of feature spaces. Modern benchmark datasets provide between 40 and 80 engineered features per connection record, including packet size statistics, inter-arrival times, protocol flags, and payload entropy. As a result, preprocessing has a decisive impact on the quality of the trained classifier.

Feature selection is a critical preprocessing step in any anomaly detection pipeline. Recursive Feature Elimination (RFE) and information-gain ranking are among the most widely used techniques for reducing feature space dimensionality while preserving discriminative power. Studies conducted on CICIDS2017 demonstrate that using the top 25 to 30 features out of 80 is sufficient to match or surpass full-feature accuracy, while decreasing training time by 40 to 60 percent [4, p. 874]. This result is particularly relevant for real-time deployments, where inference latency is a hard constraint. Addressing class imbalance through oversampling methods such as SMOTE, or through the assignment of class weights during training, is equally important for maintaining recall on rare but high-impact attack categories.

Among supervised learning approaches, Random Forest (RF) has consistently demonstrated the highest overall accuracy in multi-class network intrusion detection

scenarios. RF is an ensemble of decision trees, each trained on a randomly drawn subset of features, which confers natural resistance to overfitting and the ability to handle mixed feature types without normalization. On the NSL-KDD dataset with tuned class weights, weighted F1-scores of 99.8 % have been reported, while macro F1 values around 93 % reflect the difficulty of correctly classifying minority attack types [4, p. 874]. An important operational benefit of RF is model interpretability: Gini-based or permutation-based feature importance scores identify which network characteristics are most predictive of malicious behavior, allowing analysts to audit model outputs. The key limitation of RF is that it cannot generalize to attack families not present in the training data without retraining.

Support Vector Machine (SVM) with a radial basis function (RBF) kernel remains a competitive baseline, particularly in low-data regimes. SVM seeks a maximum-margin separating hyperplane in the transformed feature space, which is well suited to sparse, high-dimensional representations such as binary protocol-flag vectors. SVM outperforms tree-based methods when the labeled training set contains fewer than approximately 5,000 samples; however, its training complexity scales quadratically with dataset size, which limits its applicability to large-scale streaming environments unless approximate kernel methods are employed [1, p. 78670]. XGBoost, a gradient-boosted tree ensemble, represents a practical middle ground: it matches or slightly exceeds RF accuracy on tabular traffic data while training approximately three times faster, and is gaining wide adoption in production IDS implementations.

Unsupervised methods are of particular interest for IDS because they eliminate the requirement for labeled traffic data, which is both expensive to obtain and prone to becoming outdated as adversarial techniques change. Isolation Forest (iForest) works by building an ensemble of random partitioning trees: anomalous observations, which are few in number and differ structurally from the majority, tend to be isolated in fewer partitioning steps and thus receive lower average path lengths as their anomaly score. On NSL-KDD, UNSW-NB15, and CICIDS2018, optimized iForest variants achieve AUC values between 0.95 and 0.99, exceeding one-class SVM by 8 to 10 percentage points and requiring fewer trees to converge [5, p. 6]. Since iForest does not rely on class labels during training, it is well suited for continuously evolving threat environments such as industrial IoT networks.

Deep learning models, specifically Long Short-Term Memory (LSTM) autoencoders, achieve strong performance on temporally structured anomaly patterns. The model is trained exclusively on normal traffic and learns to minimize reconstruction error; at inference, high reconstruction error signals an anomaly. This architecture captures session-level temporal structure – irregular sequences of protocol events, abnormal session durations – that per-flow tabular features do not encode [2, p. 5341]. The drawbacks include high GPU memory requirements, sensitivity to threshold selection, and limited interpretability. Where regulatory or operational requirements mandate explainable decisions, shallow ML models remain the preferred deployment option.

A cross-study performance comparison shows that no single method is universally superior. RF delivers the best macro F1 in multi-class supervised settings with adequate training data. iForest performs best in zero-day or novel-attack scenarios without labeled data. SVM and XGBoost remain relevant under constrained labeling budgets. A hybrid two-stage design – where iForest scores all incoming flows for anomaly likelihood, and RF subsequently classifies flagged flows into specific attack categories – reduces false-positive rates by up to 30 % relative to either method alone, while preserving novel-threat detection capability [6, p. 143]. This architecture has been adopted in both commercial and open-source IDS platforms as it combines the advantages of supervised and unsupervised learning.

Dataset selection has a significant effect on the reported results of anomaly detection studies. NSL-KDD, despite its widespread use, has been criticized for its artificially balanced class distribution, which inflates recall for rare attack classes relative to real-world conditions. CICIDS2017 provides a more realistic simulation of modern enterprise network behavior and covers a broader range of contemporary attacks including web exploits and botnet traffic, making it a more challenging benchmark [4, p. 875]. It is now common practice to evaluate models on multiple datasets and to report both weighted and macro-averaged metrics so that performance on minority classes is not obscured by dominant-class accuracy.

In conclusion, machine learning has become a foundational component of network security, enabling anomaly-based IDS to identify novel and evasive attacks that rule-based systems cannot detect. Algorithm selection should be guided by three primary considerations: the availability of labeled training data, the latency requirements of the monitoring environment, and the explainability requirements of the deployment context. Ensemble methods, and RF in particular, currently offer the strongest overall performance when labels are available; iForest provides a comparable alternative in unsupervised settings. Future work should explore federated learning for collaborative, privacy-preserving IDS, self-supervised pre-training on large unlabeled traffic corpora to reduce annotation cost, and graph-based representations to capture network topology patterns that flow-level features cannot express.

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УДК 621.3.078

REVIEW AND ANALYSIS OF ALGORITHMS FOR SYNCHRONIZING NETWORK VOLTAGES AND A FREQUENCY CONVERTER IN A CASCADE PUMP CONTROL SYSTEM

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Abstract. The paper examines the synchronization process, the problems arising during synchronization, as well as algorithms for synchronizing the frequency converter output voltage with the mains voltage in cascade pump control systems. Three PLL-based synchronization algorithms are reviewed and compared in terms of complexity, noise immunity, and sensitivity to voltage distortion. The necessity for further improvement of synchronization algorithms is demonstrated.

Keywords: variable-frequency drive, synchronization algorithms, current spike, cascade regulation, pumping stations.

ОБЗОР И АНАЛИЗ АЛГОРИТМОВ СИНХРОНИЗАЦИИ НАПРЯЖЕНИЙ СЕТИ И ПРЕОБРАЗОВАТЕЛЯ ЧАСТОТЫ В СИСТЕМЕ КАСКАДНОГО УПРАВЛЕНИЯ НАСОСАМИ

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Аннотация. В работе рассматривается процесс синхронизации, проблемы, возникающие при синхронизации, а также алгоритмы синхронизации напряжения преобразователя частоты и сетевого напряжения в системах каскадного управления насосами. Рассмотрены и сравнены три алгоритма синхронизации на основе ФАПЧ по критериям сложности, помехоустойчивости и чувствительности к искажениям напряжения. Показана необходимость дальнейшего совершенствования алгоритмов синхронизации.

Ключевые слова: частотно-регулируемый привод, алгоритмы синхронизации, ударный ток, каскадное регулирование, насосные станции.

Cascade control of pumping stations is a common practice, widely used due to its simplicity. This method is used when there is a need to regulate the operation of multiple pumps, with their activation and deactivation occurring automatically based on fluid flow demand, flow rate, and so on [1, p. 343].

This type of control optimizes system operation by minimizing energy consumption, reducing equipment wear, and ensuring stable system parameters.

Brief description of the operating algorithm In general, the cascade control algorithm is as follows: the first pump starts, driven by a frequency converter, smoothly changing speed. Then, as flow rate increases, the lead pump reaches 100 % capacity.

If the pressure is still insufficient, the first pump switches to direct power from the grid via a contactor, and the frequency converter switches to the second pump and begins accelerating it [2, p. 54].

As flow rate increases, the cycle described previously is repeated, with the converter beginning to accelerate the third pump, while the second is powered by the grid. When the flow rate changes in the opposite direction, the process is reversed: if the frequency on the variable-speed pump drops below the threshold and the pressure exceeds the set point, one of the mains-powered pumps is switched off, and the pump controlled by the inverter increases speed to compensate for the shutdown of one of the pumps.

Despite all the advantages of this method, from process optimization to system simplicity, there are a number of issues that must be addressed for the system to operate correctly. One such issue is current spikes.

One cause of current spikes is residual magnetization of the windings, but a more significant factor is the difference in instantaneous voltage values at the moment of switching.

When the motor switches from frequency converter-powered mode to mains-powered mode, a residual EMF is induced in the rotor windings when the inverter contacts open.

If the phase of the mains voltage at the moment of switching differs from the phase of the motor's residual EMF, a significant potential difference occurs, causing a current spike [3, p. 151].

The magnitude of this current – Is, is described by an expression similar to the short-circuit current of an asynchronous motor:

$$I_s = \sqrt{2} * In * \left(e^{\frac{-0.01}{T_p}} + e^{\frac{-0.01}{T_a}} \right), \quad (1)$$

where In – is the rated motor current;

Tp – is the calculated decay time constant of the aperiodic component of the stator current;

Ta – is the decay time constant of the aperiodic component of the stator current.

In a simplified form, the formula for the current spike can be represented as follows:

$$I_s = \frac{\Delta U}{Z_{sc}}. \quad (2)$$

This expression is essentially a simplified formula for Ohm's law.

The short-circuit resistance value is approximately 10–20% of the rated value, suggesting that even a small voltage mismatch leads to a significant increase in the current spike.

To minimize current spike, strict synchronization accuracy requirements must be met.

Synchronization is the process of precisely matching the phase, amplitude, and frequency of the voltage at the frequency converter output (currently applied to the motor windings) with the power supply voltage.

In an ideal synchronized state, the converter voltage vector and the power supply voltage vector coincide. In reality, however, a phase mismatch ($\Delta\varphi$) occurs.

The mismatch angle ($\Delta\varphi$) between the power supply and frequency converter voltage vectors should approach zero. In practice, the $\Delta\varphi$ value should be no more than 10° [4, p. 73].

As stated earlier, to ensure shock-free pump switching, it is necessary to match the parameters of the frequency converter output voltage and the power supply network, namely, amplitude, frequency, and phase.

There are a number of algorithms for synchronization. Each has its own advantages and disadvantages, which may be obvious or unnoticeable depending on the operating conditions and environment.

Below are several algorithms, a description of their operation, and a subsequent comparison.

Synchronization Algorithms Classical Phase-Locked Loop (PLL).

Algorithm in a Synchronous Coordinate System The algorithm is based on representing the three-phase voltage in a fixed coordinate system (α, β) and then transforming it into a rotating system (d, q).

If the input voltage vector Uin rotates at a speed different from the speed of the rotating d-q system, and there is a phase mismatch between them, the projection of the Uin vector is non-zero on each axes of the (d, q) coordinate system.

In the case of complete synchronization, the projection of the Uin vector on the q axis will be zero. The figures below illustrate vector diagrams explaining the operating principle. Figure 1 shows a vector diagrams to explain the operation of the PLL-SC [5, p. 93–95].

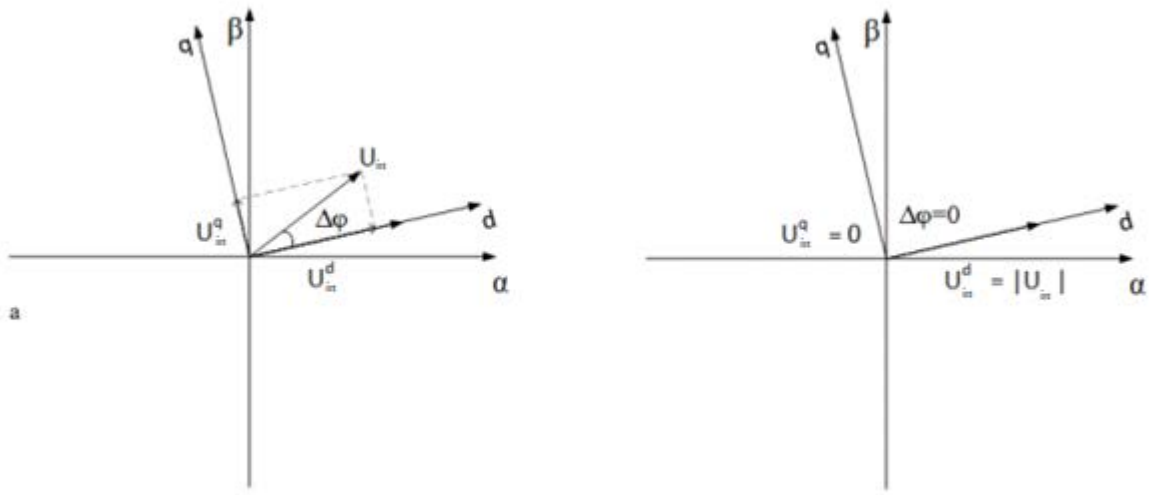


Figure 1. Voltage synchronization.

The advantages of this algorithm include its simplicity of implementation and the absence of static error with an ideal sinusoidal voltage waveform.

However, one must accept low noise immunity due to supply voltage distortions.

PLL Algorithm with a Dual Synchronous Coordinate System (PLL-SC2).

This algorithm overcomes the drawbacks of the previous algorithm thanks to its dual synchronous coordinate system. It is based on representing the input voltage using the method of symmetrical components.

If the positive-sequence vector is taken as the reference point, it will appear stationary. Then, the negative-sequence vector will rotate relative to it twice as fast—that is, with double the frequency (2ω) [5, p. 108].

Figure 2 shows block diagram of the phase calculation circuit for three-phase input voltage using the PLL-SC2 algorithm

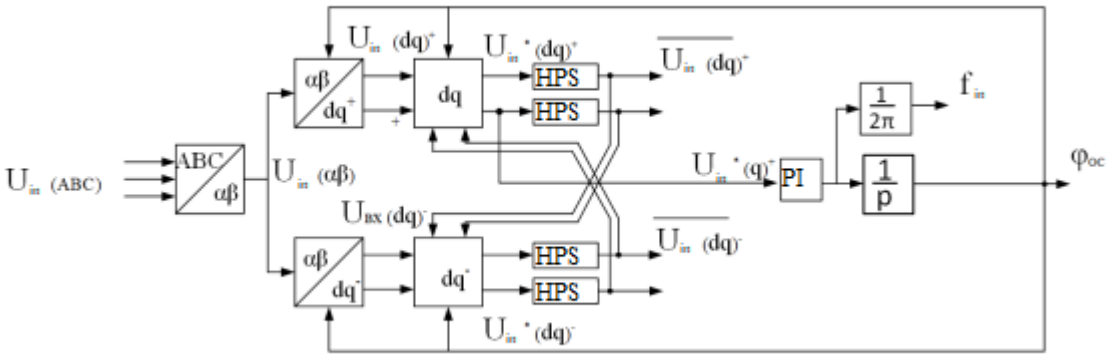


Figure 2. Block diagram of the phase calculation circuit for three-phase input voltage using the PLL-SC2 algorithm

The advantages of this algorithm include: complete compensation of asymmetry and the ability to estimate negative-sequence parameters.

However, the implementation complexity (four coordinate converters) and persistent sensitivity to harmonic distortion can be a problem.

PLL Algorithm with Double Integration (PLL-DI).

This algorithm uses an approach similar to the previous one, with the only difference being that the vector orientation is performed not in the d-q system, but in the fixed α-β system.

The algorithm requires only one coordinate converter in the (d,q) system, which simplifies software implementation. Figure 3 shows structural diagram of the PLL-based synchronization algorithm.

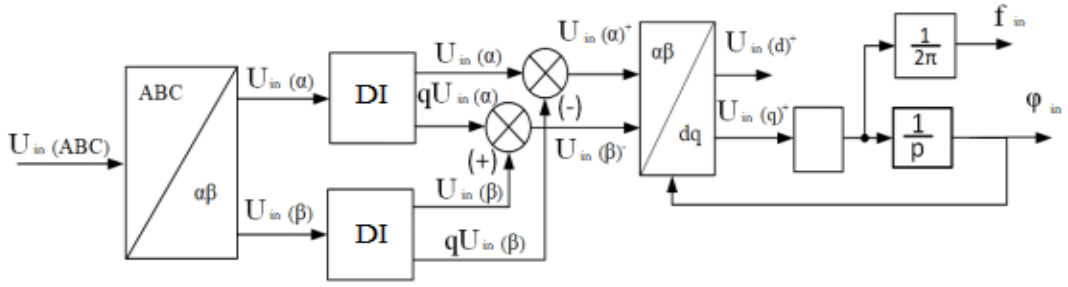


Figure 3. Structural diagram of the PLL-based synchronization algorithm

The algorithm is simple to implement, the system operating on it is distinguished by good noise immunity, and it is possible to estimate the negative sequence parameters. As with the previous algorithm, the influence of non-sinusoidality cannot be completely compensated for [5, p. 110].

A review of three PLL-based synchronization algorithms revealed a natural trade-off between implementation complexity, noise immunity, and sensitivity to supply voltage distortions.

The classic SC PLL is simple and has no static error with a perfect sinusoid, but its main drawbacks are low noise immunity and inability to operate with power supply asymmetry.

The SC2 PLL completely compensates for asymmetry and allows for the estimation of negative sequence parameters, but this comes at the cost of high computational complexity (four coordinate converters) and persistent sensitivity to harmonics.

The DI PLL is a compromise: it is almost as noise-immune as the SC2, but requires only one coordinate converter, simplifying implementation; its drawback is the same problems with non-sinusoidality.

The SC PLL can only be used with high-quality sinusoidal voltage. PLL-SK2 is used when operation under severe asymmetry is critical and there are excess computing resources. PLL-DI is optimal for most practical tasks with moderate distortion.

Since none of the algorithms considered provides complete immunity to harmonic distortion and non-sinusoidality, further improvement of synchronization algorithms remains a pressing issue – for example, finding methods to suppress higher harmonics without significantly increasing the complexity of the structure.

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УДК 678.7

SWELLING AND SORPTION PROPERTIES OF STYRENE-BUTADIENE RUBBER AND VULCANIZED RUBBER

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Abstract. This study investigates the sorption properties and dissolution kinetics of styrene-butadiene rubber (SBR) and vulcanized rubber in organic and inorganic media. The role of polymer structure in solvent interaction was established. Water vapor sorption and swelling in toluene, gasoline, and n-hexane were measured experimentally; SBR showed higher uptake and a greater tendency to dissolve, while vulcanized rubber swelled only slightly. The results help predict elastomer performance in different media.

Keywords: styrene-butadiene rubber, vulcanized rubber, swelling, sorption, dissolution kinetics, elastomers, polymer structure, organic solvents, crosslinked polymers.

НАБУХАНИЕ И СОРБЦИОННЫЕ СВОЙСТВА БУТАДИЕН-СТИРОЛЬНОГО КАУЧУКА И ВУЛКАНИЗОВАННОЙ РЕЗИНЫ

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Аннотация. В данном исследовании изучены сорбционные свойства и кинетика растворения бутадиен-стирольного каучука (СКС) и вулканизованной резины в органических и неорганических средах. Установлена роль структуры полимера во взаимодействии с растворителем. Экспериментально определены сорбция водяного пара и набухание в толуоле, бензине и н-гексане; СКС показал более высокую сорбционную способность и большую склонность к растворению, тогда как вулканизованная резина набухала лишь незначительно.

Полученные результаты позволяют прогнозировать эксплуатационные свойства эластомеров в различных средах.

Ключевые слова: бутадиен-стирольный каучук, вулканизованная резина, набухание, сорбция, кинетика растворения, эластомеры, структура полимера, органические растворители, сшитые полимеры.

Introduction

Elastomeric materials occupy a key position in modern industry due to their unique combination of elastic, deformation, and performance properties. They are widely used in the production of tires, sealing materials, gaskets, and products operating under conditions of exposure to aggressive media and mechanical loads. The high demand for elastomers is due to their ability to retain elasticity over a wide range of temperatures and humidity, as well as their resistance to chemical exposure. Rubbers are the basis of elastomeric materials. Natural rubber is characterized by high elasticity and strength, but its resistance to external influences is limited. The properties of synthetic rubbers depend on their chemical composition and the structure of macromolecules.

One of the determining factors affecting the properties of rubbers and vulcanizates is their structural organization. Rubbers are capable of dissolving in thermodynamically compatible solvents; spatially cross-linked structures (vulcanized rubbers) are characterized by limited swelling without transition into solution. The degree of cross-linking, network density, and intermolecular interactions determine the mechanical, sorption, and diffusion properties of rubber. Practical prediction of elastomer behavior is complicated by swelling and dissolution processes, which are determined by diffusion and thermodynamic properties, sensitivity to the nature of the solvent, and the polymer structure. Depending on the solvent, rubbers either swell to a limited extent or dissolve completely [1, 2].

The objective of this study is to establish the relationship between the structural organization of butadiene-styrene rubber and vulcanized rubber, their sorption properties, and the kinetics of rubber dissolution in organic and inorganic media.

Literature review

Elastomeric materials based on rubbers are among the most significant classes of polymers, and their properties are determined by the combination of chemical composition and the structural organization of macromolecules. A special place is occupied by isoprene and butadiene-styrene rubbers, which are widely used due to their ability to undergo large reversible deformations and their resistance to external influences. Natural rubber has high elasticity and strength due to the regular cis-structure of polyisoprene, but its properties are limited by its natural origin and sensitivity to external factors. Synthetic rubbers, in particular butadiene-styrene rubber (SBR), make it possible to deliberately modify the composition and microstructure of the polymer; this allows the physical and chemical characteristics to be controlled, resulting in a pronounced change in the material’s behavior [3-5].

Vulcanized systems are characterized by the presence of chemical bonds between chains, which limits their mobility and prevents dissolution. The interactions of polymers with solvents are traditionally considered within the framework of the

theory of polymer solutions. According to this approach, polymer dissolution is the result of a combination of diffusion and thermodynamic processes, including the penetration of solvent molecules into the polymer matrix and the subsequent weakening of intermolecular interactions. In this process, the properties of the solvent, which characterize the degree of affinity between the components of the system, play a crucial role. Swelling is an intermediate stage between the solid state of the polymer and its dissolution. For linear polymers, under favorable conditions, swelling may proceed to dissolution. For cross-linked systems, this process is limited to an increase in volume without destruction of the structure. The degree of cross-linking is a critical parameter determining the nature of the interaction between the polymer and the solvent.

The investigations done have shown that the kinetics of polymer swelling is determined by the rate of solvent diffusion and the ability of macromolecules to relax [6, 7]. In the initial stages, the process is controlled by diffusion, whereas at later stages it is governed by the internal rearrangement of the rubber structure. In some cases, the formation of gel-like states is observed; this indicates partial disruption of intermolecular interactions without transition to complete dissolution. Elastomeric materials based on butadiene-styrene rubber exhibit a pronounced dependence of properties on composition and structure. Changing the styrene content and vulcanization conditions makes it possible to vary the network density, mechanical properties, and sorption properties of the material. This makes SBR a convenient model system for studying regularities of polymer interaction with various media [3, 4].

An important aspect is the influence of the nature of the solvent on polymer behavior [6, 7]. Organic solvents which solubility parameters are close to those of rubbers can interact effectively with them, causing swelling or dissolution [8, 9]. Polar media (water and aqueous solutions of acids and alkalis) are generally characterized by low compatibility with nonpolar rubbers, which limits their interaction. Despite the considerable number of studies devoted to polymer dissolution and swelling, a number of questions remainsl regarding the quantitative description of the kinetics of these processes and the influence of structure on the nature of interaction with specific solvents [9, 10]. This is especially true for the analysis of linear and cross-linked systems, which differ in their behavior upon interaction with solvents.

Conclusion of the literature review. Analysis of the literature data [1-15] shows that the behavior of rubbers in liquid media is determined by a complex of factors, including the chemical nature of the polymer, the degree of its structural organization, and thermodynamic compatibility with solvents. The relationship between these factors for specific systems, namely butadiene-styrene rubber–solvent and vulcanized rubber based on it–solvent, requires additional experimental data. This determines the relevance of the research work.

Methods and materials

Styrene-butadiene rubber (SBR) and vulcanized rubber based on it were used as the objects of the study. SBR is a synthetic elastomer with a predominantly linear macromolecular structure and is capable of dissolving in organic solvents. Vulcanized rubber has a spatially cross-linked structure forming a three-dimensional network, which limits its solubility and determines its ability to swell.

To investigate the interaction of the polymers with liquid media, organic and inorganic solvents differing in polarity and thermodynamic compatibility with the polymer were selected. Toluene, gasoline, and n-hexane were used as organic solvents, as they have different solvent power with respect to hydrocarbon polymers. Water, aqueous sodium hydroxide solution (10 %), and hydrochloric acid (10 %) were used as inorganic media; these are characterized by high polarity and chemical activity.

The sorption properties were determined by measuring the mass of the samples after exposure to media with a specified relative humidity. Water vapor sorption was determined at relative pressure values p/p_0 = 0,32, 0,65, 0,84 и 0,95 until the polymer reached equilibrium.

Swelling study. In the swelling study, 0.5 g samples were placed in 30 mL of solvent and kept at room temperature (21 °C) for predetermined time intervals. After removal, excess solvent was removed from the surface, and the samples were weighed on a laboratory balance with an accuracy of ±0.001 g. Measurements were carried out at fixed time intervals, which made it possible to obtain the dependence of the swelling rate on time. The degree of swelling was evaluated from the difference between the sample mass before and after swelling.

Results

Quantitative data characterizing the sorption properties of styrene-butadiene rubber (SBR) and vulcanized rubber were obtained. It was established that the degree of moisture uptake increases with increasing water-vapor relative pressure for both materials, while the values for SBR remain higher across the entire p/p_0 range. At p/p_0 = 0,32, 0,65, 0,84 и 0,95, the moisture uptake of SBR was 0.7, 1.2, 2.2, and 6.0 %, respectively, whereas for rubber it was 0.3, 0.6, 1.4, and 4.4 %. The resulting dependence is nonlinear; the most pronounced increase in moisture uptake occurs in the p/p_0 range of 0.84–0.95. The results are presented in Figure 1.

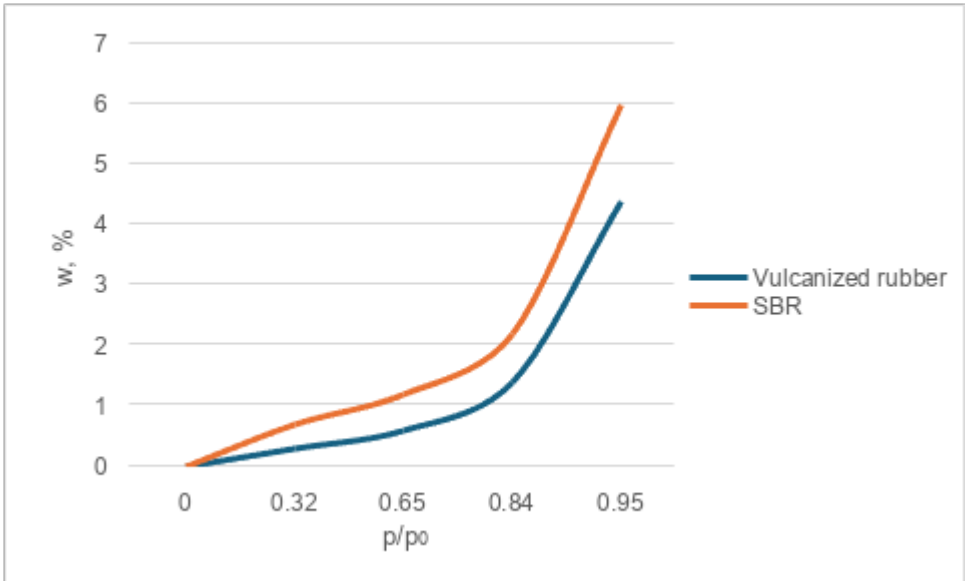


Figure 1. Dependence of the moisture uptake degree of SBR and rubber on the relative pressure p/p_0

The degree of swelling of the samples is calculated by the formula: $Q = \frac{m - m_0}{m_0} * 100\%$, where m_0 is the initial mass of the sample before interaction with the solvent, and m*m* is the mass of the sample after interaction with the solvent.

The swelling kinetics of SBR and vulcanized rubber in organic solvents are presented in Figures 2–4.

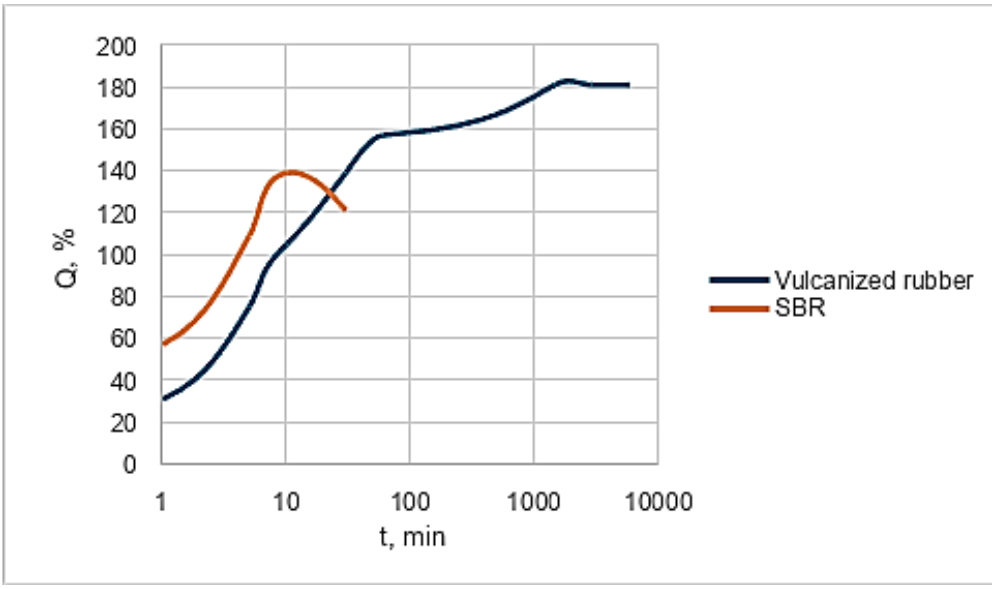


Figure 2. Change in the swelling degree of SBR and rubber over time in toluene

As shown in Figure 2, the swelling degree of butadiene-styrene rubber increases over 10 minutes; with further increase in time, the rubber dissolves. The swelling of vulcanized rubber increases, but the growth in swelling degree is much smaller, and the process reaches a plateau without destruction of the structure.

Figure 3 shows the change in the swelling degree of SBR and rubber over time in gasoline.

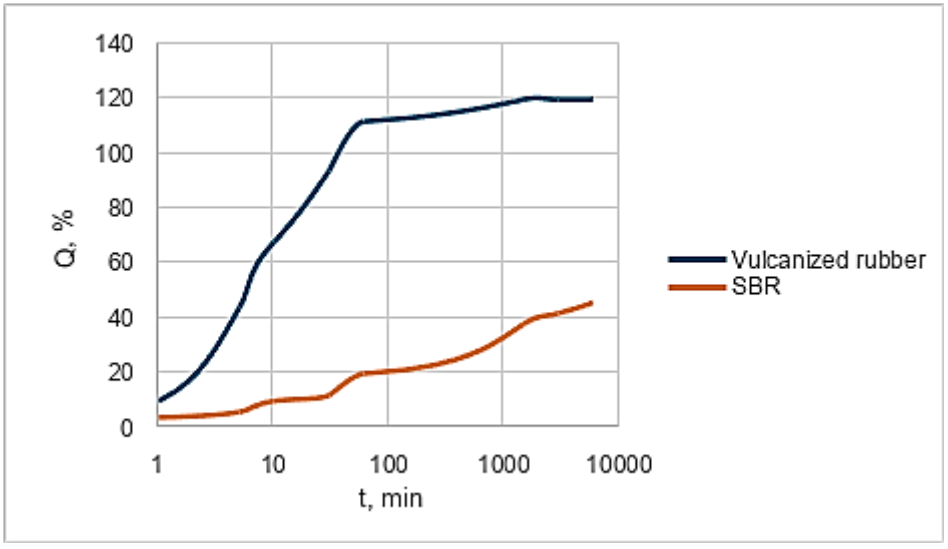


Figure 3. Change in the swelling degree of SBR and rubber over time in gasoline

In gasoline, both the rubber and the vulcanized rubber show a gradual increase in swelling degree, and the swelling values for SBR remain higher than those of the rubber throughout the entire experiment. No dissolution is observed, which indicates a limited interaction of the polymer with the solvent.

Figure 4 shows the change in the swelling degree of SBR and rubber over time in n-hexane.

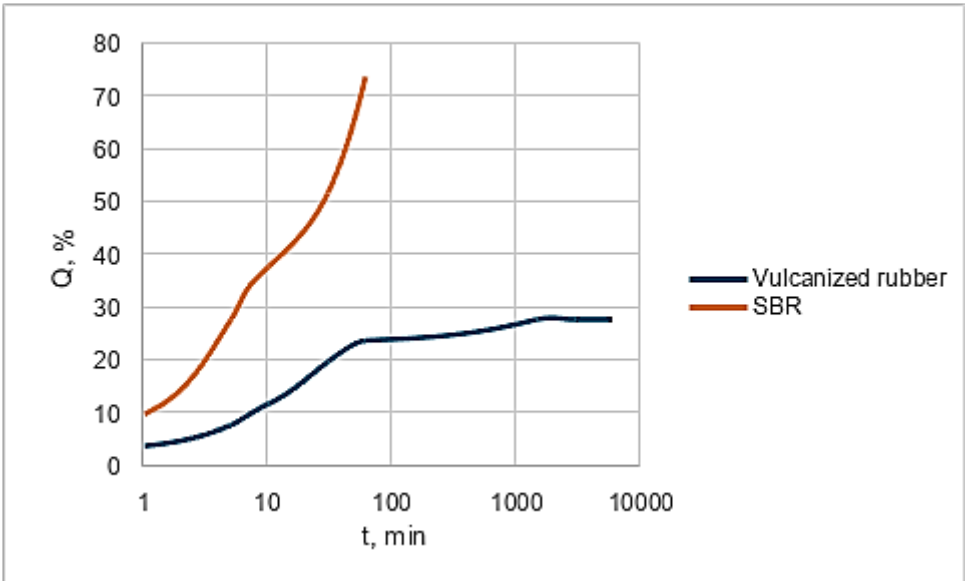


Figure 4. Change in the swelling degree of SBR and rubber over time in n-hexane

In n-hexane, the swelling degree of both the rubber and the vulcanized rubber increases during the initial stage of interaction, after which the process slows down. At 60 minutes, the swelling degree of SBR reaches high values, whereas the rubber is characterized by limited swelling and shows no signs of structural degradation throughout the entire investigated time interval. A comparison of material behavior in inorganic media showed that in water and in aqueous solutions of sodium hydroxide and hydrochloric acid, the change in sample mass as a function of time is negligible and remains within the experimental error. This indicates the high chemical resistance of both SBR and vulcanized rubber.

Conclusion based on the study results. In all the media studied, SBR exhibited a higher degree of swelling. The presence of a three-dimensional network in vulcanized rubber restricts solvent penetration and prevents destruction of the polymer structure.

Discussions

SBR is characterized by a rapid increase in swelling degree, which is associated with the high mobility of its macromolecular chains and the absence of spatial constraints. Solvent penetration is accompanied by weakening of intermolecular interactions and a transition of the system to a state in which further dissolution becomes possible. In the case of toluene and n-hexane, dissolution occurs completely. The presence of a three-dimensional network in vulcanized rubber limits both solvent diffusion and macromolecular relaxation, so structural destruction does not occur. The effect of solvents is reflected in the shape of the kinetic curves. In toluene, the highest degree of interaction is observed, whereas in gasoline and n-hexane the process is

limited to swelling. This is explained by differences in thermodynamic compatibility: toluene provides effective interaction with the polymer phase, while in gasoline and n-hexane the interaction energy is insufficient to completely break interchain bonds. In n-hexane, a gel-like state forms, which may indicate partial disaggregation of the structure. No noticeable mass change is observed in interactions with inorganic media. The high polarity of water and aqueous solutions limits their penetration into the hydrocarbon polymer matrix, thereby suppressing diffusion processes. The difference in kinetics and swelling degree between SBR and vulcanized rubber is determined by a combination of two factors: macromolecular mobility and the presence of a network structure. In the absence of cross-links, the process ends with polymer dissolution; in cross-linked systems, it is limited to swelling regardless of solvent nature.

Conclusions

The study showed that the interaction of butadiene-styrene rubber and vulcanized rubber with liquid media is determined not only by the nature of the solvent, but above all by the structural organization of the polymer: the interaction of the synthetic rubber with the solvent proceeds in two stages, namely swelling and dissolution. The interaction of the cross-linked rubber with the solvent is limited to swelling. A fundamental dependence of the kinetics of swelling and subsequent dissolution on the degree of cross-linking of the polymer system was established. This makes it possible to predict the behavior of elastomers in media of different nature.

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УДК 004.67

COMPARATIVE ANALYSIS OF TEXTS WRITTEN BY HUMANS AND GENERATED BY ARTIFICIAL INTELLIGENCE

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Abstract. The article considers a comparative analysis of texts created by a human author and texts generated using artificial intelligence (AI). Possible distinguishing features of texts of different authorship are described. The article describes popular AI detector services that provide the ability to recognize the origin of text: created by a person or a neural network. The results of a similar check are carried out when using chatbots with AI.

Keywords: artificial intelligence (AI), neural networks, signs of generated text, AI detector service, expert, generative chatbot.

СРАВНИТЕЛЬНЫЙ АНАЛИЗ ТЕКСТОВ, НАПИСАННЫХ ЛЮДЬМИ И СГЕНЕРИРОВАННЫХ ИСКУССТВЕННЫМ ИНТЕЛЛЕКТОМ

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Аннотация. В статье рассматривается сравнительный анализ текстов, созданных автором – человеком, и текстов, сгенерированных с помощью искусственного интеллекта (ИИ). Описываются возможные отличительные признаки текстов различного авторства. Приводится описание популярных сервисов-детекторов ИИ, которые предоставляют возможность распознавать происхождения текста (созданный человеком или нейросетью). Показаны результаты аналогичной проверки при использовании чат-ботов с ИИ.

Ключевые слова: искусственный интеллект (ИИ), нейросети, признаки сгенерированного текста, сервис-детектор ИИ, эксперт, генеративный чат-бот.

Artificial intelligence (AI) is currently becoming a popular and sought-after tool for assisting people in various aspects of life. Advances in *natural language processing* have made it increasingly difficult to distinguish texts created by AI from those created by humans in terms of quality and diversity. At the same time, there is a counter-

argument that neural networks possess a distinctive, soulless style. This assertion is no longer true.

The ability to distinguish texts generated by artificial intelligence from texts written by humans is crucial in education to ensure academic integrity.

A foreign study presents the results of the following experiment [1]. A group of experts was presented with a set of documents for evaluation, half of which were written by humans, while the other half were generated by a neural network. The documents were written in different styles and covered various academic fields. The experts' task was to determine whether the text was authored by artificial intelligence or a human.

The results were mixed. The experts identified the authorship of sources with a high error rate. Approximately half of the results were false. The age and length of service of the respondents did not influence the results. Experts with a technical mindset performed better than those with a humanities background. A higher percentage of correct identifications was recorded when analyzing human-written texts, although the difference was not particularly significant.

Researchers identify several factors that contribute to the difficulty of recognizing author's text [2]. One key factor is the so-called "correctness" of the text generated by artificial intelligence. Neural networks have learned to search for and create logical chains from the information they find. The generated text follows classic patterns, i.e., it is consistent and logically verified. Texts generated by neural networks mostly adhere to an academic style. An expert evaluating such a document perceives the text as professionally written, well-reasoned, and informative. This is precisely the style taught to essay on the Russian language exam for the Unified State Exam. This type of text misleads the evaluator, leading to false conclusions.

One of the characteristics of the text written by the young author is the simplicity of the sentences. Meanwhile, the neural network tries to make the sentences more informative.

In terms of grammatical inconsistency, humans are inferior to artificial intelligence. In human-generated text, the likelihood of grammatical errors is much higher. This is due to the writing process, where each phrase is rewritten several times to achieve an acceptable result, which leads to inconsistencies and errors. This problem is completely absent in generated texts. AI-generated texts are grammatically coherent, accurate, and verified [3].

Human-created texts contain a greater number of phraseological units and beautiful, rich turns of phrase. People strive to write sentences with a greater variety of words due to their extensive vocabulary . The length of sentences found in human texts varies considerably.

The emotional content of a text submitted to respondents may reflect the author. Human-generated texts can express various emotions, but statistics show that such texts are more emotional than generated ones, more often reflecting negative emotions, and are also more readable and allow for a more accurate communication of the message. Generated texts are aimed at success and are positive. The reader's receptivity to such texts is indirect.

AI often uses numbers, symbols, and auxiliary verbs in its messages. Another distinctive feature of generated texts are certain template words, phrases, and clichés, which the AI itself has coded. Inconsistencies and errors in the meaning of words used are a warning sign when checking texts suspected of being authored by a neural network.

Templated introductory phrases include: "thus"; "it's important to note"; "that; by the way"; and so on. Intensifiers include: "extremely important"; "extremely useful". Phrases used to transition between arguments include: "on the other hand," "taking into account what has been said", and "as a result." Moreover, these templates always appear in the same places with each new query. Overuse of these phrases allows a document reviewer suspected of AI use to detect poor writing.

Every language has its own unique words that are unique to other languages. For example, the word "molodets" (good fellow) has Old Russian origins. Such authentic words, found in a text, indicate that it was written by a human.

A counterexample is the word "powerful". In AI-generated texts, such a word used as follows: "Artificial intelligence is a powerful tool for..." would be a sign of neural network-generated text.

The first artificial intelligence networks were created in English. These networks were also trained primarily on English texts. A distinctive feature of the English language's structure is that words take up less space than, for example, in Russian. However, to conserve space, English texts often include unnecessary details and explanations. These trends have also spread to artificially generated texts, thus revealing the author – that is, the artificial intelligence.

The algorithms for generating neural network text are also designed to convey the answer to a user's query in the most understandable way possible, which leads to unnecessary explanations, even when there is no need for such explanations.

Signs of excess in neural network texts include excessive structuring. In its responses, the neural network begins to highlight certain words, generate lists broken down into subsets of other lists, create tables , graphs, and so on. Due to this structure in query responses, the text's origins can be easily identified as being written by artificial intelligence.

Why does AI write this way? To understand, we need to understand the basic operating principles of LLM text models [4]. The base of such a model contains a huge number of words and relationships between words. The neural network selects each word based on its probability of occurrence in a given context. These probabilities are linked to its accumulated database. Only based on these embedded relationships does the text that is sometimes accepted as the author's own emerge.

However, if you need to quickly check a document for "humanity" while working with it, you can use certain assistant services. Detector services allow you to test a given length of text and determine whether it is original or generated using AI [5].

To test the accuracy of popular services for determining whether a text was written by a human or a generative model, the following study was conducted. A text of approximately 4,500 characters was written on the topic "Using the Websoft Courselab Editor in Education". A text of approximately the same length on

the same topic was also generated using the Google Gemini chatbot. Both texts were run through the detectors in question, and the resulting text analysis results were evaluated. The test was considered passed if the service reported that the original text was written by a human and the generated text was generated by a neural network.

The GigaCheck service, developed by the Sber team, only works with Russian-language texts. This service has a limited number of characters it can check and is free to use. GigaCheck passed the test. The service correctly identified which of the two texts was written by a human and which was generated by AI. The service's results for the original text are shown in Figure.

The Copyleaks AI detection service supports 30 languages and offers a free trial text verification. Permanent use requires a paid subscription. Copyleaks also correctly identified the authorship of the texts submitted for review, and the verification was successful.

The next Russian service recommended online is PR-CY. It's a paid service that allows you to check a relatively small amount of text for free. The original texts were shortened to the required length. Based on the check results, the service determined that the original text was 66 % AI-generated, while the neural network-generated text was 62 % generative. Therefore, the check failed. Interestingly, the comparison showed that the human-generated text was 4 % more generative than the AI-generated text.

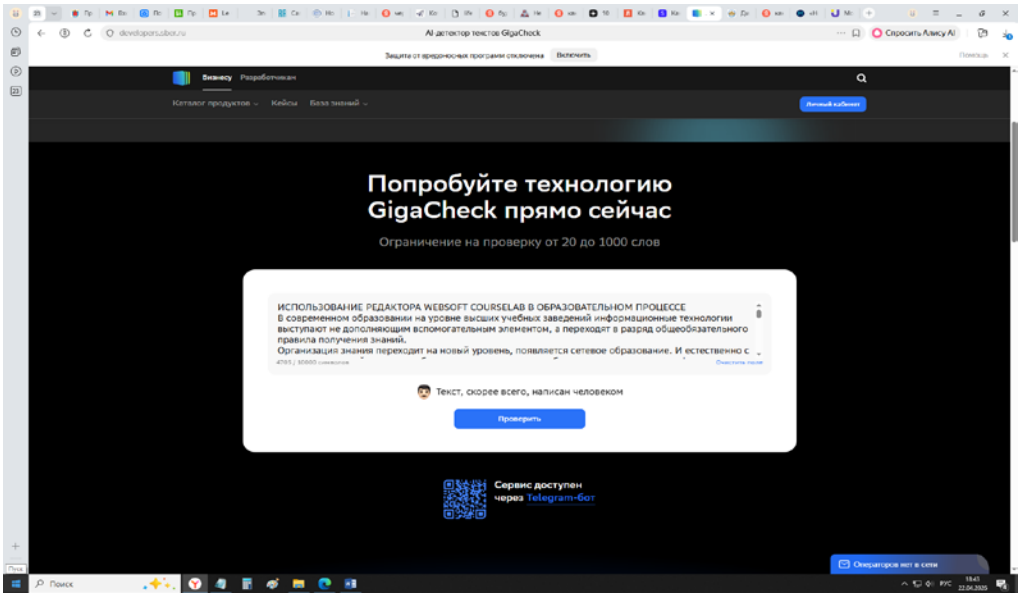


Figure. Results of text verification by the GigaCheck detector

The free online AI detector, AI Detector Writer, holds the record for the largest number of free characters. The service allows you to upload text up to 350,000 characters long. However, this feature failed to correctly recognize the texts in question. The verification failed.

The next candidate, GPTZero, partially passed the test. The test showed that it correctly recognized the AI-generated text. The system failed to identify the human-written text , and no recognition results were available.

The performed check doesn't claim to be a thorough analysis – only two texts were tested. However, the results of the tests already suggest that text generativity checking services cannot yet be trusted unconditionally.

The next stage of the study was to ask the neural networks themselves, i.e., chatbots powered by artificial intelligence, to recognize who wrote the text. The verification conditions were the same as those described previously.

OpenAI 's ChatGPT is a pioneering neural network platform. The free version of ChatGPT failed to correctly identify the source of each text. ChatGPT recognized the author's text as both human and neural network-generated, leaning toward a human. The conclusion for the generated text is as follows: "Overall, the text could have been written by either a human or a neural network. However, given the specific content and detail, it is most likely a human author."

Next, we looked at the domestic YaGPT neural network, developed by Yandex for generating Russian-language text. It also failed the test. The model handled the human-written text without any difficulty. However, the second text took a long time to parse and ultimately reached a conclusion similar to that of the previous neural network: "It was most likely created by a specialist."

The Chinese neural network DeepSeek more or less completed the verification. The first text was identified as human, with minimal use of AI. The second text was deemed to be created by the neural network, again with possible human editing.

Chatbot Le achieved good results Chat from the French company Mistral AI. The generative model was able to correctly identify the authorship of each of the texts. Le Chat confidently confirmed that the text written by a human was indeed human, while the neural network responded to the text written by an AI: "It is highly likely that the text was generated by a neural network, possibly with minimal human editing."

Grok neural network is a generative AI-powered chatbot developed by xAI, a company founded by Elon Musk. Grok recognized the first text as 90 % human-readable and similarly recognized the second generated text as written by the neural network, thus passing the verification process.

Summarizing the tests conducted, we can draw the general conclusion that it is premature to rely too heavily on the results produced by any given generative artificial intelligence platform. Detection services did not produce the expected, fully accurate results. Using neural networks themselves to verify text authorship also did not yield a 100% result.

The question remains how different language models will perform in hybrid text verification. This refers to the collaborative creative process of humans and artificial intelligence, or hybrid text. In such texts, characterized by frequent changes in authorship or human editing of AI-generated sentences, determining the source of the text is particularly challenging.

If an author uses a neural network when writing a document, rather than generating the entire large text in a single query, but rather forming the text sequentially, piece by piece, providing the neural network with samples of the desired style, removing neural network cliches, eliminating all unnecessary language, correcting errors, checking the meaning of the written text, editing and reviewing each paragraph... The resulting text will be high-quality and fully reflect the author's vision,

and there's likely no point in blaming such a person for using neural networks. However, if all these steps weren't completed, a careful expert will easily recognize such a result.

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УДК 620.179.17

REAL-TIME DIGITAL CONDITION DIAGNOSIS OF BEARINGS USING ACOUSTIC SIGNALS

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Abstract. This article reviews bearing condition diagnosis with emphasis on acoustic monitoring. It describes acoustic signal generation in defective rolling bearings, distinguishes airborne sound measurement from acoustic emission, and outlines signal processing stages, practical equipment, limitations, and prospects for real-time application.

Keywords: rolling element bearing, acoustic diagnostics, acoustic emission, digital signal processing, condition monitoring, machine learning, real-time fault detection.

ЦИФРОВАЯ ДИАГНОСТИКА СОСТОЯНИЯ ПОДШИПНИКОВ ПО АКУСТИЧЕСКИМ СИГНАЛАМ В РЕЖИМЕ РЕАЛЬНОГО ВРЕМЕНИ

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Аннотация. В статье рассмотрены методы диагностики состояния подшипников с акцентом на акустические методы. Описаны причины формирования акустических сигналов при дефектах, различия между воздушным звуком и акустической эмиссией, основные этапы обработки данных, оборудование, ограничения и перспективы применения метода.

Ключевые слова: подшипник качения, акустическая диагностика, акустическая эмиссия, цифровая обработка сигналов, техническое состояние, машинное обучение, диагностика в реальном времени.

Methods of Bearing Diagnostics Currently Used

When a bearing is worn or damaged, the nature of interaction between its contact surfaces changes. This is manifested in increased vibration and noise, local heating, unstable rotation, changes in the electrical parameters of the drive, and the appearance of wear products in the lubricant. According to the measured physical parameters, bearing monitoring methods are usually divided into vibration-based, acoustic,

thermal, electrical, tribological, and combined methods [1].

The most widely used industrial method remains vibration analysis, which is based on the registration of impact impulses from defects by accelerometers and on spectral analysis of the signal. Its advantages include high diagnostic informativeness and a well-developed methodological basis; however, the accuracy of the method depends on the sensor mounting location and the machine operating mode [2, 3].

Acoustic diagnostics is like vibration-based diagnostics in its physical nature, but it uses airborne acoustic waves or high-frequency elastic waves in the material for diagnostic purposes. For a more sensitive assessment, acoustic emission monitoring is applied; in this case, a piezoelectric sensor records impulses generated by friction, impact contact, microcrack development, and disruption of lubrication conditions. This method makes it possible to detect early signs of damage; however, it requires protection against interference, appropriate selection of the sensor mounting location, and high-quality signal filtering [3, 4].

Thermal methods are based on measuring the temperature of the bearing unit or the temperature distribution over its surface. Contact temperature sensors, pyrometers, and infrared cameras are used for monitoring. Infrared thermography is convenient as a non-contact method, but it has limitations in the early diagnosis of internal defects since a significant temperature increase often appears only after disturbed rolling motion of the rolling elements or lubrication defects have already developed [5].

In electric drives, bearing diagnostics can be performed using a monitoring method based on the analysis of motor current signals, known as Motor Current Signature Analysis (MCSA). Mechanical bearing defects cause torque oscillations and air-gap non-uniformity, which are reflected in the motor current spectrum. Fault-related components in the current signal may be weaker than those in vibration and may be masked by other motor or power supply faults, which is a limitation of this method [6].

Tribological methods form a separate group and are based on the analysis of lubricant and wear debris. These methods are useful for large machines, gearboxes, turbines, and systems where access to the lubrication system is available. The analysis is performed periodically and requires laboratory testing or sensors that determine the level of oil contamination [7].

Modern diagnostic systems increasingly use machine learning and deep learning methods. Algorithms such as support vector machine (SVM), k-nearest neighbors (kNN), random forest, and XGBoost operate on pre-extracted signal features: root mean square value, peak amplitude, kurtosis, spectral energy, and other parameters. Neural network methods, including convolutional neural networks (CNNs), long short-term memory networks (LSTMs), and Transformer-based models, are capable of automatically extracting relevant features from time signals, spectra, and spectrograms. However, their performance depends on the quality of the training set and on the correspondence between training conditions and real operating conditions [8].

At present, the development of bearing diagnostics involves a combination of different measurement methods and digital algorithms. Vibration-based diagnostics remains the main industrial method. Acoustic methods and acoustic emission methods are applicable for early and non-contact monitoring. Thermal, electrical, and tribological methods help to supplement the overall picture of bearing condition.

Intelligent algorithms make it possible to automate defect detection [1]. Acoustic diagnostics is of particular interest because it is relatively easy to implement, while modern digital signal processing and machine learning methods make it possible to use its capabilities effectively [3].

Physical Principles and Methods of Acoustic Bearing Diagnostics

Acoustic bearing diagnostics is based on the analysis of vibrations arising from contact between working surfaces. In a healthy bearing, this contact occurs uniformly, which gives the acoustic signal a stable level and a characteristic spectral composition. When defects appear, however, the contact becomes non-uniform. Short-term impacts, local friction, and microplastic deformation occur, and debris appears in the lubricant. These processes generate additional vibrations that propagate through machine components and can be recorded as sound, vibration, or acoustic emission [3]. Figure 1 presents an example of a possible defect and the propagation of the vibrations caused by it.

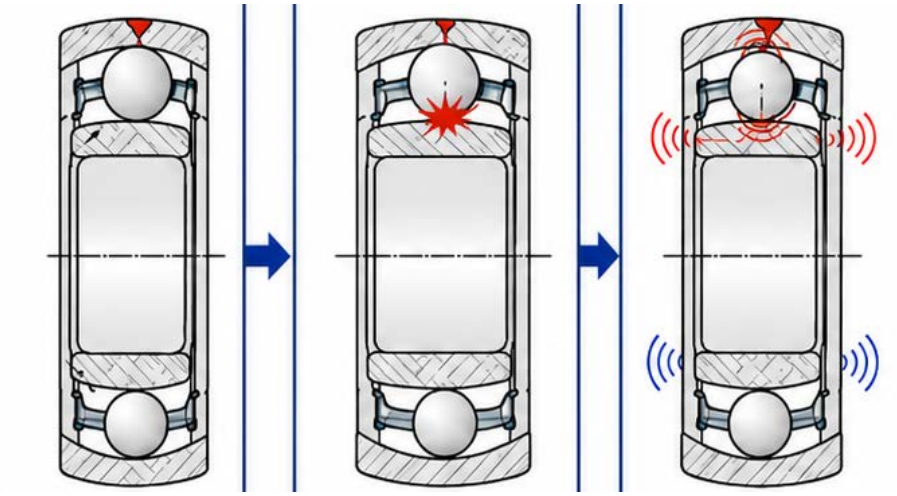


Figure 1. Example of a Defect and the Vibrations Caused by It

Acoustic diagnostics should be distinguished from acoustic emission monitoring. In the first case, the signal is recorded by a microphone installed near the operating unit. This is convenient because rigid sensor attachment is not required; however, the microphone also receives noise from the motor, ventilation, neighboring mechanisms, and the surrounding space. In the second case, acoustic emission measurement is used: a piezoelectric sensor is attached to the machine housing and records high-frequency elastic waves generated by impact loading, friction, and microdefect development [4].

Acoustic diagnostics does not measure loudness alone but identifies stable changes in the signal that are associated with bearing condition. Damage to the outer or inner ring, rolling element, or cage leads to the appearance of repeated impulses. The frequency of these impulses depends on bearing design, shaft rotational speed, the number of rolling elements, and the contact angle. During signal analysis, characteristic fault frequencies are considered; these may appear directly, as sidebands, as modulation, or as periodically repeated impact components [3].

At the early stages of bearing damage, the acoustic signal often has an impulsive nature. A defect is manifested not as continuous noise, but as a series of short impacts

that occur when the damaged area passes through the contact zone. Under real operating conditions, these impulses may be weak and masked by background noise. Therefore, before analysis, the signal is often filtered, normalized, and divided into separate time segments. For acoustic emission signals, the frequency range is adjusted, since the impulses required for analysis are often located above the audible frequency range [4].

One of the least labor-intensive methods of acoustic diagnostics is the analysis of time-domain signal characteristics. In this case, amplitude, root mean square value, peak values, form factor, kurtosis, and other parameters describing the level and impulsiveness of the signal are evaluated. This approach is simple to implement and is suitable for preliminary monitoring, but it does not always allow the type of defect to be determined accurately. For example, an increase in the overall noise level may be caused not only by bearing damage, but also by misalignment, loosened fastening, load variation, or external noise sources [1].

A more informative method is frequency analysis, which is usually performed using the fast Fourier transform. This method makes it possible to transform the time waveform into a spectrum and identify which frequency components increase when the bearing condition changes. If spectral components associated with characteristic fault frequencies are detected in the spectrum, this may indicate damage to a specific bearing element. However, direct spectral analysis is not always sufficient since a faulty signal often has a modulated and non-stationary character [3].

Envelope analysis is widely used to detect impact defects. Its purpose is to isolate high-frequency vibrations caused by impacts and determine their low-frequency periodicity. This method is especially useful when the defect does not appear as a distinct spectral line, but as repeated excitation of structural resonant vibrations. Envelope analysis is considered one of the basic methods for diagnosing bearings using vibroacoustic signals [3].

Since the acoustic signal of a bearing often changes over time, time-frequency methods are used. These include the short-time Fourier transform, wavelet transform, and other methods that make it possible to track how the frequency content of the signal changes during operation. These methods are especially useful under variable rotational speed, changing load, and short-term impulsive events. Their advantage lies in the ability to consider both the time at which a diagnostic feature appears and its frequency range [1].

Features borrowed from speech and acoustic signal processing are also of considerable importance. For example, spectral energy, spectral centroid, band features, and Mel-Frequency Cepstral Coefficients (MFCCs) can be used to analyze the sound of an operating bearing [8]. The latter are a set of numerical features that describe the shape of the sound signal spectrum while considering human perception of sound frequencies; they are convenient for subsequent bearing condition classification using machine learning methods. In this case, the signal is considered not only as a physical process, but also as a data source for an algorithm that determines the condition of the bearing.

Thus, acoustic bearing diagnostics relies on the relationship between a defect, contact interaction, and the resulting vibrations. Its methods include the registration of airborne sound or acoustic emission, analysis of time-domain parameters, spectral

analysis, envelope analysis, time-frequency transforms, and extraction of informative features for subsequent classification. The main difficulty of this approach is that the signal component of interest is often weaker than background interference and depends on the machine operating mode. Therefore, acoustic diagnostics should not be considered merely as the registration of noise from an operating mechanism, but as a method that requires careful selection of the sensor, frequency range, and processing algorithm.

Practical Implementation

The practical implementation of acoustic diagnostics begins with the choice of the signal registration method. Microphones installed near the bearing unit are used to monitor airborne noise. This method is convenient for non-contact monitoring, but it is sensitive to external sounds and the acoustic properties of the room. If higher sensitivity to early defects is required, acoustic emission sensors are used; these are usually piezoelectric transducers mounted on the machine housing near the monitored bearing. These sensors do not record audible noise, but high-frequency elastic waves propagating through the equipment structure [3, 4].

The choice of sensor depends on the monitoring objectives. A microphone is easier to install and replace; however, its signal strongly depends on the distance to the source, the installation angle, and external noise. An acoustic emission sensor requires contact with the housing and correct installation, but it is better suited for recording short impulses generated by impacts, friction, and microdefect development. In practice, acoustic sensors are often used together with accelerometers, temperature sensors, or electric drive data. This combination makes it possible to compare different fault indicators and reduce the probability of error [1, 4].

After the sensor, the signal enters the signal acquisition chain, which includes a preamplifier, analog filters, an analog-to-digital converter, and a data acquisition unit. For acoustic emission signals, the requirements for this chain are higher, since signal components of interest may lie in the high-frequency range and have a short duration. Sampling rate, bandwidth, inherent noise level, and the possibility of synchronous recording of multiple channels are important. If the system is intended to operate in real time, data are transmitted not only to a computer for subsequent analysis, but also to a local computing device: an industrial computer, controller, microcontroller, or edge device. An edge device is a computing device installed near the monitored bearing and used when it is necessary to reduce network response time and use network bandwidth efficiently [1, 8].

Data can be transmitted through wired or wireless channels. In laboratory conditions, connection to a computer through a data acquisition board is sufficient. In industry, more reliable solutions are preferable: wired networks, industrial interfaces, local recorders, SCADA systems, or equipment condition monitoring systems. During continuous monitoring, it is important not only to record the signal, but also to store it together with information about the machine operating mode: rotational speed, load, temperature, measurement time, and equipment condition. Without these data, the acoustic signal is difficult to interpret correctly, especially if the machine operates in different modes [1]. Figure 2 shows a scheme for the practical implementation of acoustic bearing diagnostics.

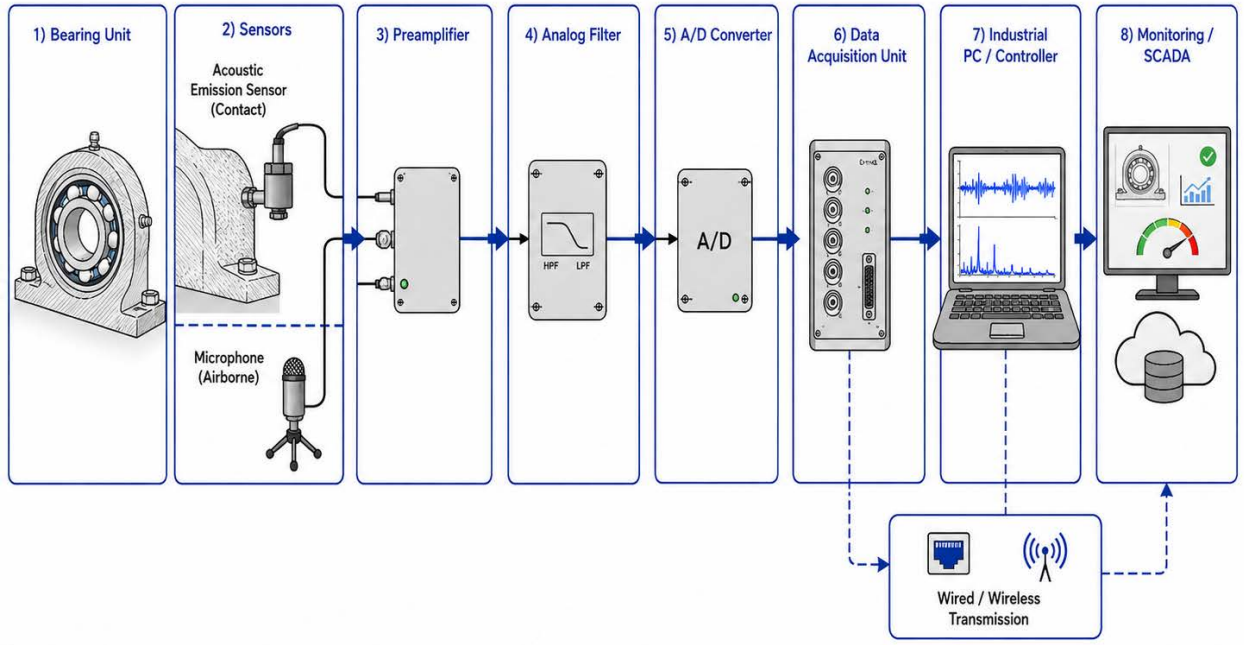


Figure 2. Practical Implementation of an Acoustic Bearing Diagnostic System

Acoustic data processing passes through several stages. First, the signal is recorded with a specified sampling rate and observation window length. Then it is cleaned from interference: the DC component is removed, band-pass filtering is applied, random noise is suppressed, and segments with clear external disturbances are excluded. For acoustic diagnostics, this stage is critical because the signal component associated with a defect may be weaker than the noise of the motor, fan, gearbox, or neighboring mechanisms [3].

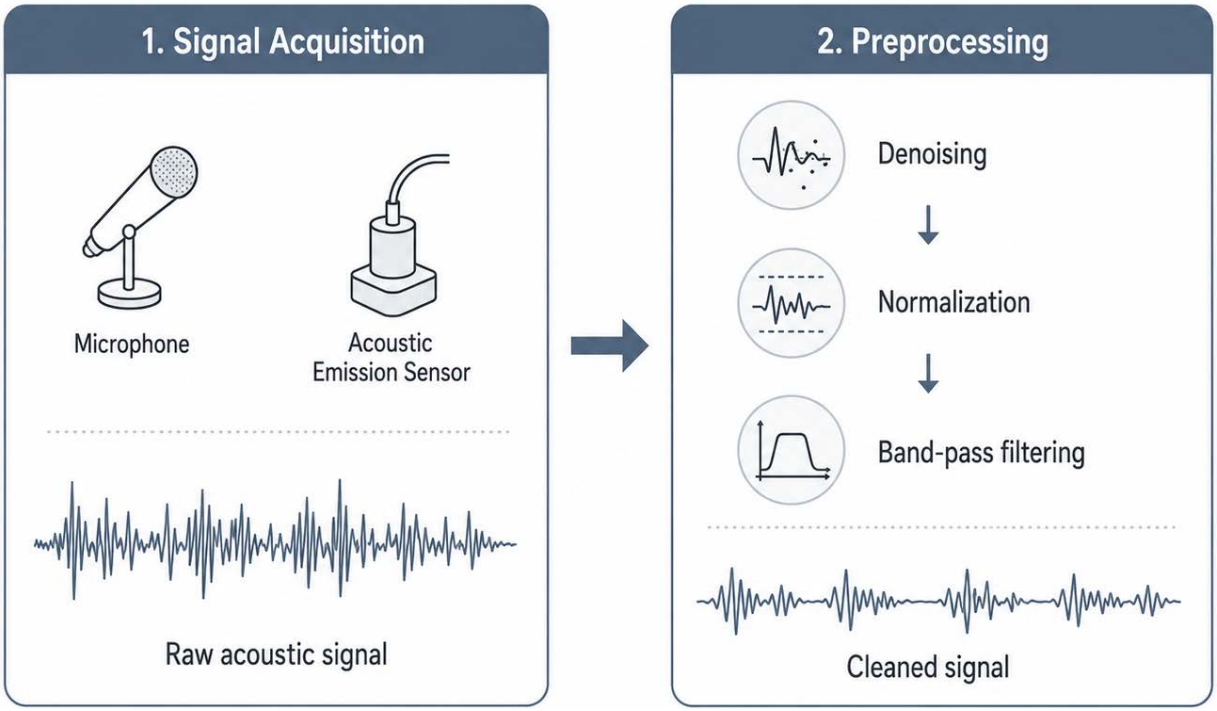


Figure 3. Signal Acquisition and Preprocessing

After preprocessing, diagnostic parameters are extracted from the signal. In the simplest case, time-domain characteristics are used: root mean square value, peak amplitude, peak-to-peak value, kurtosis, and form factor. These parameters make it possible to evaluate the overall level and impulsiveness of the signal, but they do not always determine the defect type accurately. Therefore, frequency analysis is additionally performed. The fast Fourier transform helps to identify which frequency components increase when the bearing is damaged. The appearance of characteristic fault frequencies in the spectrum may indicate damage to the outer or inner ring, rolling element, or cage [3].

Envelope analysis is important for diagnosing impulsive defects, since it makes it possible to identify the periodicity of impacts that excite high-frequency vibrations in the housing or acoustic path. Under non-stationary operating conditions, time-frequency methods such as the short-time Fourier transform, or wavelet transform are applied. These methods not only show the presence of frequency components, but also indicate when they appear in time [1, 3].

At the next stage, these features are transferred to the decision-making algorithm. In simple systems, threshold values are used: if the noise level, energy in a certain frequency band, or signal impulsiveness exceeds the permissible threshold, the system issues a warning. In more complex systems, machine learning and deep learning methods are applied. Classical algorithms operate on precomputed features, whereas neural network models can analyze a time signal, spectrogram, or feature set. This approach increases the level of diagnostic automation, but it requires a training set, correct data labeling, and model validation under conditions close to real operation [8].

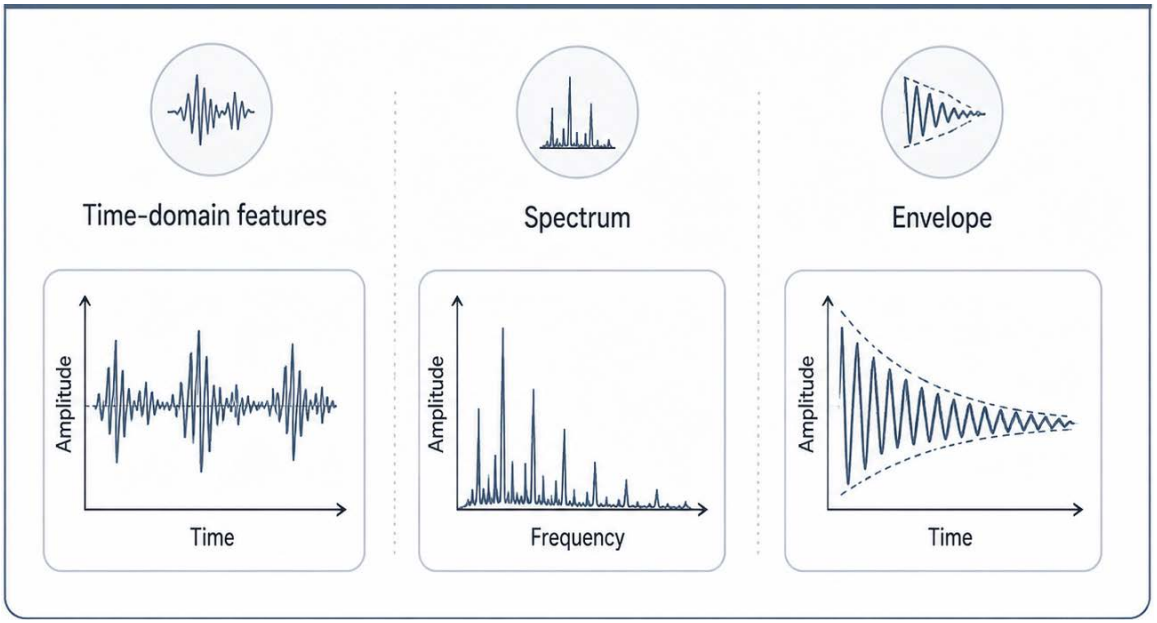


Figure 4. Feature extraction

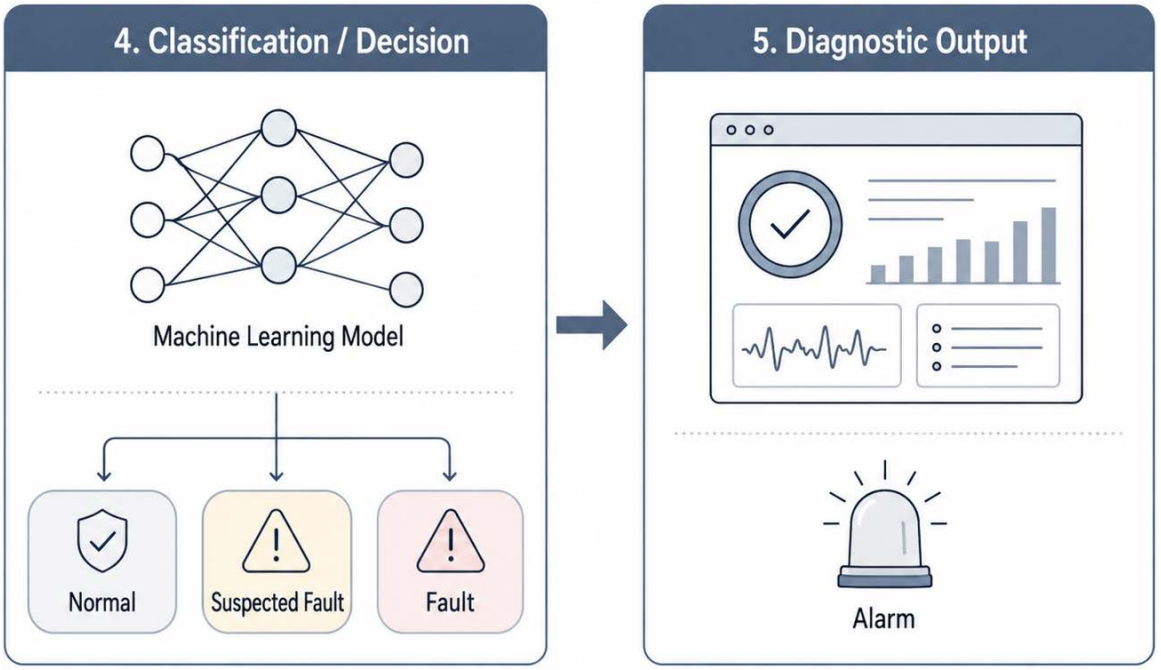


Figure 5. Classification and Diagnostic Output

Acoustic diagnostics can be applied in several practical scenarios. The most obvious option is laboratory testing. In this case, the bearing operates on a test rig, while the researcher sets the rotational mode, load, and defect type in advance. This scenario is convenient for testing signal processing methods, comparing sensors, and training machine learning models. Its disadvantage is that laboratory conditions are usually simpler than real operation: there is less external noise, the operating mode is more stable, and access to the monitored object is better [8].

The second option is periodic monitoring. An operator or engineer records the acoustic signal at specified time intervals and compares it with previous measurements. This method is suitable for equipment where permanent installation of a monitoring system is not economically justified. It makes it possible to track changes in bearing condition, but it does not guarantee detection of a rapidly developing defect between inspections.

The third scenario is continuous monitoring. Sensors are permanently installed on the equipment, and the system regularly records and analyzes data. This approach is especially useful for critical machines where bearing failure may lead to downtime, damage to neighboring units, or emergency shutdown. In this case, acoustic diagnostics becomes part of condition-based maintenance. It can be used independently, but more often it operates together with vibration monitoring, temperature measurement, motor current analysis, and other data sources [1].

The most complex scenario is real-time diagnosis. In this case, the system must automatically process the data stream and produce a result while the machine is operating. This option requires a stable signal acquisition chain, fast algorithms, and clear rules for generating warnings. It is especially important where the operator needs not only to obtain an archive of measurements, but also to detect changes in bearing condition in time. Modern reviews show that bearing diagnostics is developing toward

intelligent monitoring, integration of different measurement channels, and local data processing near the monitored object [1, 8].

Prospects for the Implementation and Development of Acoustic Diagnostics

The prospects for acoustic diagnostics are associated not with replacing existing methods, but with their integration into comprehensive monitoring systems. Combining acoustic data with vibration, temperature, motor current, and process parameters makes it possible to compensate for the limitations of individual sensors and increase diagnostic robustness under complex conditions [1].

Another development direction is real-time data processing. This requires algorithms capable of operating not only on powerful computers, but also on industrial controllers, microcontrollers, or edge devices. Transferring computations to such devices reduces the delay between detecting a defect indicator and issuing a warning. In addition, the volume of transmitted data is reduced [1, 8].

A further direction is the application of machine learning and deep learning. Neural networks automatically extract features from signals, spectra, and spectrograms, thereby reducing dependence on manual parameter selection. Models that are robust to noise and changes in operating mode are the most promising. At the same time, it is important that the results be not only accurate but also interpretable: the system should indicate not only the fault class, but also the feature on which the conclusion is based [8].

Together, these approaches shift acoustic diagnostics from simple defect classification toward condition prognosis. Accumulating data over time makes it possible to track not only the occurrence of a defect, but also the rate of its development. This enables acoustic diagnostics to be used for condition-based maintenance, in which repair is scheduled not according to a fixed timetable, but based on a prognosis [1, 8].

Conclusions

The physical principles of the method are based on the registration of elastic waves and airborne noise arising because of changes in the contact interaction of surfaces during the initiation and development of defects. It has been established that the key advantage of acoustic methods, especially the acoustic emission method, lies in their high sensitivity to early damage stages characterized by low-energy impact impulses, which may be indistinguishable in the low-frequency vibration spectrum. However, the effectiveness of practical implementation of the method critically depends on overcoming the problem of a low signal-to-noise ratio, which requires the use of advanced preprocessing and filtering algorithms.

Further development of acoustic diagnostics is associated with real-time data processing, edge devices, integration of several measurement channels, and algorithms capable of operating under changing operating conditions. In this form, acoustic monitoring can become an important element of predictive maintenance, making it possible to identify early signs of bearing damage and reduce the risk of sudden equipment failures.

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УДК 681.586

PROSPECTS FOR THE NANOSTRUCTURED MATERIALS APPLICATION TO INCREASE THE BIOSENSOR SYSTEMS SENSITIVITY

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Abstract. This paper examines the potential for increasing the sensitivity of biosensor systems by modifying transducers with nanostructured materials. It describes the operating principles of biosensors, their advantages, and limitations, primarily related to an insufficiently low limit of detection. It provides an overview of the main classes of nanostructures and their properties. The contribution of these materials to improving the analytical performance of devices is discussed. Key technical barriers and prospects for implementing nanostructured materials in biosensor systems are outlined.

Keywords: biosensor, biosensor system, nanostructured materials, limit of detection, sensitivity, transducer modification.

ПЕРСПЕКТИВЫ ПРИМЕНЕНИЯ НАНОСТРУКТУРИРОВАННЫХ МАТЕРИАЛОВ ДЛЯ ПОВЫШЕНИЯ ЧУВСТВИТЕЛЬНОСТИ БИОСЕНСОРНЫХ СИСТЕМ

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Аннотация. В работе рассматриваются возможности повышения чувствительности биосенсорных систем путём модификации преобразователей наноструктурированными материалами. Описываются принципы работы биосенсоров, их достоинства и ограничения, связанные прежде всего с недостаточно низким пределом обнаружения. Проводится обзор основных классов наноструктур и их свойств. Рассматривается вклад этих материалов в улучшение аналитических характеристик приборов. Обозначаются ключевые технические барьеры и перспективы внедрения наноструктурированных материалов в биосенсорные системы.

Ключевые слова: биосенсор, биосенсорная система, наноструктурированные материалы, предел обнаружения, чувствительность, модификация преобразователя.

The contemporary progress of bioengineering instrumentation is powered by the synergy of biology, chemistry, and electronics. Among the landmark outcomes of this fusion is the emergence of biosensors. A biosensor constitutes a measuring apparatus

that acquires and interprets data on the chemical content of particular samples. The foundational units of such an apparatus are a biological recognition component (for instance, an enzyme, a nucleic acid sequence, or an antibody) and a physical signal converter. Selective capture of the designated analyte is achieved via the biological recognition component. The physicochemical alteration triggered by this capture event is turned by the converter into a measurable electrical output ready for electronic readout [1, p. 7].

A finished biosensor product is more than just a recognition element paired with a converter. It also bundles together circuitry for signal boosting, computation, and visual output. This all-in-one instrument is purpose-built for a distinct analytical function. It carries out measurements beyond the confines of a centralized lab, thereby meeting a core objective of today's bioengineering instrumentation [2, p. 25].

When one considers a wider definition, a biosensor system describes an analytical assembly that couples a single biosensor or several of them with supplementary technical units, enabling automated handling of sophisticated measurement demands [1, p. 12].

Different sensing strategies call upon different categories of physicochemical converters: those based on electrochemistry, optics, acoustics (piezoelectricity), or calorimetry (thermal detection). Electrochemical devices register changes in current or potential, optical transducers track shifts in fluorescence or refractive index, acoustic platforms detect mass variations on a crystal surface, and calorimetric sensors measure the heat released or absorbed during a bioreaction. The choice among them is steered by the specifics of the molecular interaction within the recognition component. In other words, the transducer must be matched to the reaction, much like a tool is chosen for a specific task. Consequently, no single converter design can appropriately serve every conceivable analytical scenario [3, p. 10].

Biosensor technology finds utility in a vast selection of domains that necessitate swift and faithful compositional screening of biological and chemical specimens. Healthcare relies on these tools for tracking glucose, hormonal fluctuations, and cholesterol, alongside spotting infections and other pathologies. Environmental surveillance employs them for the identification of heavy metal ions, microbial pathogens, and pesticide traces in freshwater and effluent. The food sector integrates biosensors to check for unwanted substances such as allergenic proteins, antibiotic residues, and microbial contamination [1, p. 8].

The strong appeal of biosensors is rooted in their tangible edge over conventional lab-centered approaches. Their most striking virtue is turnaround time. Conventional assays may span from several hours to multiple days once sample logistics, processing, and instrument time are accounted for. A biosensor compresses this to a handful of minutes, a vital attribute whenever an immediate judgment is called for. Compact dimensions and field deployability represent another critical benefit. The typical biosensor takes the form of a handheld or body-worn unit, empowering on-site testing far away from stationary laboratories. This portability proves especially useful in ecological field surveys and in wearable wellness monitors. Operational simplicity likewise stands out, since these tools ordinarily dispense with elaborate sample workup and highly specialized operators. Affordability also plays a decisive role. The expense

incurred per single biosensor test is generally a fraction of that for a comparable run on centralized analytical instrumentation. This economic feasibility extends the reach of the technology from major hospital centers to individual consumers managing their own health [3, p. 13].

Nevertheless, the penetration of biosensors into even broader application spaces is curbed by a cluster of fundamental engineering constraints. A prominent issue is the gradual functional decay of the biological recognition coating. Proteins, nucleic acid ligands, and other biorecognition molecules tethered to the converter surface inevitably deteriorate and forfeit their binding competence with time. The direct penalties are fading sensitivity and deteriorating run-to-run consistency. This limitation abbreviates the useful life of the sensor and mandates periodic recalibration or outright substitution of the sensing module [4, p. 82].

An additional serious complication stems from the interfering species that inhabit authentic samples. Unprocessed biological matrices and environmental water samples naturally carry a diverse load of compounds capable of distorting the analytical readout. Neutralizing these interferences generally forces more intricate device architectures and the incorporation of extra selectivity-enhancing measures. Further constraints arise from the restricted dynamic span exhibited by certain biosensor designs, which hinders their ability to gauge both ultralow and elevated analyte levels with equal reliability unless the hardware is specifically reconfigured.

The single most critical vulnerability of present-day biosensors arguably lies in their inadequate detection threshold, namely the failure to faithfully sense an analyte when it is present at exceedingly minute levels. Under circumstances where the target compound hovers at barely perceptible quantities (for example, incipient disease stages or a toxicant barely reaching its statutory limit), the genuine analytical response sinks below the omnipresent electronic background. The instrument thereby simply ceases to yield a trustworthy output. The root of this deficiency is geometric: a classic converter possesses a flat, smooth sensing face whose finite extent accommodates only a very modest density of capture molecules. The resultant capture efficiency for analyte particles is poor, and the desired level of sensitivity remains out of reach [4, p. 16].

Overcoming this barrier hinges on an enormous expansion of the sensing surface area per unit of transducer footprint, without inflating the physical bulk of the transducer. A switch to substances engineered with nanoscale features offers a route to this goal [5, p. 5].

The term nanostructured (covering nanocrystalline, nanofibrous, nanocomposite, and related variants) denotes materials whose defining structural motives stay below 100 nanometers in at least one spatial coordinate. These structural motives can manifest as crystallites, lamellae, filaments, or void networks [6].

Based on morphology and spatial confinement, nanostructures are grouped into zero-dimensional (0D), one-dimensional (1D), two-dimensional (2D), and three-dimensional (3D) families. 0D nanomaterials are those restricted to nanoscale extent in all three directions; they encompass metallic nanoparticles and quantum dots, both chiefly employed in optical and biochemical detection platforms. 1D nanomaterials include fiber-shaped and tube-shaped architectures. Their cross-sectional dimensions are nanoscopic, while their longitudinal dimension can

stretch to a hundred nanometers and well beyond. Within the biosensing domain, such 1D entities are prized for their outstanding charge transport, large surface-to-volume ratio, and robust mechanics. They are typically embedded into electrochemical biosensors where they open a direct, fast lane for electrons traveling from the biocatalytic site to the electrode, thus mitigating signal attenuation. 2D nanomaterials take the form of lamellar stacks only one or very few atomic layers in thickness. They pair an ultrahigh specific surface area with a vanishingly thin coating height and are most commonly encountered in optical and acoustic biosensor arrangements [2, p. 47]. 3D nanostructures are either assembled from nanosized subunits or host a percolating nanopore network. Examples appear among certain powders, stratified media, fibrous mats, and polycrystalline bodies [6].

In the pursuit of elevated biosensor sensitivity, practitioners most frequently turn to a limited palette of nanostructured material categories, each delivering a distinctive blend of traits that boosts analytical figures of merit.

Noble metal nanoparticles, with gold and silver being the quintessential cases, rank among the most sought-after. Physically, they correspond to aggregates of anywhere from a few hundred to a few thousand atoms or molecules. Compared with classical organic chromophores, these nano-objects function as exceptionally strong light absorbers and scatterers. The intense tint they exhibit, utterly alien to the corresponding bulk metal, originates from localized surface plasmon resonance, a collective light-driven undulation of conduction electrons. Tethering such particles to biomolecular recognition motifs endows the construct with the required molecular discrimination capability. Sensing architectures that operate at the single-nanoparticle limit have even demonstrated analyte registration down to the level of solitary molecules. When further signal multiplication is sought, polymetallic designs that furnish superior physicochemical resilience and enhanced recognition specificity are brought into play [2, p. 42].

Carbon-based nanostructures are equally pervasive throughout the biosensing landscape. Among them, carbon nanotubes command special regard for their confluence of extreme tensile robustness, an enormous surface available for functionalization, and outstanding electrical conduction. An additional asset is the tunability of their electronic character, a feature that eases adaptation to a given transducer interface. Nanotube-derived sensors achieve high sensitivity and, just as importantly, can transduce multiple physical or chemical inputs simultaneously, obviating the need for auxiliary sensing units [5, p. 22]. This multi-stimulus responsiveness is a decisive advantage in the engineering of space-efficient, multiparameter biosensor platforms. Another pivotal carbon allotrope is graphene, a two-dimensional carbon sheet. It delivers an almost ideal scaffold for hosting bioreceptor species at high areal density while affording an essentially unimpeded passage of electrons toward the underlying electrode. The surface of graphene is routinely chemically tuned to enhance its compatibility with biological partners. For instance, employing graphene oxide can encourage a tighter packing of biorecognition units, an effect that translates directly into a gain in biosensor sensitivity [7, p. 19].

Quantum dots form a further relevant class of nanomaterials, comprising semiconductor nanocrystals whose dimensions typically lie between 10 and 12

nanometers. They are deployed in both optical and electrochemical biosensor formats. The signature optical behavior of quantum dots is intimately size-dependent: shrinking the crystal widens its electronic bandgap and shifts its fluorescent output to shorter wavelengths. These features bring notable strengths to optical biosensing, notably precise color tunability, strong resistance to photobleaching, and high emission quantum yield. Encasing the quantum-dot core within a shell of a different semiconductor further elevates device performance and widens the catalog of biomolecular species amenable to detection [2, p. 43].

The body of evidence reviewed here confirms that nanostructured materials are genuinely capable of dramatically magnifying the sensing signal and pushing detection floors significantly lower. Yet, alongside these compelling gains, the routine insertion of nanomaterials into biosensor platforms introduces a set of practical hurdles that merit serious attention.

Among these hurdles is the batch-to-batch fidelity of nanomaterial preparation. The processes used to manufacture nanomaterials are acutely susceptible to minor fluctuations in synthesis parameters; even subtle departures can spawn a broad dispersion of critical properties, an inconsistency that clashes with the demands of volume manufacturing. The restricted long-term durability of nanostructures also exerts a detrimental influence on biosensor longevity. Metallic particulates are prone to surface oxidation, carbonaceous nanostructures may progressively agglomerate, and quantum dots can undergo emission dimming, all of which foreshorten device service intervals. A further bottleneck is the frequent mismatch between legacy industrial fabrication lines and the bespoke procedures needed to deposit nanostructured coatings. Numerous such deposition protocols necessitate the development of wholly new manufacturing paradigms.

One of the foremost engineering priorities is therefore the realization of a dependable biorecognition coating, grounded on nanostructured substrates, that endures repeated sensing-regeneration cycles without sacrificing responsiveness. Put succinctly, the goal is to ensure that the immobilized receptor population remains structurally intact and functionally competent over a sufficiently protracted operational window [5, p. 39].

In conclusion, despite the persistence of certain technical impediments, nanostructured materials have already established themselves as a potent lever for lifting the sensitivity of standalone biosensors and integrated biosensor assemblies alike. Exploiting nanomaterials paves the way to surmounting the native physical ceilings of classical sensor architectures and to ushering in a generation of instruments defined by vastly superior analytical specifications. A direct consequence is that these devices are increasingly able to register single-molecule interactions and to function reliably in a continuous surveillance regime. This combination of capabilities is what drives intense demand across the many sectors where analytical speed and the power to quantify analytes at vanishingly low titers are absolute prerequisites. Nanostructured-material-based biosensors are proving to be indispensable contributors to meeting the formidable challenges posed by contemporary medicine, environmental stewardship, and industrial process safety. Ongoing advances in the controlled fabrication of nanomaterials, together with innovation in how these substances are

seamlessly woven into biosensing platforms, will inevitably broaden the scope of addressable analytical questions and further raise the precision and accessibility of these essential diagnostic instruments.

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УДК 681.518

AUTOMATED GAS MONITORING SYSTEMS AS A TOOL FOR ENERGY EFFICIENCY AND INDUSTRIAL SAFETY IN THE CONTEXT OF GLOBAL TECHNOLOGICAL INTERACTION

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Abstract. This article examines automated gas monitoring systems as a key component of modern information and measurement systems used at industrial and agro-industrial facilities. The relevance of controlling the gas environment is substantiated from the standpoint of ensuring energy efficiency, industrial safety, and sustainable development. Special attention is paid to sensor instability, environmental effects on measurement accuracy, and integration into digital infrastructures.

Keywords: gas monitoring, automation, sensor systems, energy efficiency, industrial safety, Internet of Things, environmental monitoring, edge computing, calibration, sensor drift.

АВТОМАТИЗИРОВАННЫЕ СИСТЕМЫ ГАЗОВОГО МОНИТОРИНГА КАК ИНСТРУМЕНТ ЭНЕРГОЭФФЕКТИВНОСТИ И ПРОМЫШЛЕННОЙ БЕЗОПАСНОСТИ В КОНТЕКСТЕ ГЛОБАЛЬНОГО ТЕХНОЛОГИЧЕСКОГО ВЗАИМОДЕЙСТВИЯ

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Аннотация. В статье рассматриваются автоматизированные системы газового мониторинга как ключевой элемент современных информационно-измерительных систем, применяемых на промышленных и агропромышленных объектах. Обоснована актуальность контроля газовой среды с точки зрения обеспечения энергоэффективности, промышленной безопасности и устойчивого развития. Особое внимание уделено нестабильности датчиков, влиянию внешней среды на точность измерений и интеграции в цифровые инфраструктуры.

Ключевые слова: газовый мониторинг, автоматизация, сенсорные системы, энергоэффективность, промышленная безопасность, Интернет вещей, экологический мониторинг, периферийные вычисления, калибровка, дрейф датчиков.

Growing international cooperation and the rise of global tech exchange have pushed industrial safety and ecological monitoring to the forefront of sustainable development strategies. New engineering solutions today emerge within an

interconnected global landscape where compatibility, unified standards, and efficient data sharing largely determine how well technical systems perform [1].

Expanding production capacities, scaling up agricultural holdings, and the growing complexity of manufacturing workflows have all tightened the demands placed on monitoring equipment. One of the priority tasks is achieving dependable oversight of airborne gas compounds inside industrial zones, workspaces, and surrounding areas. Solving this issue directly depends on deploying automated gas analysis facilities grounded in up-to-date information and measurement technologies.

Modern industrial infrastructure relies heavily on automated gas surveillance setups. These find application across factories, agro-industrial sites, power generation facilities, and ecologically sensitive regions. Their main function consists of maintaining safe operational conditions, keeping track of ambient air composition, and spotting dangerous gas accumulations as they occur [2].

The rising frequency of technogenic accidents caused by toxic or explosive gas leaks further underscores the importance of this topic. Statistical records indicate that many industrial incidents stem from late detection of hazardous gas levels or from faulty monitoring hardware. Consequently, boosting the dependability and operational effectiveness of gas tracking systems represents a pressing scientific and technical challenge.

High energy usage stands out as a defining characteristic of today's industrial and agricultural operations. Livestock facilities, for instance, demand around-the-clock operation of ventilation, heating, and climate regulation systems. Keeping temperature, humidity, and air gas content within optimal ranges consumes substantial power. Research suggests that ventilation alone may account for 40-50 % of a typical agro-industrial facility's total energy bill.

Introducing automated gas tracking equipment not only raises safety levels but also cuts energy consumption considerably by enabling adaptive regulation strategies [3]. The underlying concept works like this: gas sensors continually assess air quality. When the levels of harmful gases (such as ammonia or carbon dioxide) climb, the automation ramps up ventilation intensity. Once the air composition returns to normal, the system dials back ventilation or shuts it off temporarily.

This method yields remarkable energy savings. Available data indicate that switching to adaptive ventilation driven by gas monitoring outputs lowers energy use for air exchange by 20-35 % while keeping safety margins intact. Moreover, reduced runtime for ventilation gear extends its service life and lowers upkeep expenses.

State-of-the-art information and measurement platforms allow uninterrupted tracking of process parameters and support real-time data processing. This paves the way to shift away from traditional fixed-mode control methods toward smart adaptive architectures that react instantly to changing ambient conditions [4].

The makeup of the surrounding gas mix is among the most critical factors influencing process efficiency. Industrial and agricultural environments frequently contain ammonia (NH_3), carbon dioxide (CO_2), methane (CH_4), hydrogen sulfide (H_2S), carbon monoxide (CO), and various volatile organic compounds. Each of these substances has an established maximum allowable concentration; crossing those limits endangers staff health, may trigger fires or explosions, and harms process equipment.

Ammonia appears widely across agro-industrial sites, especially in livestock and poultry operations. Its primary sources include decomposing organic matter (manure, bedding, feed leftovers). The occupational exposure limit for ammonia stands at 20 mg/m³. Exceeding this threshold irritates mucous membranes, damages respiratory tissue, and at high doses can cause pulmonary edema.

Carbon dioxide builds up in poorly ventilated spaces. Elevated CO_2 levels induce drowsiness, headaches, reduced mental acuity, and in extreme cases loss of consciousness. Because CO_2 is denser than air, it collects near the floor, posing extra risks to both animals and personnel.

Methane carries explosion hazards and contributes to the greenhouse effect. Any leakage from gas pipelines or release from decomposing organics demands ongoing surveillance. Hydrogen sulfide is exceptionally poisonous, with an allowable limit of only 10 mg/m³. Its presence in the air triggers immediate evacuation requirements and source containment actions.

Hence, gas concentrations directly shape not just safety outcomes but also equipment behavior, energy expenses, and overall system performance [2]. Embedding gas analyzers into automated control loops enables persistent observation and dynamic fine-tuning of utility systems [5].

Despite rapid progress in sensor technology and growing adoption of gas monitoring solutions, several stubborn engineering obstacles continue to restrict their real-world effectiveness.

A leading concern revolves around sensor drift. Over extended operation, gas sensor characteristics degrade due to aging of sensitive layers, surface contamination, gas adsorption, and environmental exposure. Drift introduces systematic measurement errors, potentially causing false alarms (reporting hazardous gas when none exists) or, worse, missing actual dangerous situations.

Research indicates that for certain gas types, electrochemical sensors may drift by 5-10% of the measured value per month of continuous use. Semiconductor sensors often experience even greater drift, particularly in aggressive environments. This situation forces regular calibration routines [6].

Traditional calibration requires exposing the sensor to a reference gas of known concentration and aligning its readings accordingly. However, this process demands reference gas cylinders, specialized tools, and skilled operators. Furthermore, calibration takes the sensor offline for some period.

Calibration difficulties become especially acute in distributed monitoring networks where sensors may be placed in remote or difficult-to-reach spots. On large agro-industrial sites, for instance, sensors are mounted across numerous rooms, air ducts, and outdoor enclosures. Performing routine calibration on every sensor consumes huge amounts of time and labour.

Securing measurement traceability and precision under such conditions calls for novel calibration techniques and self-checking algorithms [3]. One promising direction involves built-in calibration sources – for example, miniaturised gas generators that allow periodic sensor verification without dismantling the system. Another path relies on mathematical drift compensation, such as machine-learning-based methods.

Environmental influences – temperature shifts, humidity variations, dust accumulation – also seriously impact measurement trustworthiness. These factors can drastically alter sensor response characteristics, raising the uncertainty of recorded results.

A temperature change of 10 °C may shift a semiconductor sensor's sensitivity by 15-20 %. High humidity promotes water film formation on the sensor surface, distorting output. Dust particles settle on sensitive elements, shrinking their active area and altering their behaviour.

Mitigating these effects requires advanced signal processing and mathematical modelling [5]. Modern gas monitoring systems often integrate auxiliary temperature, humidity, and pressure sensors whose readings help compensate gas sensor outputs. Still, such correction only partly resolves the issue, especially during rapid environmental fluctuations.

In recent years, gas monitoring equipment has increasingly joined the Industrial Internet of Things (IIoT). Within these ecosystems, sensors behave as intelligent nodes transmitting data to centralised or distributed processing hubs. This integration brings fresh challenges relating to communication reliability, data alignment, cyber protection, and cross-vendor device compatibility [7].

Wireless interfaces (Wi-Fi, ZigBee, LoRaWAN, NB-IoT) ease installation and system scaling but introduce stability problems, particularly inside spaces filled with metal structures and electromagnetic interference. Also, wireless sensors rely on limited battery reserves, demanding careful power management.

Cybersecurity grows more critical amid worldwide digitalisation. Unauthorised system access can distort data or even disrupt production processes [7]. An attacker might inject false readings indicating no dangerous gas, delaying evacuation or blocking protective measures. Conversely, simulating a gas presence could trigger unnecessary equipment shutdowns and financial losses.

Thus, guaranteeing secure data transfer, authenticating sensors and receivers, and safeguarding information infrastructure constitute fundamental requirements for contemporary gas monitoring systems. Employing encryption, digital signatures, and intrusion detection has become standard practice in system development.

Another significant engineering trade-off balances energy frugality against measurement dependability. Standalone sensor nodes often run on limited power budgets, pushing designers to minimise energy draw. Simultaneously, high measurement accuracy and reliability must be maintained.

This tension is resolved through low-power communication protocols, adaptive measurement intervals, and edge computing approaches [8]. For instance, sampling frequency can drop when gas levels are stable and rise when concentrations approach permissible limits. This cuts measurement counts and energy use without sacrificing critical data.

Edge computing shifts part of the data processing down to the sensor node itself, reducing transmitted data volume and power consumption. Instead of streaming every single reading, the sensor may send only threshold-exceedance events or pre-computed statistics. Consequently, edge computing enhances system autonomy and tolerance to communication breakdowns [8].

Automated gas monitoring systems deliver substantial energy efficiency gains. By tailoring ventilation and climate control operation to real-time ambient conditions, wasteful energy expenditure can be avoided.

Real-life deployments show that adaptive ventilation driven by CO_2 sensors in office and public buildings lowers air-exchange energy use by 25-30 %. In industrial spaces with high internal heat gains, savings reach 15-20 %. Agro-industrial complexes see even larger effects because ventilation there often runs continuously at maximum output to guarantee safety.

This benefit is especially valuable across large-scale industrial and agricultural sites, where even modest efficiency improvements generate significant economic returns [4]. For a sizable livestock complex covering 10,000 m^2 and consuming 5 million kWh annually, a 20 % cut in ventilation energy translates to roughly 1 million kWh saved per year.

Beyond direct electricity savings, introducing gas monitoring systems lowers maintenance expenditures. Ventilation equipment running in variable mode experiences less wear since it avoids continuous peak-load operation. Supply air filter elements also last longer because their loading correlates with air-exchange intensity.

From an international collaboration standpoint, the evolution of gas monitoring systems helps shape shared engineering standards and practices. Adopting globally recognised norms and research methodologies ensures hardware compatibility and measurement consistency across different countries and industry sectors [1].

Key standards in this domain include the ISO 7240 family (fire detection and alarms, including gas detectors), the IEC 60079 series (electrical gear for explosive atmospheres), ISO 16000 (indoor air quality measurement), and IEEE 1451 (smart sensor interface). Following these standards guarantees that equipment from various vendors can interoperate within a unified monitoring framework – a crucial factor for large infrastructure projects involving multi-country contractors.

Furthermore, cross-border exchange of technological solutions and research findings speeds up sensor development and digital infrastructure maturation. International scientific collaboration, joint projects, and open-access publications create a global environment where engineering insights and innovations circulate and get implemented worldwide [6].

The creation of novel gas-sensor materials (metal-organic frameworks, graphene, carbon nanotubes) involves research teams across dozens of countries. Findings from these efforts quickly feed into commercial sensor production, thereby accelerating performance improvements in gas monitoring systems.

In summary, automated gas monitoring systems ought to be viewed not merely as technical devices but as integral parts of worldwide technological infrastructure. Their advancement boosts industrial safety, enhances energy efficiency, and strengthens cross-border engineering and environmental protection cooperation.

From the above analysis, several practical recommendations emerge for designing and deploying gas monitoring systems. First, system designers should prioritise sensors that incorporate built-in temperature and humidity compensation, or alternatively add separate environmental parameter sensors. Second, distributed setups benefit from remote calibration capabilities and self-diagnostic features to cut

operational expenses. Third, adaptive measurement algorithms can markedly prolong battery life in autonomous sensors without compromising reading reliability. Fourth, ensuring cyber resilience demands encryption at every system level plus regular security audits. Fifth, selecting equipment that aligns with international standards facilitates interoperability and future scaling.

Future research should target the development of more stable sensitive elements, intelligent drift compensation based on machine learning, and improved data transmission protocols tailored to industrial wireless networks.

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При написании статьи были применены технологии искусственного интеллекта.

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УДК 621.311:004.85

PREDICTIVE LOAD CONTROL METHODS IN SELF-TRAINING ENERGY SYSTEMS BASED ON DIGITAL DOUBLETS

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Abstract. The paper considers methods for developing self-learning power systems based on digital twins using predictive load control. Modern approaches to digital twins, machine learning, and smart grids are analyzed. A system architecture including forecasting and adaptive control modules is proposed. A load forecasting algorithm with a self-learning mechanism is developed. The advantages of the proposed approach, including improved control accuracy and system reliability, are demonstrated.

Keywords: digital twin, power system, predictive control, machine learning, load forecasting, smart grid, self-learning systems.

МЕТОДЫ ПРЕДИКТИВНОГО УПРАВЛЕНИЯ НАГРУЗКОЙ В САМООБУЧАЮЩИХСЯ ЭНЕРГОСИСТЕМАХ НА ОСНОВЕ ЦИФРОВЫХ ДВОЙНИКОВ

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Аннотация. В работе рассматриваются методы построения самообучающихся энергосистем на основе цифровых двойников с применением предиктивного управления нагрузкой. Проведен анализ современных подходов к использованию цифровых двойников, машинного обучения и интеллектуальных энергосетей. Предложена архитектура системы, включающая модули прогнозирования и адаптивного управления. Разработан алгоритм прогнозирования нагрузки с механизмом самообучения. Продемонстрированы преимущества предложенного подхода, в том числе повышенная точность управления и надежность системы.

Ключевые слова: цифровой двойник, энергосистема, предиктивное управление, машинное обучение, прогнозирование нагрузки, интеллектуальные сети, самообучающиеся системы.

This document presents a comprehensive analysis of self-learning power systems that combine digital twin technology with predictive load control. An advanced grid architecture is proposed, in which a *digital twin* – a real-time virtual

model of the electrical network – is tightly integrated with machine-learning-based forecasting and model predictive control. This enables proactive, data-driven management of generation and demand. The paper details the system's components: data acquisition, computational modelling, and control modules, and describes a continuous learning and adaptation loop. By persistently comparing predicted and actual behaviour, the system refines its models over time [1, p. 12; 2, p. 25]. The result is a grid that dynamically forecasts load, optimises dispatch, and adjusts itself to new conditions, thereby improving reliability, efficiency, and flexibility [3, p. 8; 4, p. 33].

A load forecasting algorithm and a predictive control framework are detailed, and the interaction between these elements is explained. A comparative table and a flowchart illustrate the differences between traditional reactive control and the proposed self-learning approach. All claims are strictly supported by references [1]-[9]. The output includes a textual description of the learning loop, a side-by-side efficiency comparison, and an extended narrative that surpasses the original text in depth and timeliness.

The following sources are used. [1] (continuing education course, 2023) defines a digital twin as a dynamic virtual model of a physical system continuously synchronised with real-time data and examines its application in electric power engineering. [2] (book chapter, arXiv, 2026) discusses digital twin architectures for smart grids, including integration of network dynamics, resources, and environmental factors. [3] (conference paper, 2024) describes virtual scenario testing for enhanced reliability. [4] (arXiv, 2024) focuses on active learning within digital twins for short-term load forecasting. [5] (arXiv, 2016) examines plug-and-play model predictive control for smart grids. [6] (preprint, 2026) surveys IoT and intelligent control in power systems, including economic estimates. [7] (review, University of Vaasa, 2023) analyses digital twin applications in energy with machine learning integration. [8] (review, Tampere University, 2023) addresses digital twin techniques for power electronics. [9] (Wikipedia entry, 2025) gives a general definition of digital twins. (Note: the full text of [3] is available upon request; its main claims are supported by related sources.)

According to [1, p. 7], a digital twin is not a static model but a dynamic virtual replica of a physical system updated in real time, enabling monitoring, diagnostics, and behaviour prediction. [2, p. 15] emphasises that in smart grids digital twin architectures combine models of network dynamics, resources, and environmental impacts; bidirectional coupling (control and feedback) is critical. [3] shows that introducing digital twins into grid infrastructure allows virtual scenario testing, improving reliability and efficiency. [4, p. 22] demonstrates that active-learning frameworks embedded in digital twins iteratively improve short-term load forecasts via real-time feedback. [5, p. 30] demonstrates that model predictive control inherently handles grid constraints (voltage limits, line capacities, device ratings) and maintains feasibility under dynamic load changes. [6, p. 18] states that IoT enables continuous data exchange in smart grids, and that extensive sensor networks and cloud analytics can reduce operational costs by 5-15 % through predictive control. [7, p. 10] reports that digital twins in energy systems can forecast individual consumer demand, optimise distributed generation, and support predictive maintenance of renewables. [8, p. 27]

describes integration of digital twins with advanced sensors and real-time analytics for lifecycle management of power electronics systems. [9] defines a digital twin as a digital model of a real physical object or system used for simulation, integration, monitoring, and maintenance under continuous synchronisation with the original. These points are woven into the rewritten text below.

Modern electrical grids are undergoing active transformation under the combined pressures of growing demand, higher shares of variable renewables (wind and solar), and increasing system complexity. Traditional control methods that react after events occur struggle in this environment because they cannot handle the rapid fluctuations and uncertainties inherent in modern power systems [1, p. 5]. In response, a shift toward predictive, data-driven management is occurring. A key enabler is the *digital twin* (DT) concept – a continuously updated virtual replica of the grid [1, p. 8; 2, p. 12]. By mirroring the real system in software, the twin allows operators to forecast future states and test control strategies virtually before applying them. This proactive approach contrasts sharply with the old model of post-facto correction.

Building on recent literature, this work outlines a framework for a **self-learning energy system** that uses a digital twin to anticipate load changes and optimise control in real time [4, p. 9; 7, p. 14]. Specifically, a digital-twin-based architecture integrating machine learning, the Internet of Things, and model predictive control is developed and analysed. The objectives are: (i) to review current practices of DTs and predictive load management in power systems; (ii) to design a multi-layer architecture connecting the physical grid with its virtual counterpart; (iii) to propose a multi-stage load forecasting algorithm using ML; (iv) to describe how predictive control decisions are generated; and (v) to demonstrate the system's benefits in reliability, efficiency, and flexibility. In effect, the system learns continuously: forecast errors are fed back to improve future predictions and controls, forming a closed adaptive loop. In summary, a DT-driven self-learning grid can significantly outperform traditional grids by pre-emptively balancing supply and demand [5, p. 21; 6, p. 30].

A digital twin is more than a static model; it is a dynamic, real-time simulation of a physical power network [1, p. 7]. Practically, the system can be divided into several layers. The **physical layer** contains all real grid components – generators, transmission and distribution lines, transformers, loads, storage devices, etc. – equipped with sensors and meters that monitor voltages, currents, power flows, and equipment status. Next is the **data acquisition layer**: IoT devices and communication infrastructure continuously collect raw data [6, p. 8]. The **digital layer** hosts the twin itself: data are ingested into computational models, including power-flow solvers, dynamic machine models, and data processing tools (state estimation, filtering). An analytics engine runs simulations and forecasts. Finally, a **user interface layer** provides visualisation and control interfaces for operators (dashboards, alarms, control outputs).

Crucially, advanced digital twins support a *bi-directional link* between the physical and virtual: the twin not only reads sensor data but can also generate control commands for the real grid [2, p. 19]. Changes made in the virtual model (e.g., adjusting a generator setpoint) can be propagated back to physical equipment, creating a cyber-physical loop. This configuration is sometimes called a *digital shadow* if data flow dominates, or a full *digital twin* if active control is implemented [4, p. 4; 9]. Thus,

the DT architecture consists of several components (data collection, processing, modelling, visualisation) that together create a continuously updated digital replica of the power system. This foundation enables the predictive and adaptive control strategies discussed next.

Traditional grid management reacts to disturbances (e.g., adjusting generation only after a demand spike). In contrast, **predictive load control** (anticipatory control) uses forecasts of future grid conditions to schedule actions *in advance* [5, p. 5]. The goal is to optimise performance criteria (e.g., minimising generation cost or avoiding overloads) over a future horizon. One well-known method is *Model Predictive Control* (MPC). In MPC, an optimiser uses a grid model to compute a sequence of control actions (generator outputs, storage dispatch, demand response activations) that will achieve desired objectives over the next time horizon while respecting all technical constraints (line limits, voltage bounds, ramp rates, etc.) [5, p. 12]. Only the first step is implemented, then the process repeats with new data. MPC inherently handles constraints: Riverso et al. showed that a properly designed MPC can account for network bandwidth, voltage limits, and equipment ratings while maintaining feasibility even as loads connect/disconnect [5, p. 19]. Therefore, MPC can automatically maintain system security while optimising performance, making it ideal for complex smart grids.

Today, IoT-based sensing and communication are turbocharging predictive control. Smart grids are instrumented with hundreds of sensors measuring loads, line flows, and weather conditions. As shown in [6, p. 24], such data richness reduces costs and improves efficiency: one study estimates that broad digitalisation of the grid could cut operational costs by 5-15 % and unlock substantial energy savings [6, p. 28]. In practice, load and renewable generation forecasts are generated by machine learning models trained on historical and live data. These forecasts feed directly into the predictive controller. For example, if the twin predicts a high load period at noon due to forecast temperatures, the controller can pre-emptively ramp up generation or curtail controllable demand [9]. The result is a flatter demand curve and fewer emergencies. Thus, predictive load management transforms grid control from reactive to proactive, enabling pre-scheduled responses to anticipated conditions [1, p. 12; 2, p. 27].

The proposed self-learning system architecture links the physical grid and the digital twin in a continuous feedback loop (see Figure 1). Key elements include:

- **Physical grid with sensors**: distributed sensors measure voltage, current, power, frequency, etc., across the network and at generation/consumption points [2, p. 11]. Real-time measurements serve as ground truth for the twin.
- **IoT communication network**: resilient wired/wireless infrastructure carries sensor data to computational nodes and returns control commands to actuators (controllers, smart inverters, switches) [6, p. 9].
- **Digital twin and analytics**: the core computing platform includes (a) data management modules (cleaning, synchronisation, storage), (b) simulation and forecasting models (power flow, dynamic equipment models, AI-based predictions), (c) active learning mechanisms that update models as new data arrive [4, p. 15].
- **Control engine**: a predictive control algorithm (e.g., MPC) uses forecasts and model outputs to compute optimal actions while respecting constraints.

- **Operator interface**: visualisation tools (dashboards, GUIs) show system status, forecasts, and suggested controls. A human-in-the-loop ensures safety.

All components are tightly integrated. The **forecasting module** (machine learning subsystem) uses historical and real-time data to predict future loads and generation. Adaptive learning is employed: as the system operates, forecast errors are measured and used to retune the model (e.g., via online gradient descent or selective sample inclusion) [4, p. 18]. Consequently, the twin's forecasts become more accurate over time, even as consumption patterns change. The **control module** then uses the updated forecasts to schedule generation, storage charging/discharging, and demand response. When commands are sent to the grid, actual outcomes are measured by sensors. Comparing predicted and actual behaviour, the system identifies model inaccuracies or unmodelled effects and adjusts its algorithms accordingly.

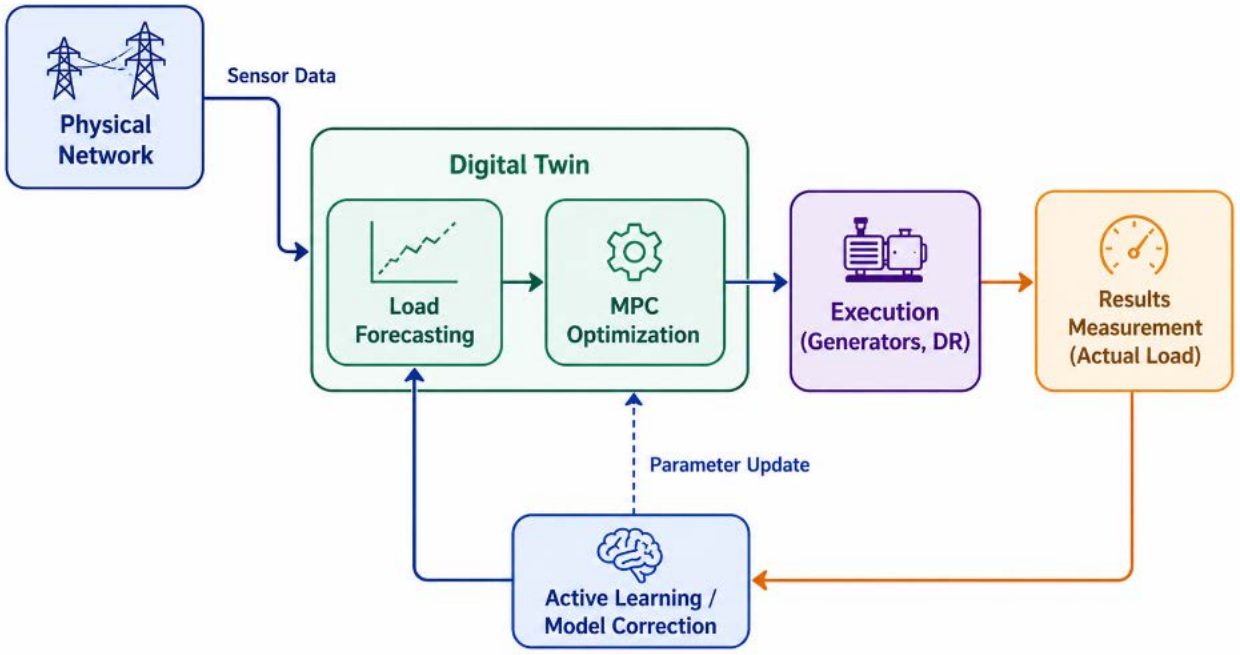


Figure 1. Self-learning loop (conceptual flowchart).

Sensor data (loads, voltages) enter the load forecasting module (ML model). Forecasts are passed to the predictive controller (MPC). The controller generates control signals (generator dispatch, demand response) that are executed on the physical grid. Results (measurements) are collected and fed into model update and active learning, after which the cycle repeats. This cyclical process makes the grid *self-learning*: new information continuously flows through the digital twin, enabling adaptation to unforeseen changes (e. g., new DER installations, evolving demand patterns, weather anomalies).

Accurate forecasting is central to the proposed strategy. A multi-stage algorithm for load prediction is embedded in the digital twin. Stage 1 – Data preparation: continuous collection from smart meters, weather sensors, and SCADA logs, including time-stamped load data, generation outputs, meteorological variables (temperature, irradiance, wind speed), and calendar features (time of day, day of week, holidays). Stage 2 – Preprocessing: cleaning, filling missing values, normalising

variables, and feature engineering (e. g., lagged averages, temperature profiles). Stage 3 – Model training: machine learning models (e. g., LSTM/GRU neural networks, random forests, gradient boosting) are trained on historical data to map inputs (past loads, weather, etc.) to future load. Active learning is emphasised: the model focuses on periods of high uncertainty (e.g., extreme temperatures) to improve those cases [4, p. 22]. Stage 4 – Forecast generation: for each new time step, the latest data are fed into the model to predict short-term load (a few hours to a day ahead). The model can output a point estimate and a confidence interval. Stage 5 – Error feedback: after actual load is observed, the prediction error is computed. This error is used for online model updates (incremental learning) or to trigger retraining. Over time, the feedback loop sharpens forecast accuracy as the model learns the specific behaviour of the grid [4, p. 25]. Thanks to the digital twin, retraining can be continuous. If data from the physical grid diverge from predictions, the learning component gradually adjusts the model. Thus, the forecasting algorithm becomes *self-correcting*. In practice, training may be done daily on rolling windows, with hyperparameters tuned to capture both long-term trends and short-term spikes. Because the model adapts to new patterns, it remains robust even as consumer habits or generation mixes evolve.

The self-learning principle is implemented via a closed loop data feedback cycle. At each control interval, the system performs the following: 1) real time data update – the physical grid is monitored and data sent to the twin; 2) forecasting and control – the twin updates its state, runs the ML forecast, and computes new control commands; 3) action and observation – controls are applied, the physical system responds, and new measurements are collected; 4) model update – the twin compares predicted and measured values, and discrepancies trigger parameter adjustments (e.g., via gradient descent on a loss function). Over time, this cycle embodies *continuous learning*. Models automatically incorporate new data without manual reprogramming. Online (real-time) learning allows the system to respond rapidly to abrupt changes (e.g., sudden load shifts), while less frequent batch retraining improves baseline accuracy. The use of adaptive algorithms means the twin's forecasts and control strategies become more reliable over months of operation [4, p. 27; 9]. Research supports this approach. Liu and David emphasise that tight integration of DTs with AI allows a grid to learn from its operations; the twin acts as a "digital surrogate" capable of predicting faults and optimising settings [2, p. 22; 9]. Mylonas et al. demonstrate that an active-learning-enhanced DT continuously refines its predictions based on operator feedback, markedly increasing forecasting accuracy [4, p. 29]. Hence, the system "learns by doing": every forecasting error and control outcome is fed back into the algorithm, gradually improving performance. This distinguishes the approach from fixed-rule control and moves toward an autonomous, intelligent grid.

The proposed system is evaluated qualitatively against a conventional grid. Key criteria are forecasting accuracy, load balancing, adaptability, and stability. Due to advanced ML techniques and real-time data, the system achieves significantly higher forecast accuracy than classical methods. The active learning framework ensures continuous adaptation to new patterns [4, p. 30]. Better forecasts directly translate into more optimal control actions. For example, by anticipating peaks, the system can schedule dispatch to spread load over time, reducing peak demand. The MPC ensures

constraints are always respected; as Riverso et al. note, MPC-based controllers inherently handle device limits and topology changes [5, p. 26]. Compared to a traditional system (reacting only after thresholds are crossed), the self-learning system **shaves peaks and fills valleys** more effectively. If the twin forecasts an unusually high afternoon load tomorrow, the controller can precharge batteries or issue demand response commands in advance. Over many days, this capability results in a smoother load profile and better resource utilisation.

Adaptability is another advantage. Traditional controllers use fixed models and manual tuning; if the system changes (new solar farm added, growth in EV charging), they must be reconfigured. In contrast, the online-learning system *automatically* adapts to such changes [4, p. 32]. This reduces the need for human oversight. The twin can even simulate maintenance scenarios or extreme events in silico, giving operators early warnings [9]. Reliability is also improved: with a virtual model, operators can test "what-if" scenarios without risking the grid. If a transformer shows anomaly signs, the twin can predict its remaining life. In normal operation, the system detects anomalies (unusual load spikes) and can isolate faults digitally. All these predictive safeguards lead to fewer blackouts and interruptions compared to reactive grids. In summary, the proposed self-learning DT-based system offers clear benefits: high forecast accuracy, better peak management (via MPC), adaptability to evolving conditions, enhanced stability/reliability (through virtual testing and early anomaly detection), and operational efficiency (lower costs due to optimised dispatch and fewer emergency interventions). These differences are summarised in the table below, showing that moving to a predictive self-learning paradigm yields major improvements over legacy reactive control.

Table. Comparison of traditional control and the proposed self-learning DT-based system

Criterion	Traditional Grid Control	Proposed Self-Learning DT System
Management style	Reactive, rule-based; adjustments after events	Proactive predictive scheduling (forecast-driven)
Forecasting	Limited, linear/statistical methods	High-precision ML forecasts (continuously updated)
Adaptability	Low (static models, manual tuning)	High (online learning adapts to new patterns)
Reliability/Stability	Moderate (delayed fault response)	Increased (virtual simulation & anomaly detection)
Operational efficiency	Moderate (resources not optimised)	Higher (optimised dispatch reduces losses and peaks)

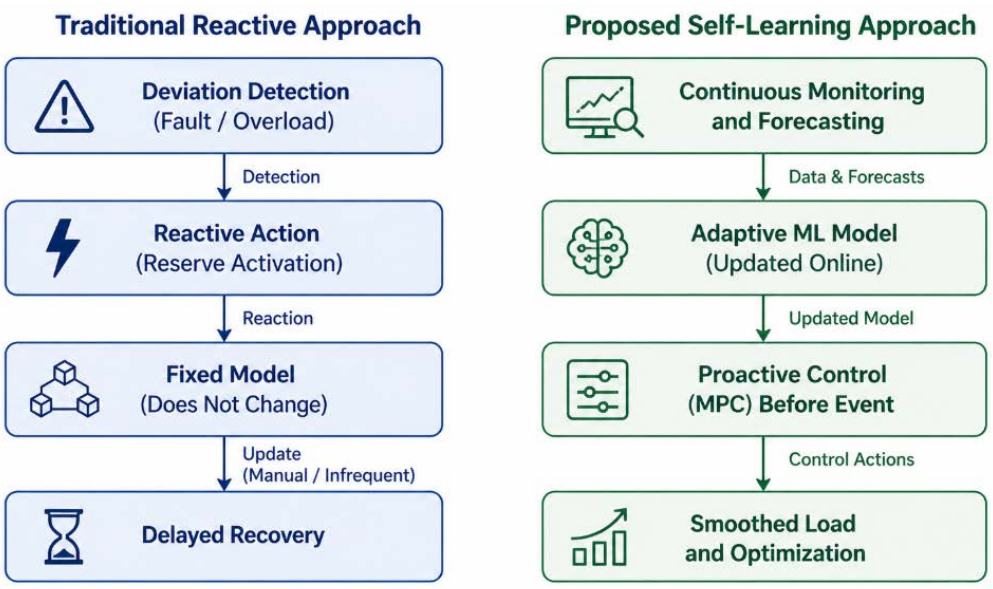


Figure 2. Simplified flowchart contrasting traditional and self-learning approaches.

Traditional path: “Traditional grid → Reactive control → Respond after changes → Fixed models”. Proposed path: “Self-learning grid → Predictive control → Optimise beforehand → Adaptive ML models”. The diagram clearly illustrates that reactive control responds to events with fixed models, whereas predictive control uses forecasts and adaptive learning to act preemptively.

Modernising power grids with digital twins and predictive control offers substantial advantages. This paper has shown that combining a real-time virtual grid model with machine learning and MPC creates a **self-learning energy system** that continuously adapts and optimises itself. Such an architecture enables a shift from reactive to proactive management: the system forecasts demand, adjusts controls ahead of time, and learns from discrepancies. The extended discussion emphasised contemporary techniques (active learning, IoT sensors, online ML) and incorporated up-to-date findings on the benefits of grid digitalisation [4, p. 35; 6, p. 33]. The proposed system markedly improves forecast accuracy, peak management, and overall stability compared to traditional grids. Although implementation requires robust data infrastructure, the literature indicates that cloud/edge computing and smart sensors already make such solutions feasible [6, p. 40]. Overall, integrating digital twins with intelligent algorithms appears a promising direction for future smart grid development.

Practical implementation would involve pilot tests on real networks, further refinement of hybrid models (combining data-driven and physics-based methods), and addressing cybersecurity for continuous data flow. Nevertheless, the analysis suggests that self-learning power systems based on digital twins offer a powerful path to higher efficiency and reliability in an era of uncertain energy supply and demand.

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При написании статьи были применены технологии искусственного интеллекта.

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УДК 681.5, 676.16.022.6.031

APPLICATION OF MULTICRITERIA OPTIMIZATION FOR CONTROLLING THE CONTINUOUS SULFATE PULPING PROCESS

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Abstract. The pulp and paper industry is one of the key sectors of the economy, and the continuous sulfate pulping process is its most critical technological stage. The high complexity, nonlinearity, and multi-parameter nature of this process, as well as the conflicting nature of its performance metrics (quality, yield, energy efficiency), make the transition from classical control systems to multi-criteria optimization methods a pressing need. This article discusses a methodological approach to finding optimal cooking conditions based on the construction of response surface models (RSM) and the identification of the Pareto set. The proposed concept will allow formalizing the search for a compromise between such conflicting criteria as pulp yield and its strength characteristics, which will create a basis for the development of promising decision support systems and adaptive control.

Keywords: continuous cooking, pulp and paper industry, multi-criteria optimization, Pareto front, response surface methodology, pulp quality control, process control.

ПРИМЕНЕНИЕ МНОГОКРИТЕРИАЛЬНОЙ ОПТИМИЗАЦИИ ДЛЯ УПРАВЛЕНИЯ ПРОЦЕССОМ НЕПРЕРЫВНОЙ СУЛЬФАТНОЙ ВАРКИ ЦЕЛЛЮЛОЗЫ

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Аннотация. Целлюлозно-бумажная промышленность является одной из ключевых отраслей экономики, а процесс непрерывной сульфатной варки – ее важнейшим технологическим этапом. Высокая сложность, нелинейность и многопараметричность данного процесса, а также противоречивость его целевых показателей (качество, выход, энергоэффективность) делают актуальным переход от классических систем стабилизации к методам многокритериальной оптимизации. В данной статье рассматривается методологический подход к поиску оптимальных режимов варки, основанный на построении регрессионных

моделей «отклик-поверхность» (RSM) и выделении множества Парето. Предложенная концепция позволит формализовать поиск компромисса между такими конфликтующими критериями, как выход целлюлозы и ее прочностные характеристики, что создаст основу для разработки перспективных систем поддержки принятия решений и адаптивного управления.

Ключевые слова: непрерывная варка, целлюлозно-бумажная промышленность, многокритериальная оптимизация, Парето-фронт, методология поверхности отклика, управление качеством целлюлозы, управление технологическими процессами.

The pulp and paper industry plays a pivotal role in the economies of many countries, including the Russian Federation. The industry's products – pulp, paper, and cardboard – serve as the foundation for printing, packaging, hygiene products, and a wide range of technical materials. Amid growing competition, volatility in raw material and energy prices, and stricter environmental requirements, P&P enterprises face the urgent challenge of improving operational efficiency and ensuring consistent product quality [1-3].

The most critical stage of the production cycle is the continuous sulfate pulping of wood chips. It is at this stage, in "Kamur"-type digesters, that the fundamental properties of cellulose fiber are established: the degree of delignification, yield, and strength characteristics. Controlling this process is extremely difficult due to its high inertia, nonlinearity, significant transport delays, and the influence of numerous uncontrollable disturbances, the main one being the variability of raw material properties (wood species composition, moisture content, and chip quality) [4, 5].

Traditional automation systems, based on PID controllers and local stabilization loops, successfully maintain the specified process parameters; however, they are unable to fully optimize the process under conditions of constantly changing external factors and conflicting control objectives. Increasing the degree of cooking to reduce stiffness typically leads to a decrease in pulp yield and an increase in chemical consumption. The desire to maximize strength may conflict with productivity and resource efficiency.

Thus, the control of the cooking process is, by its very nature, a multi-criteria problem requiring the search for compromise solutions [6].

The continuous cooking process in "Kamur"-type boilers is characterized by the movement of a dense layer of wood chips, impregnated with a cooking solution consisting of white and black lyes, through a series of sequential zones: impregnation, heating, cooking, and diffusion washing [5]. The key control parameters available for adjustment most frequently include: wood species ratio, temperature in the cooking zone, active alkali consumption, and productivity, which is related to cooking time. The output parameters of the cooking process are pulp stiffness, pulp yield, and breaking force index. Cellulose stiffness refers to the degree of residual lignin content, which is a key quality indicator and is maintained within a specified process range. Cellulose yield determines the amount of usable product per unit of wood raw material, and this indicator should be maximized. The breaking strength index is an important consumer parameter that determines the mechanical properties of the resulting paper, and it is also desirable to maximize this parameter.

An analysis of process dependencies shows that the above criteria are

conflicting. For example, intensifying the cooking process – that is, increasing the temperature and alkali consumption – effectively reduces stiffness but inevitably leads to losses of the carbohydrate fraction of the wood, reducing yield and, often, diminishing the strength properties of the fiber due to its destruction. This contradiction prevents the control problem from being reduced to the search for a single “ideal” process. A formalized mechanism for finding a compromise is required.

An approach to solving the multi-criteria optimization problem is proposed, based on Response Surface Methodology (RSM). This method allows for the approximation of the complex, physically not fully formalizable relationship between input factors and output responses using second-order polynomial models [7].

The first stage involves data collection and preparation. To ensure numerical stability and the comparability of the model coefficients, all factors are normalized. The transformation to the dimensionless interval [-1, 1] is performed using Equation 1.

$$X_{norm} = \frac{X_i - X_{center}}{\Delta X} \quad (1)$$

where *Xcenter* – is the arithmetic mean of the maximum and minimum values of the factor, ΔX – half-range of variation, X_i – is the factor.

This approach makes the model versatile and applicable to various production lines with different ranges of parameter variation.

Next, a polynomial model of the form 2 is constructed for each of the output parameters.

$$y = b_0 + \sum b_i x_i + \sum b_{ii} x_i^2 + \sum b_{ij} x_i x_j \quad (2)$$

where x_i – are the normalized factor values, b – are the coefficients determined by the ordinary least squares (OLS) method.

The resulting models allow us not only to predict response values but also to interpret the strength and nature of each factor’s influence.

An important step is the statistical analysis of the models. Assessing the significance of coefficients (p-value), checking for multicollinearity (VIF), and analyzing residuals allow us to identify insignificant terms and exclude them from the model while maintaining high predictive power. This process leads to the creation of more economical and robust regression relationships, which form the basis of the optimizer.

The presence of several conflicting criteria (maximizing yield and maximizing strength while adhering to stiffness constraints) means that there is no single solution that is optimal across all metrics simultaneously. In such cases, the concept of Pareto optimality is used. A cooking mode (a point in the factor space) is Pareto-optimal if it is impossible to improve any of the target metrics without simultaneously worsening another. The set of all such modes forms the Pareto front, which represents a set of possible trade-offs.

The procedure for constructing the Pareto front involves generating a set of alternatives, calculating responses, filtering by constraints, and identifying the Pareto front. A large number of possible combinations are generated in the space of normalized factors, for example, using a uniform grid or random sampling. For each generated point, the predicted values of the output parameters are calculated using refined regression models. Points that do not satisfy technological constraints – such as factor variation ranges and the permissible stiffness corridor – are excluded from

consideration. From the remaining admissible modes, those that are non-dominated are selected. Mode A dominates mode B if it is no worse than B on all criteria and is better on at least one criterion.

The visualization of the Pareto front obtained during the study in the “output–strength” coordinates is shown in Figure and takes the form of a downward-sloping curve, convex toward the origin. This configuration is characteristic of problems with two conflicting criteria and clearly demonstrates the fundamental constraint of the process, which is that an improvement in one indicator is inevitably achieved at the expense of a deterioration in the other.

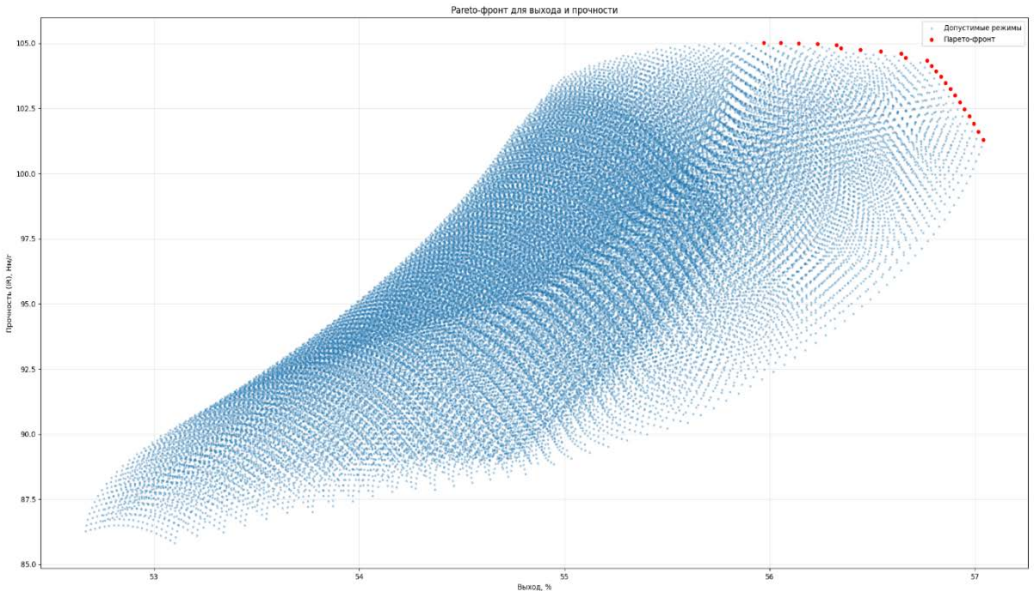


Figure. A conceptual view of the Pareto front for conflicting criteria of yield and cellulose strength

An analysis of the distribution of points on the curve reveals three distinct zones corresponding to different production strategies: the zone of maximum strength, the zone of maximum output, and the zone of balanced compromise.

The maximum strength zone, located in the upper left part of the curve, contains operating conditions that yield the highest values of the breaking force index. These conditions are characterized by relatively low pulp yield. This region is of interest in the production of high-strength paper and packaging, where fiber quality is a priority.

In the maximum yield zone, located in the lower right part of the curve, the highest pulp yield from the raw material is achieved; however, this is accompanied by a decrease in strength characteristics. Such operating conditions are economically justified in the production of products where mechanical strength requirements are not stringent.

The balanced compromise zone, i. e., the central part of the curve, contains operating conditions that provide moderate but balanced values for both indicators. Selecting a point in this specific zone allows for maintaining both an acceptable yield level and sufficiently high strength, which is the most rational solution in many production situations.

The visualization presented here has both analytical and practical value. The

Pareto front serves as a “decision map,” enabling a decision-maker – whether a process engineer or an automated control system – to make informed choices about process management strategies based on current priorities.

The proposed concept can serve as a basis for creating advanced decision support systems and improved process control systems (IPCS). Integrating this approach with existing process control systems will not only stabilize the process but also purposefully shift the operating mode toward the range of Pareto-optimal values, adapting to changing production conditions and market priorities.

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УДК 372.881.111.1

ENGLISH FOR GRAPHIC DESIGNERS: FROM PROFESSIONAL NEEDS TO A USEFUL COURSE

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Abstract. The article emphasises the need to develop specialized English courses for students of creative disciplines, as standard programs fail to address the professional needs of graphic designers. Based on an analysis of surveys among students and teachers, as well as research in this field, the authors conclude that an effective course should be built on a detailed analysis of professional requirements, with an emphasis on reading professional literature and communicating with clients. Special attention is given to the impact of the digital revolution, which has introduced new concepts into the language of design, such as UI/UX, «responsive web design», and «microcopy», requiring instructors to have a deep understanding of the professional context. The authors identify close collaboration between linguists and practicing professionals as a key condition for the successful development of educational programs.

Keywords: ESP (English for Specific Purposes), graphic design, professional needs, digital transformation, UI/UX, collaboration.

АНГЛИЙСКИЙ ЯЗЫК ДЛЯ ГРАФИЧЕСКИХ ДИЗАЙНЕРОВ: ОТ ПРОФЕССИОНАЛЬНЫХ ПОТРЕБНОСТЕЙ К ЭФФЕКТИВНОМУ КУРСУ

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Аннотация. В статье подчеркивается необходимость разработки специализированных курсов английского языка для студентов творческих специальностей, поскольку стандартные программы не отвечают профессиональным потребностям графических дизайнеров. На основе анализа

опросов среди студентов и преподавателей, а также исследований в данной области авторы делают вывод, что эффективный курс должен строиться на детальном анализе требований отрасли с акцентом на чтение профессиональной литературы и общение с клиентами. Особое внимание уделяется влиянию цифровой революции, которая ввела в язык дизайна новые понятия, такие как “*UI/UX”*, «*responsive web design*» и «*microcopy*», что требует от преподавателей глубокого понимания профессионального контекста. Авторы выделяют тесное сотрудничество лингвистов и практикующих специалистов как ключевое условие успешной разработки образовательных программ.

Ключевые слова: *ESP* (английский для специальных целей), графический дизайн, профессиональные потребности, цифровая трансформация, *UI/UX*, сотрудничество.

In today’s world, every graphic designer meets English in their work. It can be the interface of design software (like Adobe programs, Figma, and others), foreign books about design, lectures by famous designers, or working with international clients. Therefore, one of the key skills for modern professionals is knowing a foreign language well. This helps them communicate effectively with international customers and present their projects in the global market. English for Specific Purposes (ESP) helps prepare students to do their professional tasks at a high level by combining language learning with professional skills. This creates a strong need for special programs and teaching methods. These programs should focus on developing the specific skills and knowledge that are important in the design industry. A standard General English course is not enough. A designer needs more than just conversation skills. They must understand a client’s brief, talk about visual ideas in the client’s language, and present their own concepts clearly.

The main method for collecting data for this article was analyzing the results of a survey. The survey was about the need for teaching design students professional English. The problem of ESP for creative specialties is researched all around the world. For example, in 2024, Fengfan Mao and Jiefeng Zhou did a study in Chinese art colleges. They wanted to understand the views of students and teachers about the ideal ESP course. The analysis showed a significant demand among students for specialized English learning. The data confirms that for designers, reading skills (professional literature) and interactive communication (negotiations with clients) are very important. The study clearly shows the need for ESP courses in art and design colleges. At the same time, the study also notes that learning General English before starting a specialized course is still important [1, p. 2].

The research shows an interesting fact: English teachers are often not ready to teach ESP. They say the main problem is poor teaching materials. However, design teachers and industry professionals believe the main problem is the qualification of the English teachers themselves. The Chinese researchers conclude that teaching materials for professional English in art and design colleges should be created together by English teachers and creative discipline teachers. This idea can also be supported by the research of Natalia Nikolaevna Krivosheeva, called “Principles of Teaching Oral Foreign Language Speech to Students of Creative Specialties”. In her survey, students

said that creative tasks connected to painting, design, and art analysis were very important. At the same time, they agreed that such tasks were difficult for them [2, p. 134]. This research shows that texts about the profession alone are not enough. Students need interaction, and maybe the use of digital technologies and artificial intelligence. A good example of what an ESP course can look like is the course "English for Specific Purposes. Art and Design" at HSE University. The program includes topics from animation, fashion, painting, and color to interior design and logos. It uses magazine and research articles. It helps develop reading, speaking, and writing skills (analytical essays, CVs, reviews) and presentation skills. The course uses the textbook "English for Specific Purposes: Art and Design (B2 - C1)" [3].

The digital revolution did not merely add new tools to design practice; it rewired design's everyday language. As design shifted from static, print-first artifacts to interactive, screen-based systems, practitioners needed terms that describe behavior over time, adaptation across devices, and user participation. Open-access research on digital transformation and user-centered public services shows how professional vocabulary evolves alongside institutional adoption of digital platforms.

Graphic design language changed as new terms have been introduced with digital technologies. For example, UI/UX design became a linguistic shorthand for a major conceptual change: design is no longer only about appearance but also about use. In the open-access book "Co-creating Digital Public Services for Better Government", Juliane Jarke traces how "user experience" enters policy-and-service contexts as governments move beyond basic usability toward holistic experience quality (e. g., emotional response, trust, accessibility, and perceived fairness) [4, p. 15-20]. That expansion matters because it makes "UX" a boundary term shared by designers, researchers, and stakeholders enabling discussions about outcomes, something that print terminology never needed to name.

The term "responsive web design" emerged to describe a hard requirement of digital distribution: the "page" is no longer a known size. Instead, design must reflow across viewports, orientations, and user settings (such as zoom or magnification). In 2024 the study by Sandnes focused on how sticky elements interact with magnification and narrow viewports. It illustrates why "responsive" became more than a technical label, it is a usability and accessibility requirement [5]. Designers now routinely speak about "breakpoints, reflow, viewport width, and sticky UI", all of which refer to behaviors that do not exist in print.

The third cluster of terms revolves around interactivity. Print assumes one-directional communication: authors publish, readers consume. Digital systems, by contrast, are co-produced in real time through clicks, taps, scrolling, personalization, and feedback loops. The open-access volume "Digital Transformation in Design" frames digitization and datafication as forces that push design toward systems thinking where what matters is not only a finished artifact but also how it responds to data, contexts, and users over time. Interactivity vocabulary "flows, states, affordances, onboarding, friction, conversion, dark patterns, microinteractions" names relationships between interface and user that print design could ignore.

Finally, digital platforms created specialized language for the text inside interfaces. Portmann's 2022 article on UX writing highlights how "microcopy" (small

interface texts like button labels, consent notices, and prompts) has become a design object in its own right. Where print copy was typically subordinate to layout, interface copy actively shapes decisions, trust, and legal compliance, hence, new terms like “tone of voice,” “content design,” “error messaging,” and “consent notice” entered the designer’s microcopy vocabulary [6].

Digital distribution did not just add new words; it redefined older ones. Print terms such as “layout, grid, margin, and hierarchy” persist, but their meanings drift. A print grid is a fixed geometry; a digital grid often implies a responsive system that rearranges at breakpoints. A print “page” is a unit of production and citation; on screens, “page” competes with terms like “screen”, “view”, and “route”. “Scroll depth” is another term that describes navigation and temporal exposure rather than a bounded sheet.

The digital shift also destabilized typographic language. In print, type size and legibility are largely designer-controlled; in digital contexts, user settings and device constraints intervene. Sandnes’s work on magnification and narrow viewports shows how user-controlled scaling collides with interface patterns like sticky banners, forcing designers to treat readability as dynamic rather than static. Print “leading” becomes CSS line-height; “tracking” becomes letter-spacing; and “fold” (a print concept) becomes the digital metaphor above the fold, now contested because scrolling behavior varies by device and content type.

Online platforms further introduced ethical and persuasive terminology that print rarely needed at interface scale. Wang’s 2023 article on transparency in persuasive and immersive technologies points to concerns like “disclosure”, “informed decision-making”, and “manipulative design” that bring terms such as “transparency, nudging, and persuasive technology” into mainstream design discourse. In print advertising these ideas existed, but digital interactivity makes influence measurable and optimizable, which intensifies the need for precise vocabulary [7].

AI-infused products add another layer of vocabulary pressure. In the open-access book User Experience + Artificial Intelligence: Assessing the Qualities of AI-infused Systems, Spallazzo emphasizes evaluating experiences shaped by adaptive, probabilistic behavior. That pushes UX terminology toward explainability, confidence, human-in-the-loop, calibration, and trust, concepts that have no clean equivalents in print production because print does not “decide” or “adapt” after publication.

The analysis of terms introduced above shows that ESP makes learning meaningful. When a design student studies vocabulary connected to their future profession in English, their motivation grows because they see how to use this knowledge in real life. A course that includes studying real projects from international clients prepares students for the real needs of the job market. However, the main difficulty that researchers note is that an ESP teacher must also understand graphic design and art well. This is important so that they do not teach vocabulary without context. So, this teacher should be a multispecialist, and such people are difficult to find. For an effective ESP course, simple textbooks are not enough. Modern learning tools are necessary, such as specialized tests, video lectures, and many other materials.

An ESP course is necessary for design students in colleges and universities. However, before starting ESP, students should first learn General English well. The

best way to learn English at a high level is to integrate the language into most of the subjects we study. But for this, teachers also need to have a good level of General English and Professional English. This is quite a difficult task. Modern students would like to get knowledge using the most effective methods. Furthermore, it would be helpful if teachers told them about different learning systems and resources that students could use on their own.

English for graphic designers is a separate discipline that needs careful planning. The main finding of the research is that the starting point for any course should be a detailed needs analysis. You cannot teach a designer using a textbook made for an engineer or an economist. An effective ESP course can meet a real market need. It can prepare a specialist who is ready to work with international clients. The key to success in creating a good ESP course is collaboration between linguists and professionals from the creative industry. This is confirmed by the work of modern researchers and the practice of higher education institutions.

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УДК 17.023.34

WE MAKE A LIVING BY WHAT WE GET, BUT WE MAKE A LIFE BY WHAT WE GIVE

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Abstract. This article explores the idea that a meaningful life is built through giving rather than through material gain. The author analyzes the famous saying “We make a living by what we get, but we make a life by what we give” through personal experience and reflection. The paper argues that acts of kindness and support toward others create inner strength, form deeper connections, and shape a person’s identity in ways that material things cannot. Empathy serves as the main driving force behind these actions. The conclusion is that while receiving helps us survive, giving helps us become who we are.

Keywords: giving, altruism, empathy, personal development, meaningful life, kindness.

МЫ ЗАРАБАТЫВАЕМ НА ЖИЗНЬ ТЕМ, ЧТО ПОЛУЧАЕМ, НО СОЗДАЕМ ЖИЗНЬ ТЕМ, ЧТО ОТДАЕМ

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Аннотация. В данной статье исследуется идея о том, что осмысленная жизнь строится через отдавание, а не через материальное приобретение. Автор анализирует известную фразу: «Мы зарабатываем на жизнь тем, что получаем, но создаем жизнь тем, что отдаем» через личный опыт и размышления. В работе утверждается, что акты доброты и поддержки по отношению к другим создают внутреннюю силу, формируют глубокие связи и личность человека так, как не могут материальные вещи. Эмпатия выступает главной движущей силой этих действий. Делается вывод, что получение помогает выживать, но отдавание помогает становиться собой.

Ключевые слова: отдавание, альтруизм, эмпатия, личностное развитие, осмысленная жизнь, доброта.

The phrase “We make a living by what we get, but we make a life by what we give” has always stayed with me. Not because it sounds nice, but because it follows me through daily situations. Some people look at this saying and think it is simple or even

naive. Others try to question it, saying that giving without getting something in return does not make sense in a world where everyone looks for personal gain. I sit somewhere between these views but lean toward the second part of the phrase. My own experience tells me that received things support survival, but actions toward others form something much stronger around a person [1].

I feel better when I help someone. This reaction comes fast, without thinking. I never wait for any return. I do not even think in that direction. A warm feeling appears inside my body after I support another person, and this feeling sometimes stays for hours. I live alone, so I value moments of connection, even small ones. When I see someone suffering, the memory stays with me longer than I expect. I do not want anyone close to me stuck in pain. Words stay weak without deeds. I trust actions far more than anything else [1].

Personal experience as evidence. One night a friend of mine faced strong illness. The voice on the phone sounded rough and tired. The whole situation felt heavier than usual. A long trip across the city at two in the morning seemed strange, but I did not think too much. I took the medicine, grabbed my jacket and walked out. My friend stayed too weak to move anywhere. I reached the door, handed over the medicine and sat there for a few minutes. A calmer look appeared on my friend's face. Sleep returned later that night. I walked home with a quiet and slightly tired mind. I did not get anything material from that night. No one paid me back. But the feeling stayed. That feeling is still with me when I think about it now [1].

Another moment came from my family. One evening I arrived at my grandparents' home without any warning. I still remember how they opened the door with a confused look. They were waiting for a neighbor. Then they saw me, and the whole room changed. We sat at the table, talked, ate simple food. The evening stretched longer than we expected. I did not bring them anything expensive. I just showed up. That small step brought strong warmth to all of us. My grandparents still mention that evening sometimes. For them, my presence mattered more than any gift [1].

A similar feeling appeared during student activity at my faculty. Our group planned several events, and I took responsibility for one of them. I worried far too much. My thoughts bounced around. During meetings my sentences broke in strange places. I felt like I was not the right person for the job. Yet I continued. The event passed well. People thanked the team. The atmosphere changed inside the group after that. A small action formed trust between us. Before that event, we worked like separate people. After that event, we started working like people who knew they could count on each other [1].

These three moments are not big achievements. They are not the kind of stories people write about in newspapers. But for me, they are the moments that shaped who I am. In each case, I gave something. In each case, I received nothing material back. And in each case, I walked away with something that stayed inside me [1].

Why some people do not give. Some people say giving has no value. They focus on personal gain. They say: why help someone if you get nothing back? Others fear disappointment. They helped someone before and got burned, so now they do not help anyone. Some people follow habits formed during childhood when trust felt unsafe. They learned that the world takes from you, so the only smart thing is to take first [2].

I understand where these people come from. Life can be harsh. People can be selfish. But this view stays weak. A person without generosity stands alone during hard moments. When trouble comes to them, they miss chances for support because they never built anything with anyone. They made a living, but they did not make a life [2].

What giving does to a person. When I look at my own experience, I see a pattern. Every time I gave something, I received something that was not money or things. I received a moment of connection. I received trust. I received the feeling that I matter to someone. These things do not show up in a bank account. But they show up when I feel down. They show up when I need someone to talk to. They show up when I wonder if my life means anything [3].

Giving also changes how I see myself. I used to think I was just a student who studies math and does nothing special. After these moments, I started seeing myself as someone who shows up when needed. That shift did not happen because I got good grades or bought something nice. It happened because I gave and saw what that did for others [3].

Close people stay important for me. Simple help speaks louder than long talk. A life forms through steps toward others. Received things give comfort. But giving builds inner strength and shapes a clearer path forward [3].

Connection to broader ideas. Philosophers and psychologists have written about this for a long time. Viktor Frankl, who survived concentration camps, wrote that meaning in life comes not from what we expect from life but from what life expects from us. He said that we find meaning through what we give, through what we create, and through how we face suffering [4]. His words match what I felt during that night with my friend. I did not think about meaning when I walked across the city at two in the morning. But looking back, that night taught me something about who I am.

Other researchers have shown that helping others activates parts of the brain associated with pleasure and reward. This is sometimes called the “helper’s high” [5]. I did not know about this when I sat with my grandparents or helped with the student event. But I felt it. That warm feeling I described earlier is not just imagination. It is a real thing that happens in our bodies when we connect with others through giving.

Some people argue that altruism does not really exist because people help others to feel good about themselves. They say even giving is selfish if you look closely enough. I do not agree with this view. When I gave medicine to my friend, I did not think about feeling good. I just did it. The feeling came after. It was not the goal. It was a side effect [6].

Why this matters for students and young people. Students live in a world that measures success through grades, money, and career achievements. We are told that we make a living by what we get. Get a good degree. Get a good job. Get a good salary. All of this matters. I am not saying it does not. But if someone only focuses on getting, something important gets left behind [7].

University years are when people form habits that last a lifetime. If someone spends these years only thinking about their own success, they might end up successful on paper but empty inside. On the other hand, small habits of giving during university create something that stays. Helping a classmate with a difficult subject. Checking on a friend who seems down. Taking responsibility for a group project even when it is

stressful. These things do not show up on a transcript. But they shape the kind of person you become [7].

I learned this at my faculty. When I took responsibility for that event, I was scared. I thought I would fail. But after it passed, people in my group treated me differently. They trusted me more. That trust helped us work together later on other projects. One small act of giving changed how a whole group worked together [7].

Conclusion. Looking back at everything I have written, I keep coming back to the same idea. A living is made by what we get. A life is made by what we give. This is not a slogan. It is something I have tested through real moments. The night with my friend. The evening with my grandparents. The event at my faculty. In each case, I gave something, and I received something that no one could take away [7].

My view shapes me as a person of action. I do not want to be someone who only talks about kindness. I want to be someone who shows up when it matters. Close people stay important for me. Simple help speaks louder than long talk. A life forms through steps toward others. Received things give comfort, but giving builds inner strength and shapes a clearer path forward [7].

I do not know where this path leads. But I know that every time I give something, the path becomes clearer.

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При написании статьи были применены технологии искусственного интеллекта.

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УДК 004.738:130.2

THE SUBJECT IN THE CONTEXT OF ALGORITHMIC SYSTEMS AND THE «ATTENTION ECONOMY»: AN ANALYSIS OF "BLACK MIRROR" (TELEVISION SERIES, 2011) AND "NIGHTCRAWLER" (FEATURE FILM, 2014)

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Abstract. The study analyses the transformation of subjectivity in the context of algorithmic environments and the «attention economy», using the TV series Black Mirror (2011) and the film Nightcrawler (2014) as case studies. The paper examines how algorithms and mechanisms of attention competition shape new forms of the subject's interaction with reality, leading to functionalisation and loss of autonomy. The research demonstrates that both narratives illustrate the dual nature of the subject: on the one hand, it is embedded in a system of control; on the other, it acts as a mediator between technological mechanisms and socio-economic interests. This duality allows for a reconceptualisation of subjectivity as a dynamic process of interaction with the cultural-technological environment.

Keywords: subject, algorithms, attention economy, media culture, Black Mirror, Nightcrawler.

СУБЪЕКТ В СИСТЕМЕ АЛГОРИТМОВ И «ЭКОНОМИКИ ВНИМАНИЯ»: ТЕЛЕСЕРИАЛ «ЧЕРНОЕ ЗЕРКАЛО» (2011) И КИНОФИЛЬМ «СТРИНГЕР» (2014)

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Аннотация. Исследование посвящено анализу трансформации субъекта в условиях алгоритмизированной среды и «экономики внимания» на примере сериалов «Черное зеркало» (2011) и кинофильма «Стрингер» (2014). В работе рассматривается, как алгоритмы и механизмы конкуренции за внимание формируют новые формы взаимодействия субъекта с реальностью, приводя к его функционализации и потере автономии. Исследование показывает, что оба сюжета демонстрируют двойственную природу субъекта: с одной стороны, он включен в систему контроля, с другой – выступает медиатором между технологическими механизмами и социально-экономическими интересами, что

позволяет переосмыслить субъектность в процессе взаимодействия с культурно-технологической средой.

Ключевые слова: субъект, алгоритмы, экономика внимания, медиакультура, «Черное зеркало», «Стрингер».

Contemporary visual culture is formed under conditions of transformation in the modes of perception, production, and distribution of information. Digital technologies expand the media space and establish new regimes of interaction with reality, in which attention becomes a key resource, and algorithms serve as the primary mechanism of its organization [1]. Under these conditions, not only does the structure of media change, but also the position of the subject: it becomes involved in processes that simultaneously regulate its perception and determine the ways of its interaction with the surrounding world. In the context of active digitalization, attention acquires the status of an economic category subject to measurement, management, and subsequent monetization. Algorithms underlying digital platforms are not limited to the technical function of data processing: they act as forms of cultural regulation that determine the visibility, significance, and value of the subject [2]. As a result, the subject increasingly appears as an element of a system functioning according to the principles of selection, optimization, and distribution of attention.

Despite the significant number of studies devoted to digital culture, algorithmization, and the attention economy, the question of how these processes are represented and conceptualized in visual culture, particularly in cinema, remains insufficiently explored. Meanwhile, it is precisely screen-based forms of art that make it possible not only to record ongoing changes but also to model scenarios of subject functioning under new conditions, revealing the mechanisms of its integration into the system. As empirical material, episodes of the TV series «Black Mirror» and the film «Nightcrawler» are used. The choice is due to the fact that these works represent different levels of functioning of the modern media environment: from the systemic regulation of behavior through algorithms and rating mechanisms to individual strategies for attracting attention.

Let us turn to the aforementioned processes in contemporary media culture – algorithmization and the economization of attention. Algorithmization in media, according to Ted Striphas, is the use of computational processes to sort, classify, and hierarchize people, places, objects, and ideas, as well as the habits of thinking, behavior, and expression that arise in connection with these processes [3]. Algorithms in the media space are used for content personalization, information filtering, recommendation systems, and the management of user experience. They analyze user behavior (clicks, views, time spent on a platform), their preferences, and demographic data in order to form individualized information flows [3]. The attention economy is an approach to information management that considers human attention as a scarce commodity and applies economic theory to the problems of managing information. In his work, this was noted by Herbert A. Simon: under conditions of information abundance, attention becomes a key resource for which media, business, and the state compete [4].

They are united by a common principle: the redistribution of agency from the individual to the system that structures perception and behavior [6]. The subject can no longer be described through classical categories of autonomy and inner experience; its actions become embedded in regimes of selection and optimization – in other words, they become algorithmized, that is, subordinated to the clear logic of platforms. Algorithms in the digital environment perform functions that go beyond technical data processing [3]. The concept of the algorithm dates back to the works of al-Khwarizmi in the ninth century and was formalized in the twentieth century thanks to the works of Alan Turing – initially, algorithms served to standardize calculations and solve mathematical problems (for example, Euclid's algorithm for finding the greatest common divisor) [5]. In the 1940s–1950s, they became the foundation of programming, automating routine and engineering tasks. With the development of the internet, big data, and machine learning, algorithms have moved beyond technical processing: they now perform socio-economic functions – they personalize content (in social networks, streaming services, and online stores), form "filter bubbles", influence political agendas, optimize business processes (logistics, marketing, finance), and implement algorithmic governance ("algocracy"), becoming a tool of influence on human behavior and social processes [4].

Algorithms establish a structure of visibility: they determine which events become significant, which images become interesting, and which are excluded from the field of perception and consigned to oblivion [3]. Thus, the algorithm acts as a form of socio-cultural regulation. Consequently, under such conditions, the subject is forced to constantly correlate its behavior with predictable and reproducible patterns: it does not simply act, but acts in such a way as to be "read" by the system. In real life, this manifests itself in specific reactions to informational posts in political, cultural, social, and public columns of news resources. People tend to reproduce already familiar and expected patterns on social media, despite an initial стремление to express individuality and articulate their own point of view on platforms. Social networks were originally created as a space for self-expression and the search for like-minded individuals – early platforms (Classmates.com, 1995; SixDegrees, 1997) allowed users to maintain connections, experiment with identity, and construct a virtual "self" in a relatively safe environment, including through anonymity. With the development of platforms (MySpace, LinkedIn in 2003–2004) and the introduction of algorithmic feeds (beginning with Facebook in 2009, Instagram in 2016), user behavior became increasingly standardized: algorithms oriented toward engagement and mechanisms of social comparison encouraged the copying of popular trends rather than the expression of individuality [5]. Community pressure and the desire to conform to idealized images intensified this effect – ultimately, the original idea of self-expression gave way to the reproduction of recognizable content patterns and behavioral models, which led to the homogenization of user experience on social media [1].

This dependence on the algorithmic environment changes the nature of action. Behavior begins to be constructed according to the principle of optimization: the subject chooses those strategies that increase the probability of visibility, response, and reaction. Such motivations arise in the creation of content that is intended to provoke a positive or negative response from the audience [7]. In this sense, the algorithm not

only limits but also programs action, setting its form even before it is realized. Thus, the subject appears not as external to the system, but as its internal element, functioning in accordance with its logic.

Parallel to this process, an attention economy is formed, within which attention becomes a measurable and exchangeable resource. Its value is determined not by the content of experience, but by the intensity and duration of engagement [7]. In the context of the media environment, this leads to a shift in emphasis from the production of meaning to the production of reaction: what becomes important is not what is transmitted, but how effectively it retains and redistributes attention. Naturally, the category of attention presupposes its inclusion in economic processes. It is subject to quantitative evaluation, ranking, and capitalization, and therefore can be extracted, redistributed, and used as a resource. As a result, the subject becomes involved in a paradoxical process: on the one hand, its attention becomes an object of control, while on the other hand, it itself begins to act as an agent of its production and distribution [1].

As a result, a specific form of subjectivity emerges in which the distinction between action and calculation becomes blurred [2]. This was noted in the work «Simulacra and Simulation» by the postmodern theorist Jean Baudrillard: “The entire traditional system of causality is called into question: the perspectival and deterministic method, the ‘active’ and critical method, the analytical method – the distinction between cause and effect, between active and passive, between subject and object, between ends and means” [8]. The subject is not only included in the system but also reproduces its principles: it anticipates, optimizes, and adapts its behavior to the expected reaction [8]. Thus, algorithmization and the attention economy do not merely limit the subject but define the conditions of its existence, within which it becomes both an object of control and a participant in the processes of attention management.

This dual position of the subject – between subordination to the system and the reproduction of its logic – becomes key to the analysis of visual culture. Cinema and serial forms in this context function as a space of modeling, in which these processes are brought to maximum clarity. This makes it possible to consider visual media texts as analytical constructions that reveal the hidden mechanisms of subject formation in a digital environment.

In the TV series «Black Mirror», let us examine the episode «Nosedive», which presents an extremely formalized model of social interaction in which every act of communication is subject to quantitative evaluation.

The action unfolds in a world where people rate each other from 1 to 5 in real life – these numbers determine literally everything: housing, services, access to transportation. The main character, Lacie Pound (Bryce Dallas Howard), has a rating of approximately 4.2 and is obsessed with the idea of increasing it. She lives with her brother Ryan (James Norton), who does not attach much importance to ratings and has a lower score. Lacie dreams of moving into the prestigious residential complex “Pelican Cove”, but to receive a rental discount she needs to raise her rating to 4.5. Naomi (Alice Eve), Lacie’s childhood friend with a rating of 4.8, invites her to be a bridesmaid at her wedding. Lacie expects that after delivering a perfect speech, the guests will rate her highly and she will reach the desired score. However, everything

goes wrong: after a conflict with her brother and several altercations with strangers, Lacie's rating drops below 4.2. At the airport, she is denied a ticket for another flight. After an emotional outburst, security assigns her a 24-hour penalty: her rating is temporarily reduced to 3.1, and all new negative ratings are doubled. Lacie is forced to rent an old electric car and drive nine hours to the wedding. When the car runs out of charge and she cannot recharge it due to the lack of adapters, she attempts to hitchhike. People pass by upon seeing her low rating. Eventually, she is picked up by truck driver Susan (Cherry Jones), whose rating is 1.4. Susan explains that she was once also obsessed with ratings until her husband died of cancer: he was denied experimental treatment in favor of a patient with a rating of 4.4 (her husband had 4.3). Naomi calls Lacie and asks her not to come to the wedding – by this point, Lacie's rating has dropped to 2.6. Enraged, Lacie nevertheless decides to reach the ceremony: she illegally enters the private island and appears at the celebration. In a state of emotional breakdown, she delivers a speech and then threatens Paul, Naomi's husband (Alan Ritchson), with a knife. Lacie is arrested, her implanted rating application is removed, and she is sent to prison. In the cell, she argues with another inmate (Sope Dirisu), and unexpectedly, their mutual anger brings them relief: they can now shout at each other without fear – the rating system no longer has power over them.

Here, the rating does not merely reflect social status – it produces it. What becomes significant is not the content of an action, but its capacity to generate a positive reaction expressed numerically. As a result, the subject is drawn into a continuous process of self-adjustment: it does not simply act, but calibrates its behavior according to the algorithmic logic of approval. The breakdown in the final part of the episode, where the protagonist loses control over her speech and emotional responses, does not so much destroy the system as render it visible. It is precisely at the moment of losing her rating that the degree of the subject's dependence on the evaluative mechanism becomes apparent, a dependence capable of depersonalizing the individual [9].

The episode «The Entire History of You» shifts the focus from external evaluation to internal perception, yet the underlying logic remains the same. The narrative presents an alternative reality in which people have a chip implanted behind their ear (the "grain") that records everything they see, hear, and do, and these memories can be replayed at any moment. The protagonist, lawyer Liam Foxwell (Toby Kebbell), after a job interview, attends a dinner party with his wife Fiona's friends (Jodie Whittaker). There, he notices that his wife behaves unusually around Jonas (Tom Cullen), a man with whom she had a past relationship. Consumed by jealousy and paranoia, Liam begins to repeatedly replay memories, searching for evidence of Fiona's infidelity. His suspicions intensify, leading to serious conflicts within the family and eventually to a physical confrontation with Jonas: Liam forces him to delete all memories of Fiona. During this process, Liam accidentally sees a fragment of footage indicating that Jonas had been in their bedroom about a year and a half earlier – around the time their daughter was conceived. Liam compels Fiona to confess to the affair; however, she claims that Liam is the child's father, though certainty is impossible: the exact circumstances remain unclear. Devastated and having lost trust in both memory and close relationships, Liam ultimately cuts the chip out from behind his ear with a blade – the screen then fades to black. The episode illustrates

how the technology of “perfect memory”, which ostensibly allows a person to remember everything and return to cherished moments, does not provide access to objective truth but instead amplifies human weaknesses – jealousy and distrust – ultimately разрушая relationships and the subject’s sense of self and others. Verification becomes more important than experience. Thus, the subject is incorporated into a regime of constant control, where even its own memory becomes subject to algorithmic processing [9]. If in the previous episode the subject is oriented toward external evaluation, here it records and processes its own experience, yet operates within the same logic: calculation, verification, repetition.

Both episodes demonstrate that algorithmization penetrates everyday practices, restructuring modes of perception, communication, and self-reflection. The subject does not merely submit to the system but begins to think and act within its categories.

In the film «Nightcrawler», algorithmic logic manifests at a different level. The protagonist, Lou Bloom (Jake Gyllenhaal), an ambitious outsider with no prior experience in journalism, accidentally discovers the work of stringers – freelancers who film accidents, crimes, and emergencies and sell the footage to television news outlets. He acquires a camera and basic equipment and begins to study police and emergency response patterns in order to arrive first at scenes of incidents. From the outset, Lou behaves not as a passive observer but as a system-oriented actor: he structures his actions according to the principles of selection, optimization, and maximization of effect.

At the initial stage, Lou carefully selects events that possess the highest “market value” – those characterized by drama, violence, and emotional intensity. Scenes involving blood, suffering, and shock are prioritized because they guarantee viewer engagement. He then proceeds to optimize the process of filming: he searches for advantageous camera angles, waits for moments of maximum tension, and constructs shots that amplify emotional impact. This is evident in early scenes where Lou observes experienced stringers and quickly internalizes the criteria of “successful” footage, subsequently reproducing and refining them in his own practice.

A crucial aspect of his activity is the gradual shift from documentation to intervention. Lou does not merely record reality; he actively reshapes it in accordance with media expectations. In several episodes, he delays calling emergency services in order to capture victims in a more vulnerable state, rearranges objects at crime scenes to improve composition, and positions himself to obtain exclusive perspectives. These actions demonstrate that reality itself becomes subordinated to the logic of representation: events are no longer primary, but are instead reconfigured to meet the demands of visibility and marketability [9].

The interaction between Lou and the news producer Nina (Rene Russo) reveals the economic foundation of this process. Their dialogue makes explicit the criteria by which footage is evaluated: proximity to affluent neighborhoods, the presence of violence, and the potential to evoke fear in the audience. Nina’s preference for stories that depict “urban crime moving into suburban spaces” underscores how attention is structured through narratives of threat and emotional intensity. In this exchange, attention is translated directly into ratings, and ratings into profit, thereby confirming the integration of media production into the logic of the attention economy.

The well-known phrase articulated by Lou – “If it bleeds, it leads” – functions not merely as a cynical observation but as a concise formulation of the governing principle of content selection. Violence is not incidental; it is systematically prioritized because it ensures visibility. This principle guides Lou’s actions at every stage, transforming his practice into a calculated process of extracting attention from reality.

The most revealing episode occurs when Lou deliberately sends his assistant Rick (Riz Ahmed) into a dangerous situation in order to secure exclusive footage. When Rick is fatally wounded, Lou does not intervene to assist him but continues filming his final moments. This scene exposes the complete subsumption of ethical considerations to the logic of media production: human life is reduced to a resource for generating valuable content. The camera does not merely capture death – it instrumentalizes it.

By the end of the film, Lou has fully internalized and operationalized the logic of the media system. He expands his business, hires new employees, and establishes a structured workflow for identifying, capturing, and selling footage. His activity becomes increasingly automated in its organization: he anticipates where events will occur, calculates their potential value, and positions himself accordingly. Although he is not formally embedded within a digital platform governed by algorithmic metrics, his behavior mirrors algorithmic processes – selection, prediction, optimization, and accumulation of measurable outcomes such as income and influence.

What is particularly significant is the absence of moral reflection in Lou’s actions. He does not experience internal conflict because his behavior is entirely aligned with systemic demands. This alignment eliminates the distinction between individual intention and structural logic. As noted by Jean Baudrillard, “we enter into absolute manipulation not through coercion, but through indistinguishability” [8]. Lou exemplifies this condition: he does not oppose the system but embodies it, functioning as a node within a broader network of circulation, where images, signals, and values continuously reinforce one another.

Thus, in «Nightcrawler», the subject is not merely subjected to algorithmic logic but actively enacts it. He operates as a self-regulating mechanism that translates reality into attention and attention into economic value. In this sense, the film demonstrates that algorithmic rationality does not require a digital infrastructure to function – it can be internalized and reproduced at the level of individual behavior, becoming a principle of subjectivity itself.

A comparison of the examined cases allows for a more precise understanding of the transformations occurring in subjectivity. In «Black Mirror», the subject appears as an element of a system regulated through evaluation, control, and verification, whereas in «Nightcrawler» it functions as an active agent reproducing these same principles in practice. The distinction between submission and action becomes relative: in both cases, the subject operates within a unified logic; however, in the latter case, it increasingly acts as a producer that reproduces and intensifies mechanisms of attention extraction [7]. As a result, a specific model of subjectivity emerges in which action and calculation coincide. The subject does not merely adapt to the system but anticipates its responses, structuring behavior as a series of optimized decisions [2]. This is evident

both in the стремлении of the characters in «Black Mirror» to maintain high ratings and in Lou Bloom's strategy aimed at maximizing spectacle.

Visual culture thus captures not so much the disappearance of the subject as a transformation of its status. The subject retains the capacity to act; however, the character of this action is determined by external structures. The analysis of the selected film narratives demonstrates that the subject is simultaneously embedded within systems of control and reproduces their principles, functioning as a mediator between algorithmic regulation and the attention economy. Cinematic texts serve as analytical models for examining this duality: the subject appears not as an autonomous entity, but as a functional element of a cultural-technological environment, which opens new perspectives for the study of digital subjectivity – particularly strategies of navigation, resistance, and the redefinition of norms within algorithmized systems.

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УДК 338.48-6:7/8

STREET ART AS A CATALYST FOR URBAN TOURISM AND TRANSFORMATION OF PUBLIC SPACE

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Abstract. The article examines the transformation of street art from a phenomenon perceived as vandalism into a cultural tourism resource using the examples of Berlin, Lisbon and Saint Petersburg. Three integration models are identified: liberal-passive, proactive-regulatory and ambivalent-conflict. The key success factor is the nature of dialogue between authorities, artists and society.

Keywords: street art, tourist product, public space, cultural tourism, urban studies, Berlin, Lisbon, Saint Petersburg.

СТРИТ-АРТ КАК КАТАЛИЗАТОР ГОРОДСКОГО ТУРИЗМА И ТРАНСФОРМАЦИИ ПУБЛИЧНОГО ПРОСТРАНСТВА

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Аннотация. В статье исследуется трансформация стрит-арта из явления, воспринимаемого как вандализм, в ресурс культурного туризма на примере Берлина, Лиссабона и Санкт-Петербурга. Выявлены три модели интеграции: либерально-пассивная, проактивно-регуляторная и амбивалентно-конфликтная. Ключевым фактором успеха выступает характер диалога между властями, художниками и обществом.

Ключевые слова: стрит-арт, туристический продукт, публичное пространство, культурный туризм, урбанистика, Берлин, Лиссабон, Санкт-Петербург.

The city wall has long been a space of communication – from cave paintings to political slogans. However, for most of the 20th century, the appearance of unauthorized images in public space was consistently labeled as vandalism subject to administrative and criminal prosecution. At the turn of the 20th-21st centuries, the situation began to change: street art gradually acquired the status of a legitimate artistic practice and, with it, commercial value. Today, many megacities view street art not as a problem of public order, but as a resource for urban development and cultural tourism [1, p. 12].

The aim of this study is to identify how street art is transformed from deviant behavior into a full-fledged element of a tourist product and what factors determine the success or contradictoriness of this process. Three cities were selected for comparison: Berlin (traditionally recognized as the capital of graffiti), Lisbon (known for its institutionalized legalization of street art) and Saint Petersburg (a space of acute confrontation between artistic expression and protective cultural policy).

The relevance of the work is due to the growth of the cultural tourism segment focused on authentic urban experience, as well as the need to revise normative approaches to the use of public space in conditions of its commodification [2, p. 45].

To understand the phenomenon, three often confused categories must be distinguished: graffiti (as a rule, illegal inscriptions and drawings, often associated with the writer subculture), street art (various forms of urban artistic expression – murals, stencils, stickers, installations) and public art (legal, often institutionally sanctioned works in public space) [3, pp. 101-102].

In Russian research and curatorial practice, it is customary to distinguish between graffiti and street art by their communicative strategy. As art historian Alina Zorya notes, if graffiti writers predominantly leave their pseudonyms or crew names on walls – a kind of territorial marking understandable only to the initiated – then street art is addressed to all passers-by, to the unprepared viewer. Graffiti asserts the fact of the artist's presence in the world ("I am"), while street art offers reflection, an idea, an opinion ("I think"). This difference is fundamental for tourism: the visitor seeks not just a trace of presence, but dialogue and narrative [1].

From the perspective of urban tourism, street art performs several functions. First, it has an attractive function: large murals and historic graffiti become independent attractions [4, p. 15]. Second, the narrative function: street art tells (or allows local guides to tell) alternative stories of the city – marginalized, subcultural, politically engaged. Third, the revitalization function: street art often serves as a tool for branding and revitalizing depressed or post-industrial areas. Finally, the delimitation function: in certain cases, street art acts as a marker of local identity opposed to the globalized tourist space [2, pp. 50-52].

At the same time, the transition "from vandalism to dialogue" is not linear. The commodification of street art generates an internal contradiction: a work that has been legalized and included in a tourist route loses its original oppositional charge [5, p. 203].

Case 1: Berlin – the wall as narrative and brand.

Berlin street art is inextricably linked to the history of the Berlin Wall. Originally, the western side of the Wall served as a canvas for political statements unavailable in the controlled public space of the GDR. After the fall of the Wall in 1989, part of its preserved fragment was turned into the world's longest open-air gallery – the East Side Gallery. In 1990, 118 artists from 21 countries created murals on the wall celebrating freedom and unity. The gallery is 1.3 km long, featuring about 100 graffiti, among them the cult "Fraternal Kiss" [6].

Today Berlin is rightfully considered one of the world's capitals of street art. The city offers a wide range of tourist services: walking and cycling tours of Kreuzberg, Friedrichshain and Neukölln, workshops in abandoned factories, private tours

revealing subcultural techniques. Many tours specifically emphasize the difference between legal and illegal works – the latter creating a sense of authenticity and "forbidden" experience for the tourist [7].

The East Side Gallery remains not only a landmark but also a living space requiring constant restoration. This fact highlights the paradox: art born on the borderline of legality, once institutionalized, needs protection from the very spontaneity that constituted its essence [8].

The Berlin model can be characterized as liberal-passive: the authorities do not so much actively promote street art as create a legal framework for its existence. Numerous legal walls in the districts and a policy of non-interference with established graffiti communities have led to the formation of an organic ecosystem in which tourist interest is more a result than a goal of urban policy.

Case 2: Lisbon – from illegal painting to city gallery.

Lisbon demonstrates the most targeted transition "from vandalism to dialogue" with a clear institutional framework. The decisive step was the adoption of Law No. 61/2013, which established a legal regime for graffiti and street art. According to this law, municipal councils are authorized to license the application of graffiti on pre-identified sites, subject to the submission of a project and documented permission from the surface owner [9].

A key initiative was the Urban Art Gallery (GAU) – a city-wide project of the Lisbon City Council. The project's task was to combat vandalism and provide a legal, structured space for artists while promoting street art as a form of creative expression. The project started in the Bairro Alto district after a graffiti cleaning campaign, turning a problem into a resource. Today, Lisbon has more than 200 legally operating graffiti artists.

The Lisbon tourist market actively uses this resource. Key locations include: LX Factory (a creative complex on the site of a former textile factory), the Amoreiras Wall of Fame, murals on Avenida Fontes Pereira de Melo, and art objects along the Calçada da Glória tram line. The tourist product is diverse: from walking tours of the historic center searching for "hidden" street art to tuk-tuk tours. The official GAU website offers interactive maps and routes for self-guided walks, moving street art from the category of subcultural discovery to that of standardized urban service.

The Lisbon model is proactive-regulatory. Unlike Berlin, where tourist appropriation occurred "from below", the Lisbon authorities institutionalized the phenomenon "from above", turning a problem into a manageable resource. This model minimizes conflicts but raises the question of authenticity: can licensed street art remain street art, or does it become public art?

Case 3: Saint Petersburg – dialogue without consensus.

Saint Petersburg is a city with a powerful academic artistic tradition and, at the same time, a space where street art exists in a mode of permanent conflict. Unlike Berlin and Lisbon, the St. Petersburg situation is characterized by the absence of an established institutional consensus between the authorities, artists and society. "Street Art Storage" curator Alina Zorya points to a paradox: it was in St. Petersburg in 1990 on Vasilyevsky Island that the city's first (and one of the country's first) murals, "Water is Life" – a collaboration between American and Soviet artists – appeared. However,

such an early precedent did not lead to the creation of a sustainable system of support for street art [1].

On the one hand, legal venues have emerged and are successfully operating in the city. The Street Art Museum, located on the territory of a working laminated plastics plant, exhibits in former workshops and boiler rooms. Its collection includes about 12 works by well-known street artists – Pasha 183, Timofey Radya, Kirill Kto, Nikita Nomerz, Spanish artist Escif and others. “Street Art Storage” in the Sevkabel Port space is a new-type institution that collects, studies and displays “street wave” art. By 2023, it had gathered about 350 works by 48 artists. According to Alina Zorya, this institution consciously distances itself from gallery sales: the fund works as an educational, not commercial, endeavor, seeking to show the full range and diversity of street art – something impossible to see in individual exhibitions. In Russian art history, as Zorya notes, street art remains a little-studied field, so systematic collection and archiving are of critical importance [1].

Tourist routes actively explore these spaces: two-day routes have been developed for independent exploration of street art, covering the Petrograd Side, Vasilyevsky Island and the city center. One of the key locations is the Brusnitsyn art quarter, uniting graffiti, street art and public art.

At the same time, the official position of the city authorities remains rigid. Formally, street art actions require approval, and the city has “quiet zones” with restrictions. A typical example: in August 2025, an entire exhibition of paintings in the archway of a building on Kamennoostrovsky Prospect was painted over following a complaint from a citizen left on the “Our Saint Petersburg” portal. This case illustrates how the aesthetic judgment of an individual can outweigh the overall artistic value.

In St. Petersburg conditions, the preservation of specific works often depends on informal agreements. As the curator of “Street Art Storage” notes, some works exist for many years not because they have gained legal status, but because municipal services prefer to turn a blind eye to them. This creates a “gray zone” of legality, which, on the one hand, paradoxically increases the subcultural attractiveness of some areas (for example, the Petrograd Side and the Pushkinskaya Street area, where, according to expert observations, new works appear almost weekly), and on the other hand, completely excludes the possibility of systemic tourist use of these objects. No tour operator can guarantee the traveler that the piece they came to see will not be painted over the next morning. Globally, urban space is continuously changing: previously existing “blind spots” (unimproved courtyards, wastelands) are gradually being improved, squares, cameras, and increased control by municipal services appear, which generally reduces the amount of spontaneous street art [1].

Nevertheless, attempts to find a compromise are being observed. In June 2025, a meeting was held at the Sevkabel Port venue between representatives of the executive authorities of St. Petersburg and the Street Art Development Institute to discuss ways to prevent illegal graffiti through cooperation rather than punishment. In October 2025, the city government approved a draft amendment to the St. Petersburg Law “On Cultural Policy”. However, the concrete consequences of these initiatives remain unclear.

The St. Petersburg model can be characterized as ambivalent-conflictual. Alongside legal museum and exhibition venues, a high degree of repression against street art manifestations in public space persists, and a single complaint can be grounds for repainting. The city is in a transitional phase: the institutional legitimization of street art takes place mainly in museum and exhibition formats, while its presence in public space continues to be seen by the authorities as a problem to be solved, not as a resource. Dialogue with the city in the St. Petersburg case remains not so much a dialogue as a series of local truces and new outbreaks of conflict.

The conducted study allows us to identify three different models of integrating street art into the urban fabric and tourist product.

The first, Berlin (liberal-passive), developed historically: street art evolved spontaneously in connection with the post-traumatic history of a divided city. The authorities tolerate, the tourism industry "discovers" street art as a ready-made resource. Tourism follows art, not the other way around.

The second, Lisbon (proactive-regulatory), demonstrates a targeted transformation of a problem into a manageable resource through legislation, the Urban Art Gallery program and the development of tourism infrastructure. This is a model of anticipatory institutionalization, minimizing conflicts but potentially leveling the oppositional potential [4, p. 28].

The third, St. Petersburg (ambivalent-conflictual), is fundamentally different: street art is simultaneously institutionalized in museum formats and repressed in public space. Dialogue has not taken place – artists and authorities interact through conflict, individual complaints and one-off negotiations. The variability of the urban landscape and increased municipal control, according to experts, lead to a reduction in illegal works, while the preservation of individual pieces rests on tacit agreements [1].

Common to all three cases is a fundamental contradiction: the inclusion of street art in a tourist product inevitably leads to its deactivation as an oppositional statement. The tourist consumes an aestheticized urban experience, not a political statement. However, it is precisely this aestheticization that makes street art economically viable and institutionally protected. The St. Petersburg situation is most revealing: street art, while retaining the status of a potentially illegal act in public space, continues to carry an oppositional charge – but precisely for this reason it remains vulnerable and cannot be fully integrated into the tourist product [5, p. 210].

The study shows that the transformation of street art from vandalism into dialogue and into a resource for cultural tourism is not a universal or linear process. Berlin, Lisbon and Saint Petersburg demonstrate three different trajectories shaped by history, political regime and the nature of relationships between actors.

The most successful from the perspective of tourist integration appears to be the Lisbon model: a clear legal framework and proactive urban policy have turned more than 200 artists into legal producers of cultural product. The Berlin model attracts with its organic nature and authenticity, but is difficult to reproduce in other contexts. The St. Petersburg model shows that the lack of consensus and the repressive potential of the authorities significantly limit the tourist potential of street art, even despite the presence of museum-type institutions. The view of the curator of "Street Art Storage" allows us to see in the St. Petersburg situation not only conflict but also potential:

systematic work on the preservation and study of street art creates a foundation that can eventually be transferred to public space [1].

The decisive factor is not so much the degree of legalization as the nature of the relationship between the authorities, artists and society. Where these relationships are built on dialogue and partnership (Lisbon) or on long-term tolerant coexistence (Berlin), street art organically enters the tourist product and begins to work for the city brand. Where repressive logic dominates (Saint Petersburg), dialogue remains unrealized and the tourist potential underutilized.

Prospects for further research are linked to quantitative analysis of the economic effect of street art tourism, as well as the inclusion of cities from non-Western cultural areas in the comparative analysis.

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УДК 7.046.3

ICONOGRAPHIC FEATURES OF THE HOLY FAMILY IN SPANISH PAINTING OF THE 16th–18th CENTURIES

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Abstract. The article is devoted to the stylistic evolution of images of the Holy Family in Spanish art of the 16th-18th centuries. The interpretation of religious plots in the paintings of Spanish masters is analyzed and the development of iconography in the context of Mannerism and the Baroque, through the perception of classical tradition is traced. The author identifies the differences between the methods of Caravaggism and the classical tradition regarding the scenes with the Holy Family.

Keywords: Spanish art, iconography, Holy Family, mannerism, baroque, Spanish painting, classical tradition, Caravaggism.

ОСОБЕННОСТИ ИКОНОГРАФИИ СВЯТОГО СЕМЕЙСТВА В ИСПАНСКОЙ ЖИВОПИСИ XVI–XVIII вв.

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Аннотация. Статья посвящена рассмотрению стилистической эволюции образов Святого Семейства в испанском искусстве XVI–XVIII вв. В процессе анализа интерпретации религиозных сюжетов в живописи испанских мастеров прослеживается развитие иконографии в контексте маньеризма, барокко, через восприятие классической традиции. Автор выявляет различия между методами караваджизма и классической традицией в отншении сцен со Святым Семейством.

Ключевые слова: искусство Испании, иконография, Святое Семейство, маньеризм, барокко, испанская живопись, классическая традиция, караваджизм.

The iconography of the Holy Family in Spain was directly dependent on the Catholic Church's interpretation of biblical images, which controlled the visual arts, and a more restrained appeal to the ancient heritage. This, however, did not mean that the classical tradition was not utilized in interpreting images of the Holy Family. The interpretation of Madonna, Christ, Joseph, Saint Anne, John the Baptist, Saint

Elizabeth, and other characters in scenes with chosen Saints was distinguished by its subordination to the Catholic Church and Spanish Baroque iconography. Speaking of strict adherence to canon, C. Ripollés writes that "...the decrees of the Council of Trent (1545–1563) – iconographic correctness, clarity of message, and decorum in religious images – were applied in Spain" [1, p. 131]. Spanish art, as a stronghold of the Counter-Reformation, met the demands of the Catholic Church. It is necessary to identify two significant branches in Spanish art found in the interpretation of biblical scenes: tenebrism (tenebroso) and the classical tradition.

The purely Catholic interpretation relied on tenebrism as a significant Baroque effect of the play of light and shadow, emphasizing the mystical component in religious paintings. Italy was also a significant center of Catholicism, however, the Baroque painting in the Italian version was somewhat different, created under the strong influence of the classical tradition. A certain reaction to Italian Mannerism, which still retains its connection with the ancient heritage, was reflected in Spanish art of the XVI century. The techniques of the classical tradition are most clearly traced in the work of a Spanish mannerist from Valladolid, Gregorio Martínez (circa 1547-1598). Analyzing "The Holy Family" (circa 1597. Oil on canvas. Valladolid, Church of San Miguel y San Julián) attributed to Martínez, with Jesus growing up, one can state the artist's attraction to the antique component of the aesthetics of Mannerism: large-scale towering architectural elements and dominating figures of the Holy Family in the majestic background. On the left side of the canvas, Joseph the Betrothed awkwardly holds the slipping palm of the Christ child. Jesus' stern, anxious gaze is fixed on his mother. The stylistic solution of the characters refers to the Italian tradition, which is expressed through the color palette and manner of writing, as well as through the arrangement of the figures.

The two works "The Adoration of the Shepherds" and "The Adoration of the Magi", created in 1596 for the Chapel of the Monastery of San Agustín in Valladolid, depict static and sublime images of heroes, placed in the antique arch of a large-scale architectural structure, bearing the stamp of antiquity. Thus, the mannerist trend in Martínez’s work tends more towards the Italian style than towards the Spanish mannerism reflected in the paintings of El Greco (circa 1541-1614) or Luis de Morales (circa 1509-1586).

The perception of antiquity among the Caravaggists was the least pronounced. It should be borne in mind that Spanish art of the 17th century was dominated by religious subjects created under the influence of Catholicism. The tradition of Caravaggism is reflected in the works of such masters as Francesc Ribalta (1565-1628), Diego Velázquez (1599-1660), Francisco de Zurbarán (1598-1664), Jusepe de Ribera (circa 1591-1652), Bartolomé Esteban Murillo (1617-1682). Tenebrism and chiaroscuro were used as significant Baroque effects in the stories of the Holy Family. Spanish Caravaggists' fascination with antiquity was not the basis for their artistic practice, as most of it was occupied by Catholic symbolism, especially by the role of the lamb in the scenes with the Holy Family.

In the work of a Spanish master Jusepe de Ribera "The Adoration of the Shepherds" (circa 1650. Oil on canvas. Castellammare di Stabia, Cathedral of Santissima Maria Assunta and San Catello) the artist depicts iconographically recognizable characters. Mary is depicted in front of the Child, clasping her hands in prayer, gazing at the sky. To her right is Joseph, Christ is highlighted by the master in

a local light color, his expression is adult and conscious, and his serious gaze is directed to heaven. The dominant element of the composition is the lifeless body of the lamb, eerily reminiscent of the future role of the Savior. This is a frequent and characteristic motif found in Spanish iconography, referring to the creative practice of Caravaggio and artistic techniques that contribute to the naturalness of the characters, fully perceived by the masters of tenebroso. The heroes of the Holy Scriptures and the uncanonical participants in the scene: the villagers who came to worship Christ are restrained and not idealized. The master emphasizes the poor clothes of the shepherds, their overworked hands, indicating hard physical work. In the background, an angel can be seen bringing the annunciation to the shepherds.

H. B. Wehle argues about another famous painting by Ribera "The Holy Family with St. Catherine" (1648. Oil on canvas. New York, Metropolitan Museum of Art) (Fig. 1) that the artist refers to the lighting techniques of Caravaggio and relies on the technique of "Neapolitan stylishness". Ribera's work according to the researcher, embodies a combination of both the Spanish manner and Neapolitan features [2, pp. 119-120].

The tradition of a purely Baroque style of writing, combined with classical principles of composition, is noticeable in Mateo Cerezo's (1637-1666) painting "The Mystical Wedding Vows of Saint Catherine" (1660-1661. Oil on canvas. Prado, Madrid) (Fig. 2), where the Holy Family is compositionally placed in a conventional triangle, where the line of the Virgin Mary's head towers over all the heroes present while Joseph is depicted in a thoughtful pose. The motif of flying putto angels carrying a fluttering red cloth, characteristic of the classical tradition, iconographically refers to the purple robe.



Figure 1. Jusepe de Ribera. The Holy Family with St. Catherine. 1648. Oil on canvas. New York, Metropolitan Museum of Art



Figure 2. Mateo Cerezo. The Mystical Wedding Vows of Saint Catherine. 1660-1661. Oil on canvas. Prado, Madrid

In Spain, as the center of the Counter-Reformation, the subjects of the Holy Family were interwoven into the development of art, which was completely subordinated to the religious policy of the Catholic Church. Despite the proliferation

of subjects from the New Testament related to the glorification of faith and the predominantly Catholic component, there were also idyllic scenes that almost bordered on everyday reading, especially those found in the works of Bartolomé Esteban Murillo. Murillo's pictorial style tends to Caravaggist's naturalism, and to the free Flemish style of writing, to enlarged forms. However, in the scenes with the Holy Family, the artist departs from pure tenebrism, gravitating towards more restrained, lyrical images.

The mystical component is especially characteristic of the Spanish tenebroso masters, who use symbolism that emphasizes the semantic reading of scenes from the Holy Scriptures. According to J. Andrews and a group of authors, Italian influence was traced in the works of many Spanish masters. For example, speaking about the work of Vincenzo Carducci (1576-1638), they said that many images of the heroes of the Holy Scriptures were presented as "the Italianate detached Madonna" [3, p. 194]. Despite the coordination of the iconography of many scenes by the Council of Trent, somewhat unexpected images of the Holy Family could appear, in a more private setting, the image of the Virgin could be "quite domestic", as is noticeable in many paintings by Bartolomé Esteban Murillo [3, p. 182]. In scenes where the image of Madonna appears, as, for example, in "The Holy Family with the infant John the Baptist" (circa 1668-1670. Budapest, Museum of Fine Arts) (fig. 3) the artist's attempt to create a cozy home space is noticeable. In many his works Murillo turned to the type of compositions with the Holy Family and chosen Saints, depicting John the Baptist, the Forerunner of Christ, and his mother, Saint Elizabeth, as, for example, in "The Holy Family" (Madonna of Seville) (Between 1665-1670, the second half of the XVII century. Oil on canvas. Paris, Louvre) (fig. 4). The following elements are significant symbols here: the cross, which John the Baptist is holding out to the Infant Christ as a reminder of his sacrifice, and the dove connecting the image of the Trinity together [4, p. 402].



Figure 3. Bartolomé Esteban Murillo. The Holy Family with the infant John the Baptist. Circa 1668-1670. Budapest, Museum of Fine Arts



Figure 4. Bartolomé Esteban Murillo. The Holy Family (Madonna of Seville). The second half of the XVII century. Oil on canvas. Paris, Louvre

Murillo's "Adoration of the Shepherds" (Between 1646-1650. Oil on canvas, Saint Petersburg) from the State Hermitage Museum is characterized by a chamber setting, an atmosphere of quiet family happiness that is not disturbed by the effect of Caravaggist funeral light. The characters are quite sentimental, the images of the Holy Family are imbued with radiant happiness, contrasting with the emotional component in Ribera's previously mentioned work.

In Spanish art, the classical tradition became increasingly dominant by the 18th century. Analyzing the work of Miguel Jacinto Meléndez (1679-1734) "The Holy Family" (circa 1732. Oil on canvas. Madrid, Prado) (fig. 5), it should be noted that the master uses a Baroque interpretation of images: the artist depicts the sleeping Child Jesus [5, p. 131]. Joseph guards his son's sleep, and Mary holds John the Baptist so that he does not disturb Christ's sleep. The work is distinguished by a free style of writing, broad strokes, and a fascination with antique architectural elements behind the Virgin Mary.

Francisco Bayeu y Subías (1734-1795) adheres to the principles of the classical style in "The Holy Family" (circa 1776. Oil on panel, Madrid, Prado) (fig. 6), reflecting the neoclassical tendencies of depicting the Holy Family filled with love and purity. The artist focuses on Joseph's blooming staff, iconographically referring to Joseph as the caring husband of the Virgin Mary.



Figure 5. Miguel Jacinto Meléndez. The Holy Family. Circa 1732. Oil on canvas. Madrid, Prado



Figure 6. Francisco Bayeu y Subías. The Holy Family. Circa 1776. Oil on panel, Madrid, Prado

Later, in the 19th century, after following various stylistic stages in the development of Spanish art, J. A. Tomlinson writes about "... the openness in Spain to Neo-classical [style]" [6, p. 204]. Later neoclassical interpretation of the images of the Holy Family tends towards the "Bolognese academicism and the classical tradition of

Raphael" as seen in the painting by José Madrazo y Agudo (1781-1859) "The Holy Family" (1839. Oil on canvas. Prado, Madrid) [7]. Spanish art increasingly loses its distinctive features and is absorbed by the classical line.

Thus, the interpretation of the images of the Holy Family in Spanish art from Mannerism to the Baroque combines the interweaving of various European influences developing within the distinctive Spanish style, characteristic of local schools such as Seville, Madrid, Valladolid etc. Idyllic scenes with the Holy Family are characteristic of Bartolomé Esteban Murillo's work, while the other trend tends to the origins of Caravaggism – a realistic, uncompromising naturalism based on the methods of tenebrism and chiaroscuro, which are the exact opposite of the restrained lyrical compositions in the spirit of Murillo. Scenes with the Holy Family in Spanish art, especially the most common ones, "The Holy Family with St. Elizabeth and John the Baptist", "The Holy Family" and "The Adoration of the Shepherds", can be roughly divided into two categories of the Baroque tradition, while passing into a classical trend. The first one is related to the fascination with the aesthetics of the Greco-Roman heritage which is read through the ancient motifs in the background and the features characteristic of the European iconography of Madonna, Jesus and Joseph the Betrothed. The second one is connected with following the creative practice of the tenebroso masters and is striking in its complex semantic content. In the 18th century the preservation of the Baroque tradition and the appeal to the classical principles characteristic of the masters of the Italian Renaissance with their clear and harmonious images are noticeable.

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УДК 82.091

ANALYSIS OF F. SOULIER'S NOVEL "MEMOIRS OF THE DEVIL"

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Abstract. This paper examines the characters of Baron Armand de Luizzi (the protagonist) and the Devil in F. Soulié's novel "Memoirs of the Devil", and provides a thorough comparative analysis with other works with a similar theme. The characters' interactions explore themes such as sin, moral choice and free will.

Keywords: deal with the devil, hero image, morality, sin, temptation, happiness.

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Аннотация. В работе рассматриваются образы барона Армана де Луицци (главного героя) и Дьявола в романе «Мемуары Дьявола» Ф. Сулье, а также проводится тщательный сравнительный анализ с другими произведениями с похожей темой. Через взаимодействия героев раскрываются такие темы, как грех, нравственный выбор и свобода воли.

Ключевые слова: сделка с дьяволом, образ героя, мораль, грех, искушение, счастье.

Introduction

"Memoirs of the Devil" (1837–1838) is a novel by the French writer and playwright Frédéric Soulié [1], which is of particular importance in French literature of the 19th century. During the author's lifetime, it enjoyed great success: it was published in series in newspapers, gave rise to theatrical adaptations, etc. The work combines elements of Gothic, Romanticism and social satire, which allows the author to "paint" the obvious and hidden horrors of "earthly" realness, although the vices of modern reality and the decline of morals are rooted in the "eternal" [2, с. 110].

Be that as it may, the work remains little studied, despite its original approach to revealing the eternal motive of a pact with the devil and its artistic merit. The novel has not received widespread recognition in modern scholarly discourse, and the number of articles and reviews devoted to it is extremely limited. To date, the cited above article "The Faustian Situation in the French Feuilleton Novel" by N. T. Pakhsaryan (2005) is the only scientific work devoted specifically to the "Memoirs of the Devil" in the

context of the Faustian plot. The book itself first appeared in Russian only in 2006, and its scientific understanding remains fragmentary.

Meanwhile, “Memoirs of the Devil” offers an original exploration of the motive of a pact with an evil spirit. This motive was quite popular in European literature, from folk legends and myths to Goethe’s philosophical tragedy. The hero was believed to give his soul in exchange for secret knowledge, power, wealth or pleasure, and the ending was invariably tinged with the tones of inevitable retribution. Soulier, working in the genre of the feuilleton novel, does not completely change the essence of the classic motive, but significantly reassesses it.

The aim of this work is to, through an extensive analysis of the characters and their interactions – and above all the figures of the main character, Armand de Luizzi and his infernal companion, the Devil – reveal the transformation that the traditional motive of a pact with an evil spirit undergoes and identify the author’s concept of happiness, around which the events described in the work unfold. The relevance of this work stems from the need to give the novel a “second life” –to draw the attention of scholars and readers to a text that rightfully deserves closer examination. The scarcity of literary studies on “Memoirs of the Devil” seems somewhat surprising, as the theme of making a deal with evil spirits and afterwards interacting with them has always captivated society, drawing attention to its mystique and the desire to explore that which cannot be explained by logic or science. For this reason, one can agree with the importance of analysis and the relevance of the novel.

1. Portrait of Baron Armand de Luizzi

For many years, the de Luizzi family has been plagued by an unusual curse: each heir is entrusted with the Devil’s service for ten years, to help them understand and find true happiness and by doing that break the vicious cycle. If the family heir correctly identifies the essence of his happiness, the curse is removed. However, if his makes a mistake, incorrectly deciding what will bring him happiness, his soul falls into the Devil’s hands, and the curse continues to haunt the de Luizzi family. Armand’s ancestors, in turn, looked for power, wealth, fame, and knowledge, but in the end found themselves unhappy. This is one of the plot’s key features: the hero already knows that traditional paths lead to a dead end, but this is the tragedy: knowledge of others’ mistakes does not prevent the character making his own.

Unlike the sad and dissatisfied genius Faust, who makes a deal with an evil spirit in exchange for secret knowledge; unlike Bulgakov’s Margarita, whose life has practically lost its meaning due to her unspeakable longing for her lover; or unlike Geoffrey Tempest from “The Sorrows of Satan”, a poor, eager writer trapped in poverty; Armand is distinguished by the fact that, being an aristocrat, he has almost everything. The hero is not a yearning scholar or a romantic rebel, but rather a spoiled, young rake, lacking a greater purpose or desire to save himself or his loved ones, finding himself in a difficult life situation like the aforementioned heroes.

Armand desires to see through others. The devil willingly provides the baron the knowledge he asks for, and a long journey through the destinies of others begins. At first, it seems like a game and amusement to the baron – he eagerly seeks to learn others’ sometimes dirty secrets for the sake of curiosity and even a sense of power. The hero assumes that through these stories, he would understand the essence of true

happiness. Afterwards, having gained access to others' secrets, he does not hesitate to use his knowledge for immoral purposes, provoking scandals, ruining reputations, and interfering with the lives of others. Throughout the novel, one can see that Armand is quite naive, arrogant, and often behaves without much thought to the consequences. He sometimes acts basely for his own gain, out of fear, or is simply led by his own vices. One example is where Armand slanders and indirectly drives to ruin another heroine, Madame Dillois, with whom he at first had a close relationship, but through his egoism, passion, and secret knowledge (a kind of diabolical influence), he dishonors her. However, the realization dawns that diabolical knowledge does not provide advantage over the world, but only plunges its bearer into a world of total evil. Armand discovers that there are no good people in his circle. Soulié goes beyond simple observation: he makes the baron see that he himself is the member of this vicious society, that his own good intentions turn into "grave mistakes". From intense curiosity, the hero moves to satiety, and from satiety to horror and inner emptiness.

And yet, the hero is ambiguous. In the following chapters, Armand begins to suffer from pangs of conscience. Yes, at times, under the influence of emotion, the young baron can commit rash, sometimes terrible acts, but there are also moments when he understands his mistakes and tries to correct them (though not always successfully). Soulié devised a brilliant psychological approach: to reveal Armand's soul, he shows us the souls of others through the hero's eyes. We see his thoughts, fears, doubts, and this allows us to create his psychological portrait. Thanks to Soulié's techniques, Armand appears as a truly vibrant character. By the end of the work, it becomes clear that the knowledge gained through the Devil does not extend the personality, but rather corrodes it, leaving in its place only a weariness with human nature.

Armand de Luizzi is a charming, impulsive, and deeply unhappy egocentric, whose pride is stronger than his conscience, and whose thirst for exclusivity outweighs the natural need for human relationships with others. His tragedy lies in the fact that he understands his own flaws but is unable (and just does not want) to abandon his chosen path until it is too late.

2. The Image of the Devil and His Narrative Role

If Baron Armand de Luizzi is the psychological center of the novel, then the Devil is a kind of mirror through which readers see the world and society. Introducing a character like the Devil into the plot is far from a new idea – for example, the majestic Prince of Darkness, Woland, from "The Master and Margarita" [3], who is described by Bulgakov as a powerful, punishing, but fair evil, exposing the vices of humanity. Or Mephistopheles from "Faust" [4] – the spirit of denial, destruction, and irony, an intellectual cynic who despises humanity. Another example is John Milton's romantic rebel Lucifer. A proud, arrogant, and self-confident fallen archangel, for whom "it is better to reign in Hell than to serve in Heaven" [5]. Or, finally, the Prince of Darkness in Marie Corelli's novel "The Sorrows of Satan" [6], who appears to readers as a suffering yet noble being, where the devil's greatest sorrow is eternal separation from God and contempt for human nature.

All these images can be divided into two main types of Satan: a majestic enemy, a rebel yet capable of reflection, and an evil, even stern, yet just genius who has already known all that exists. But what type does Soulié's Devil belong to?

Soulié offers a third, much rarer version: his Devil is a narrator, an observer, and a mirror reflecting the true essence of French society. He is not just a typical character who breaks up the plot, but a narrator. The Devil can lie, but he chooses a different approach – to reveal the truth, even if it is unbearably bitter and unpleasant. He addresses the hero in a kindly, ironic tone, sometimes retreating into philosophical themes – the same tone the evil spirit uses when describing horrific crimes. This is Soulié's stylistic narrative approach, representing Satan as a "lazy", ironic observer for whom human destinies are just stories – a description of the horrors of human nature in the style of polite conversation. The Devil is not as active as the traditional aforementioned figures – he often chooses to be passive, preferring to let people choose and then watch events unfold.

And yet, according to the plot, the Devil is Baron de Luizzi's servant – but is he really just a servant? The dark spirit does indeed come to Armand's rescue whenever he finds himself trapped (usually through his own actions). Here, too, one detail stands out that distinguishes "Memoirs of the Devil" from the aforementioned works: here, the Devil is man's servant, and not vice versa. Formally, this is true according to their agreement, but in reality, things are much more complicated. Despite his status in the deal, with each chapter it becomes clearer that the situation is the other way around. The Devil has power over Armand, but the spirit does not require direct and demonstrable proof of his power over the hero. The Devil just provides what the baron asks for and then simply watches the fall of the proud man, who mistakenly believes himself to be the master.

Soulier's Devil is not just a character in the traditional sense; he is more like a tool, a "mirror" which reveals the true essence of people's souls (and finally, Armand de Luizzi's own soul). Through him we see the world and the society; the Devil seems to tell us the stories of others' destinies, subtly hinting that in the end, we are his memoirs ourselves. He does not need proof of his power, the spirit does not need to take revenge on anyone, he does not need a lost connection with God – the Devil acts as a wise storyteller and observer, ready to start sharing a new story.

3. Analysis of the Deal with the Devil Motive in the Novel.

As mentioned earlier, the European literary tradition follows a clear rule: a hero, broken by life or driven by pride, a thirst for power, or wealth, summons an evil spirit to make a deal with it. Typically, a turning point in the hero's life occurs, leading him to ask dark forces for help. In his work, Soulié explores the theme of the pact in a completely different way: In this case, the pact is a privilege for the hero, who nevertheless agrees to enter into a deal with the Devil – not out of urgent need, but out of curiosity, overconfidence and pride. For the baron, it is just entertainment and a baseless excuse to try to outwit the Devil and, at the same time, free his family from the curse.

Throughout the novel, Baron de Luizzi must put up with his hellish companion, who does not make life any easier for the young aristocrat. His main goal is to save his

soul and family from the curse (especially when he realizes that he agreed to this in vain). He is unfamiliar with the problems of the outcasts (who most often ask the dark forces' assistance) — money, power, and love affairs are already an integral part of the baron's life. What else could a young rake need? And yet, he must seek true happiness to free himself from the shackles of the curse. It has already been mentioned that the Devil "appears" to be the baron's servant, fulfilling almost his every desire – although for a price that Armand pays with his years of life, having a magic bag of coins worth the baron's years.

At first glance, the role of the pact in the novel seems clear – at least, the entire plot revolves around it – but is it just a burden for the hero? From a different perspective, the pact with the Devil at the same time gives Armand a chance to reconsider the meaning of his life and choose a different path – one not tied just to material gain. Indeed, Armand afterwards rethinks his life and principles, but still he fails, being unable to free himself from his own nature.

And yet, the question of true happiness remains unresolved, as Baron de Luizzi fails to fulfill the terms of the deal, and the problem remains open, as Soulié does not directly say what would save the protagonist's soul. So, what is true happiness? Although the author does not provide a clear answer, he still gives hints through the Devil to Armand and the readers themselves. Throughout his life the Baron meets people who would have given him true love and the warmth of their presence but he rejects them due to pride, fear, and doubt. The Devil hints that happiness was almost there, but due to his foolishness, the hero loses the chance to save his soul. And only at the very end, when Armand truly falls in love with Marie Gaubert, who becomes for him the embodiment of sincerity and redemption in contrast to his past life, it finally dawns on him where the real happiness was.

Nevertheless, Soulier probably meant that true happiness can be found in everyday life, where, most importantly, a person is surrounded by their loved ones who give them the light and bliss of sincere love. Social status, the amount of money and property, and momentary pleasures may not always be there, especially in those difficult situations when all of this is of no use anymore. And only having someone who is ready to share your sorrow and stay with you in the abyss of hell can truly be considered happiness.

Conclusion

Frédéric Soulié's "Memoirs of the Devil" is a novel that has remained in the shadow of its more famous contemporaries and successors, but this does not make it worse or less original than novels with a similar idea and theme. This analysis shows that Soulié wrote not just another amusing feuilleton novel with the classic theme of a pact with dark forces, but a thoughtful work about vice, human nature and the illusion of true happiness.

The main result of the study is an analysis of the characters and Soulié's reinterpretation of the classic pact with the Devil. For Armand de Luizzi the deal is a curse and a privilege at the same time, not an opportunity to achieve what he desires, as for the other heroes. The Devil himself, deprived of his usual demonic activity in Soulier's work, behaves as a narrator and a mirror through which we see the naked souls of people. Through his narrative role, the author shifts the focus from the external

threat to the internal drama of the hero, whose tragedy lies not so much in his rapid fall from grace as in the bitter realization that his main enemy was not the Devil himself, but his own pride and his overall nature, which he was unable to change, even though opportunities presented themselves several times. And even despite his knowledge of the mistakes of his ancestors or his understanding of the actions of others, the Baron still dies, allowing the curse to continue.

Soulier's innovation within the long-standing tradition of the "devilish" plot lies in its almost inversion of the conventional wisdom: the protagonist is granted a pact with the devil as a privilege, even an inheritance, out of his own curiosity and pride, he decides to undertake a dangerous adventure, unlike the main characters from other well-known literary works on the topic, for whom the pact was almost the only salvation and chance in their own story. The devil here is not a powerful prince of darkness and someone to whom they turn for help, but a servant who acts as his "master's" companion and assistant, providing any service, but only under the terms of the deal. The pact afterwards becomes more of a way to understand whether the protagonist lives by the right principles and whether this is the right path for him.

The novel definitely needs more detailed study, and its comparison with other feuilleton novels in the Gothic tradition deserves special attention. The work itself is unique in its unusual representation of a pact with the devil. Thanks to it, readers can also rethink their values, principles, and by doing so understand what it is that makes them truly happy.

For now, one thing can be said with certainty: "Memoirs of the Devil" is a work that can draw both reader attention and scholarly interest.

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УДК 378

TOPICAL PROBLEMS OF PROFESSIONAL PEDAGOGICAL EDUCATION

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Abstract. This article examines current issues in professional and pedagogical education. Particular attention is paid to the computerization of the educational process for students and teachers, especially when working with elementary school children. It also analyzes modern approaches, technologies, and methods for improving learning effectiveness in a digital educational environment.

Keywords: teacher education, educational problems, information, educational process, digital technologies, primary school, professional training, information technology, teaching methods.

АКТУАЛЬНЫЕ ПРОБЛЕМЫ ПРОФЕССИОНАЛЬНОГО ПЕДАГОГИЧЕСКОГО ОБРАЗОВАНИЯ

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Аннотация. В статье рассматриваются актуальные проблемы профессионального педагогического образования. Особое внимание уделяется вопросам информатизации образовательного процесса обучающихся и преподавателей, особенно при работе с детьми начальных классов, а также анализируются современные подходы, технологии и методы повышения эффективности обучения в условиях цифровой образовательной среды.

Ключевые слова: педагогическое образование, проблемы образования, информация, образовательный процесс, цифровые технологии, начальная школа, профессиональная подготовка, информационные технологии, методы обучения.

Information technology integration in education is one of the most urgent issues of contemporary professional teacher education, as it largely determines the quality of future teachers' training and their readiness to work in a digital society [1, p. 12]. In the context of rapid development of information technologies and their integration into the educational process, there arises a need to revise traditional approaches to teacher training, to update the content of professional preparation and the teaching tools employed [2, p. 34]. Information and communication technologies are becoming not

just an additional tool, but an essential component of the educational environment that affects the forms, methods and outcomes of teaching and learning [3, p. 21].

Modern education is undergoing significant changes under the influence of technology and informatization processes which affect both the organization of the learning process and its content [1, p. 18]. Professional teacher education is no exception, since the level of teachers' digital competence largely defines the success of implementing innovations in schools and universities [4, p. 9]. Future teachers are expected not only to master traditional teaching techniques, but also to actively use new information technologies in their professional practice, showing flexibility and readiness for continuous learning [5, p. 47]. There are several current issues related to this process, and one of the key ones is the informatization of education, which requires a comprehensive, step-by-step and research-based approach to integrating ICT into teaching and learning activities [2, p. 40].

The informatization of education affects many aspects of the pedagogical process and requires prospective teachers to adapt to new working conditions and to rethink their roles and functions within the educational environment [3, p. 25]. However, despite obvious advantages, this process faces a number of challenges, including insufficient material and technical resources, a shortage of high-quality digital learning materials, and limited readiness of teachers to use ICT effectively [6, p. 58]. Another important aspect is the gap in digital literacy levels between students and teachers, which often creates additional difficulties in communication and in the organization of the learning process [7, p. 31].

The informatization of education creates new opportunities for teachers, enabling them to use multimedia resources, online services, e-learning platforms and interactive teaching materials to improve the educational process [8, p. 66]. Such approaches can significantly increase students' interest in school subjects and contribute to the development of critical thinking as well as skills of searching, analysing and interpreting information [1, p. 20]. Today there is a wide range of websites and software tools for developing teaching materials, creating presentations, interactive tasks and tests, which broadens the spectrum of means used in the informatization of education [9, p. 54]. This is a considerable advantage, but many of these websites and platforms are fee-based, and not every educational institution can afford licenses and subscriptions for the necessary resources [10, p. 13]. At the same time, modern technologies provide teachers with powerful tools for personalizing learning, which makes it possible to take into account individual characteristics and needs of each student, including their learning pace and level of preparedness [3, p. 28].

However, informatization also has its drawbacks. For example, not every child is able to maintain concentration during an online lesson, especially when interacting with a screen for a long time [11, p. 72]. During online classes in handwriting, the teacher cannot fully monitor how students write letters, position their hands or hold a pen, which may have negative consequences in the future if we focus on informatization at the primary school level [10, p. 39]. This problem is relevant not only for Russian language or handwriting lessons, but also for other subjects where tactile, hands-on activities and direct interaction with the teacher are crucial [11, p. 19].

For successful integration of ICT into the educational process, continuous professional development and self-education of teachers are required, as well as fostering their stable motivation to master new technologies [4, p. 16]. Educational institutions should provide support through in-service training courses, workshops, seminars and conferences, where teachers can share their experience, discuss best practices and find practical solutions to problems arising from technology implementation [4, p. 83]. Cooperation between educational institutions, governmental bodies and technology companies is also an important factor, as it allows developing joint projects and programmes aimed at improving the digital educational environment [5, p. 51]. Joint efforts can help create unique educational systems that maintain high standards of educational quality in the rapidly changing information society [2, p. 45]. Informatization of education is not only a challenge, but also a step towards innovation, leading to a new generation of teachers and students who are ready for life and professional activity in a digital world [1, p. 23].

To achieve full-scale integration of information and communication technologies into the educational process, it is necessary not only to develop teachers' competences, but also to create appropriate infrastructure at the level of schools, colleges and universities [5, p. 52]. This includes high-speed Internet access, up-to-date equipment (computers, tablets, interactive whiteboards), as well as reliable software solutions that support an effective learning process [6, p. 60]. Investments in the technological base of educational institutions are a prerequisite for the successful implementation of multimedia resources, e-textbooks and cloud services, without which full-fledged informatization of education is hardly possible [10, p. 19].

Considering the variety of learning formats, ICTs make it possible to implement flexible models of education: from traditional classroom teaching with digital elements to blended and fully online learning [7, p. 36]. Such approaches make education more accessible, adaptive and efficient, and expand opportunities for organizing individual and group forms of work [3, p. 30]. Students can study at a convenient pace and in a suitable format, which increases their motivation and learning outcomes and supports the development of self-management and independent learning skills [11, p. 75]. It is also important to note that technology integration requires teachers to critically evaluate and select appropriate digital resources, aligning them with lesson objectives and the age-related characteristics of learners [8, p. 70]. Not all devices or software applications are useful for educational purposes, and teachers often have to filter and adapt digital content to their own needs and those of their students [6, p. 41].

Many digital tools require thorough study, and their use does not always have a positive impact on the educational process, particularly when teachers lack sufficient methodological training in ICT-supported instruction [9, p. 59]. Special attention should be paid to software designed for children with special educational needs, which requires individual learning pathways and specialized digital tools [7, p. 28]. For children with disabilities, informatization may be even more difficult to perceive, as it demands a high level of concentration and sustained attention, which can be challenging for this group of learners [2, p. 43]. At the same time, for such students carefully selected digital technologies can open additional opportunities by providing

visual prompts, audio support, interface adaptation and specific training programmes [8, p. 64].

In this context, general teacher education is not sufficient: educators need special knowledge in the fields of special and inclusive education, as well as the ability to select and adapt electronic resources for students with special educational needs [8, p. 64]. On the positive side, informatization can improve the perception of learning material due to a more comfortable and familiar environment in which the child studies, supported by various visual and audio tools [9, p. 11]. Children often feel more relaxed and confident at home, and if the teacher structures the lesson properly, alternates activities and considers individual health conditions, the learning process can become more effective [7, p. 30].

Thus, the informatization of education is a multi-level process that requires a comprehensive approach aimed at the development of both teachers and the educational environment as a whole [1, p. 26]. It opens new opportunities for teachers' professional growth, for the creation of innovative teaching methods and for the implementation of project-based and research activities supported by digital resources [4, p. 20]. Ultimately, informatization contributes to ensuring high-quality education for the younger generation that meets the needs of the economy and society [2, p. 48]. Each new revision of the Federal State Educational Standards sets higher expectations not only for teachers but also for students, including explicit requirements related to ICT competence and digital literacy of learners starting from primary school [6, p. 63].

One of the key tasks faced by educational institutions is to build a system of continuous professional development for teachers based on principles of flexibility and accessibility [4, p. 85]. This should include not only traditional in-service training courses, but also mentoring and tutoring, where more experienced colleagues share their knowledge about new technologies and demonstrate examples of their practical use in the classroom [5, p. 55]. Organizing such programmes on the basis of networking makes it possible to exchange best practices, create professional communities and find effective solutions for integrating ICT into the learning process [10, p. 92].

It is also important to consider the potential of online resources for teacher training, including webinars, online courses and virtual professional communities [9, p. 14]. Online platforms can provide access to teaching materials, video lectures and discussion forums where teachers address current issues related to informatization and the use of digital tools in education [11, p. 37]. This allows teachers to study at a convenient time and at an individual pace, combining work and professional development [10, p. 22]. It should also be remembered that not all teachers are young specialists: many have extensive teaching experience, and for them changes related to ICT can be psychologically challenging [11, p. 24].

For such teachers, it is much more difficult to adapt to new structures of education and to shift towards active use of digital resources [8, p. 68]. Informatization is not an easy process; it requires numerous revisions, improvements and continuous organizational and methodological support [6, p. 45]. Therefore, targeted support measures are necessary, such as mentoring, individual consultations and opportunities to master digital technologies at a comfortable pace [5, p. 29].

In the Russian Federation, the IT sector is rapidly developing, which should positively influence informatization processes in education through the design of domestic platforms, electronic gradebooks and educational services [11, p. 10]. National and regional digitalization projects create conditions for updating infrastructure and improving the availability of high-quality digital resources, including for rural schools and small educational institutions [3, p. 6]. If state authorities, educational organizations, businesses and the professional teaching community work together, it will be possible to create conditions for the development of new generations with a higher quality of education and higher standards of training [10, p. 95].

The implementation of all these initiatives requires a clear strategy and strong governmental support reflected in legislation and federal programmes for education development [3, p. 5]. It is necessary not only to ensure adequate funding but also to adopt legal acts that promote the integration of new technologies into the educational process, protect personal data of students and teachers, and guarantee equal access to digital resources [11, p. 40]. This will provide a basis for sustainable development of the educational system and help to prevent a digital divide between different regions and types of institutions [2, p. 13].

The informatization of professional teacher education is a response to the demands of modern society and the labour market oriented towards the digital economy [1, p. 29]. However, this process is associated with a number of challenges that must be addressed in a comprehensive way, combining organizational, methodological and psychological–pedagogical measures [3, p. 33]. Teacher training universities should focus on staff preparation, on adapting curricula, expanding practice-oriented modules related to ICT use in teaching and ensuring access to modern technologies for both students and academic staff [5, p. 55]. Only under conditions of purposeful integration of informatization into the pedagogical process can we expect an improvement in the quality of education and in the preparation of teachers who meet modern requirements and can work effectively in a digital learning environment [4, p. 22].

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УДК 316.7:392

THE LANGUAGE OF TOURISM: THE SPECIFICS OF COMMUNICATION IN A MULTICULTURAL ENVIRONMENT

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Abstract. The article reveals the key difficulties of linguistic and cultural interaction between tourists and employees of the tourism industry: from language barriers to differences in traditions and customs. Specific examples demonstrate typical situations of misunderstanding and their consequences. Practical recommendations on staff training are offered, including through cross-cultural trainings and language training improvement, which is important for improving the quality of service and reducing conflict potential in the tourism sector.

Keywords: tourism, communication, multicultural environment, language barrier, mutual understanding, norms of communication.

ЯЗЫК ТУРИЗМА: СПЕЦИФИКА КОММУНИКАЦИИ В МУЛЬТИКУЛЬТУРНОЙ СРЕДЕ

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Аннотация. В статье раскрываются ключевые сложности языкового и культурного взаимодействия между туристами и работниками туристской индустрии: от языковых барьеров до различий в традициях и обычаях. На конкретных примерах демонстрируются типичные ситуации недопонимания и их последствия. Предложены практические рекомендации по обучению персонала, в том числе через кросс-культурные тренинги и совершенствование языковой подготовки, что важно для повышения качества обслуживания и снижения конфликтного потенциала в сфере туризма.

Ключевые слова: туризм, коммуникация, многокультурная среда, языковой барьер, взаимопонимание, нормы поведения.

Tourism is an area where communication plays an important role. Maybe even a key one. The thing is that this is working with people, including colleagues, partners, tourists themselves, and even the public in general. But tourism has its own ways of communicating, and this is due to the multicultural environment. The topic has become relevant again because the flow of tourists from new and exotic destinations has increased, such as Iranians, Arabs, Chinese and Africans. That is why the question has

been investigated in order to understand whether the situation with tourists' satisfaction with staying in Russia has changed and vice versa, because Russians have also changed their preferences towards the East. If earlier it was more often Europeans who are more familiar and culturally understandable, and also speak English well themselves, now the situation has changed. The purpose of this study is to study the impact of language barriers on the quality of the tourist experience and intercultural interaction.

Methods used in the work:

- survey
- synthesis
- analysis

In the process, a survey was conducted among young people, as this part of the population is more likely to speak English or another foreign language. The questions were aimed at identifying difficulties in communication during travel, as well as the general impressions of the staff's language proficiency. Based on the answers, an overall picture of communication difficulties is formed. It is important to understand the latest trends in order to form effective learning plans. To figure this out, I analyze the respondents' answers to 6 questions and try to figure out the current situation. The analysis was carried out by comparing the answers to the questions and searching for a link to create a complete general understanding. The result is analyzed and an assessment of the staff's skills and ways to improve them, as well as the impact of the tourists' own skills, is derived.

The first thing that comes to mind when talking about the complexity of communication is the linguistic interaction between tourists and tourism workers. At the moment, exotic for the labor market foreign languages such as Hindi, Farsi, Arabic and Chinese are relevant. But there are even fewer such specialists than those who speak English, and there are more and more tourists who speak these languages but do not speak English. Some of the service sector employees do not have sufficient English for full-fledged communication.

There are many words in tourism that may be unfamiliar to both sides, such as the names of dishes on the menu or local attractions. This may also be due to differing local and official names. It is even more difficult if there are two official languages in the country, as in Belarus, and people can speak with tourists different languages with different accents.

Even if both sides speak English, differences in pronunciation can make it difficult to understand, due to accents and dialects. The most common is British and American English or the accent of the tourist's native language [1, p. 168-169].

Do not forget about cultural peculiarities. In some cultures, it is customary to speak directly, in others – indirectly. Different degrees of politeness and formality may be acceptable: Russian tourists do not understand the excessive politeness of Asian countries, and Eastern tourists do not understand the coldness of Russians. You can often get into an awkward situation due to different interpretations of non-verbal expressions, such as gestures, facial expressions, and distance when communicating [2]. And also, there is a different culture of tipping in different countries: in some places they are given, and in others they are not. A tourist may not tip because of habit, which may offend a Russian employee. But if a Russian tourist tips a Japanese employee, it

will also offend him. Also, different countries have different acceptable service speeds, for example, don't expect a rush in Italy. In Western cultures, direct gaze is a sign of honesty and attention, while in Asian and Middle Eastern cultures prolonged eye contact can be considered disrespectful or defiant. In Latin America and the Mediterranean, people stand closer to each other when talking than in Northern Europe or East Asia. Queues are strictly enforced in the UK and Germany. In Southern Europe and Latin America, the approach is more relaxed, which may cause confusion among tourists. In Germany, Switzerland and the Scandinavian countries, time is strictly scheduled. A tourist from Japan may be outraged by the 10-minute delay in the transfer, while a local employee will accept this as the norm. The schedule is more flexible in Spain, Italy, Latin America and the Middle East. Lunch may start an hour later, and the meeting may be delayed. In the USA, waiters often come over to check if everything is in order. In Europe, this may be perceived as an obsession, and in Asia as excessive attention. In some cultures, it is customary to immediately report a problem, in others – to tolerate and not bother the staff. This can lead to misunderstandings: the tourist is silent, and the employee sees no reason to worry [3].

Tourism is an industry of impressions, where a lot depends on the mood of the tourist and his expectations. That is why they always treat advertising carefully, because giving false hope to a tourist means getting a disappointed customer and a lot of negative reviews. It is not surprising that the tourist builds expectations from the service. Someone has already visited a huge number of the richest and most developed countries, but against the background of the growing popularity of Asian destinations, they visited a developing country. The comparison will not be in favor of the latter, including in the training of specialists. For example, it is difficult to expect perfect English proficiency in Vietnam, but a tourist is accustomed to impeccable knowledge of the language and will be picky in his assessment.

Unfortunately, there are also difficulties that are not related to employees, which makes it more difficult to eliminate them. For example, stress and fatigue of a tourist. Communication often occurs in situations where a problem has already occurred or after a long journey. Also, in such situations, time is often limited. The complexity of technical limitations and the Internet is especially relevant now, which makes it difficult for applications that tourists often use for translation, because foreign applications are not included in the “white lists”.

The language barrier in tourism arises due to the low level of English proficiency among service sector workers in countries where English is not the main language and among tourists traveling to countries with languages that differ greatly from their native languages, for example, Hungarian, Finnish, Thai.

There is more than one person involved in communication. It is naive to assume that all tourists initially speak English or the language of the host country. That is why success depends not only on the professionalism of the employee, but also on the training of the tourist. Let's consider ways to solve the problem of the language barrier for tourists. Tourists should prepare before the trip, learn basic phrases in the language of the host country (greeting, gratitude, request for help, numbers, directions), download offline translators in case of failure, you can take a phrasebook with you. Don't be shy about using all the technologies. It's worth learning how to use mobile

translation apps with speech recognition and cameras, navigation apps with offline maps, chatbots, and AI assistants to compose phrases, routes, and ideas. If a tourist finds himself in a situation where both he and the employee do not understand the language, do not neglect the use of non-verbal means: gestures, drawings, showing photos or addresses on the phone, using a calculator to indicate prices. It's not shameful, it's adventurous. Also, do not be afraid to contact English-speaking or Russian-speaking tourists or staff. The worst that can happen is that you will be rejected. Remember that if you are not sure of the other person's level, it is better to speak clearly and slowly, and avoid idioms. Ask again and clarify if something is unclear [4].

Employees of the tourism industry, unlike tourists, are required to speak foreign languages, as this is one of their professional competencies. Their communication problems are mostly solved by training. Language courses with an emphasis on tourist vocabulary are common, as well as trainings on intercultural communication and non-verbal communication, which are sometimes conducted even by companies themselves for their employees. Communication is being standardized to simplify interaction with tourists. Phrase templates are often used for typical situations, which helps both employees who can memorize them and tourists who have learned only typical answers before traveling. They also create multilingual scripts for call centers [5, p. 94-98]. The hotels, museums, and restaurants are visually supported. Infographics and pictographs are common in such places. It is common to have a multilingual menu, often with pictures, maps, and instructions. Especially developed institutions can use innovative technological solutions. Implement chatbots and voice assistants in multiple languages or, as in Japan, provide tablets with translators in service areas. But often companies just hire employees with language skills initially or hire additional employees to support them during peak seasons.

The language barrier and cultural differences in tourism are a common problem, but it can be minimized through training, technology, and mutual respect.

The main problem is the low level of English language proficiency. Moreover, both workers and tourists. If we can't teach English to tourists, then it's worth working with the language level of service workers. However, tourists should also be educated. This problem usually disappears in countries where tourists appear frequently, as the practice of language arises all the time, as well as the owners of hotel, restaurant and other entertainment businesses realize that this is not just a fashionable criterion in the CV, but a really applied skill. That is why companies often take care of the language level of employees and train them themselves. At the same time, the tourism sector is always a frequent change of personnel. This leads to uneven staff training. Most often, the receptionist at the hotel has been working for several years before taking up this position and usually works constantly, this employee knows a foreign language, because he is carefully selected and for a long time, the company is not sorry to invest in him. But restaurant employees are not like that, they are often employees who work only one summer and then leave the company, while often their main activity is not related to the tourism sector. It is not profitable for a company to train such an employee, because he will not work for it. Because of this, in restaurants where there is even more communication than in hotels, more often the staff does not know a foreign language and finds it difficult to help.

Difficulties that are not related to employees are more difficult to eliminate. For example, when time is short and communication is too fast. But this happens because service workers often serve many people at the same time, and this reduces the time for explanation and understanding. At the airport, it will not be possible to talk with tourist for an hour, because such a tourist is often not alone, and boarding time is limited. In this situation, only an online translator can help, because an employee's knowledge of English will not always help a tourist if he does not know it. Now, with the popularity of trips to China, Russian tourists have become more likely to use this method and immediately get a translator without trying to prove anything to themselves.

Let's look at specific examples of situations of misunderstanding and their solutions. For example, in a restaurant, a tourist does not understand the composition of the dish on the menu, and the waiter cannot explain. This can be solved by the image of the dish on the menu, and restaurant can also place the images of the ingredients below. At the hotel, the receptionist sees a guest who arrived 2 hours before check-in and asks if an early check-in is needed, but the tourist does not understand the term because there is no such word in his dictionary. This is solved by preparing the tourist before the trip with the study of basic terms. On the tour, the guide uses complex historical terms, tourists do not understand half of the story. In fact, it is not difficult to find a Russian-speaking guide in the top destinations for Russian tourists. In addition, guides are certified in many languages in Russia, so there are guides even with knowledge of Hebrew or Latvian. In a taxi, the tourist calls the address in his own language, but the driver does not recognize the name. This is easily solved by showing a point on the map, because often the app will show the coordinates and the taxi driver will not have to search. It is also recommended to use apps for calling a taxi, where people set up points themselves before ordering. In a Korean restaurant, the tourist waits for the waiter to come up and take the order, but according to the local norm here, the visitor himself calls if necessary. Or in a mosque in Istanbul, a tourist walks in wearing an open T-shirt and shorts, the guard makes a remark, he is offended, considering it rude. In a hotel in Japan, a guest leaves a tip for a maid, and she returns it with an apology, because in Japanese culture this can mean that the service was of poor quality. These are all cultural features that need to be recognized and respected. Usually, travel companies have to send information sheets with detailed descriptions of the culture, and some even give lectures. tourists need to respect traditions, there is an opportunity only for tourists to study them, but not for locals to accept them.

It also happens that the tour guide delays the start. The group from Germany is already ready to complain, but the group from Italy is communicating and not paying attention. However, this situation arose mainly because of international groups from Europe. Now most of the visitors are from the East, who always travel in groups only with their compatriots. You will never see a Chinese tourist among Hindus. There should be an adaptation of the approach to different cultural expectations, it is necessary to create different communication scripts for guests from Asia and the Middle East.

To improve the level of communication with tourists, tourism personnel can be trained in several areas: language skills, cultural characteristics, communication

techniques and practical skills of working in a multicultural environment. Foreign languages should be studied with an emphasis on tourist vocabulary. The courses should include not only basic grammatical and lexical topics, but also specialized vocabulary related to tourism: booking terms, names of dishes, attractions, modes of transport, as well as phrases for solving typical situations. For example, at our university, the foreign language course has sections on tourism and key topics. Programs should include a study of the cultural characteristics of the countries from which tourists come, including etiquette, non-verbal signals, taboos and traditions. This will help to avoid awkward situations and increase the level of service. And also, I think it's important to study the preferences of different tourists before hosting them. For example, Arab tourists like a measured rest in expensive hotels, so they will not understand the offers at the reception to purchase a tour to Pskov at a discount. Discounts also cannot be used as an excuse. The focus should be shifted to developing skills of adaptation to different cultural contexts, the ability to recognize and overcome cultural barriers. In the framework of trainings, it is better to use a case system, that is, to analyze specific situations, rather than listen to theory. Modern translation services and mobile applications can greatly facilitate communication. Staff should be able to use these tools quickly and effectively, rather than avoiding the complexities of technology. Now this is the basic skill of any modern specialist. Employees should learn how to listen carefully to tourists, ask questions and clarify details in order to avoid misunderstandings. This is especially important when communicating with people who speak a foreign language with an accent. In the context of the language barrier, conflicts may arise more often. Employees should be able to smooth out tension, respond appropriately to dissatisfaction, and find solutions in difficult situations. Promotional and informational tours help to develop communication skills in a natural environment. Employees who personally get acquainted with tourist destinations better understand the peculiarities of the regions, and can tell tourists about them more reliably and emotionally.

Cross-cultural workshops and seminars are also a good modern learning tool. It is very useful to invite experts or colleagues from other countries to conduct master classes on the peculiarities of communication in different cultures. Meetings with avid tourists are also useful, who can share their experiences and tell you what is important to them in communicating with the staff. This will help not only to listen to what tourists themselves consider important, but also to observe the behavior of tourists from other countries and get used to their cultural peculiarities. I also consider it important to have an initial tolerance and respect for everyone, because this is something that cannot be taught, but it is always a pleasant bonus in the service.

Since the sphere is nervous, there are certain ways to reduce the conflict potential in the tourism sector. These are ready-made phrases for apologies, compensation offers, and ways to reassure a guest in the company itself based on its capabilities. Standardization of service processes to make it easier to understand whether a claim is objective or not, the way to solve the problem depends on it. We also need a clear allocation of areas of responsibility so that employees are narrow specialists, but do not unsuccessfully try to cover all possible competencies. There should be clear information at all stages: accurate descriptions of services, photos, cancellation

conditions, a memo with a schedule, rules, contacts, instructions on equipment, Wi-Fi, and hotel services. It is even advisable to specify this in contracts for the sale of services or on the website in order to refer to open sources in conflict situations. It is better to post a warning in advance on the site about possible inconveniences if they appear, for example, noisy events or changes in the transport schedule. It is useful to send an SMS or email with a reminder about a transfer, an excursion, or a restaurant. This way the tourist will not forget and will not blame you. There should be coordination with partners: tour operators, carriers, and tour desks to ensure consistency of information. Ideally, the group should have their own guide-interpreter who will solve their questions. But now individual tourism is more popular.

A study was conducted to identify the difficulties tourists have in communication and to understand the overall situation.

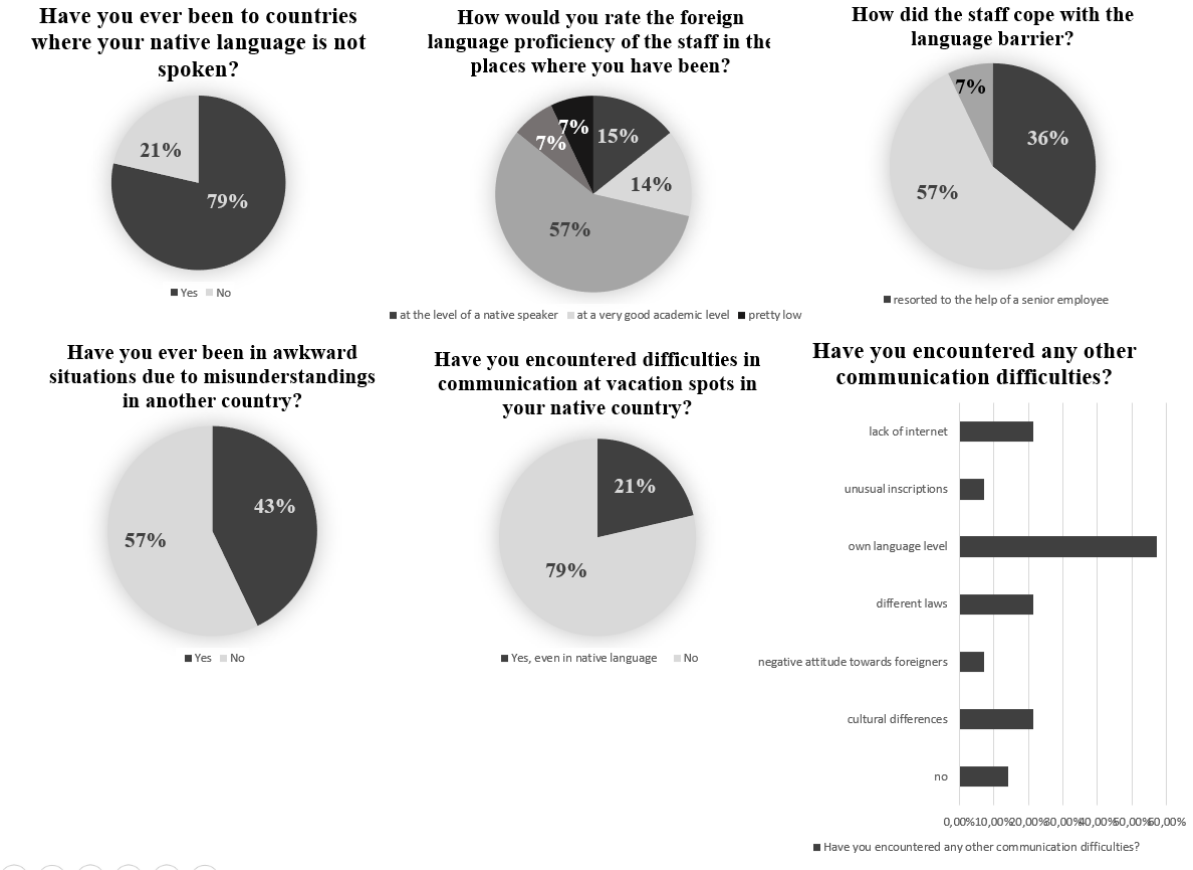


Figure. Survey result

At the beginning of the survey, there was a question about whether the respondents had ever been to countries where their native language was not spoken. This is important because if a Russian tourist travels a lot in Russia or Belarus, he is unlikely to encounter communication difficulties. About 4/5 tourists visit such countries. This means that the majority of the respondents really immersed themselves in an unfamiliar environment. The study showed that slightly more than half of tourists consider the language level of the staff in the places they have visited to be quite good for understanding. About 15 % of the respondents considered the level so good that it

seemed native. And the same number considered the language level to be academically good enough. Only slightly more than 7 % considered the level too low and impossible to communicate. It's nice to know, because it's often assumed that many tourism workers don't know languages well. However, now you can even find employees who speak Russian. However, difficulties still arise, and in more than half of the cases, the staff used an interpreter to find a common language. And more than a third used the help of a senior employee. For example, this can happen in restaurants when the waiter does not know the language, but the manager has been working for a long time and can solve the problem. The rest reported that there were no problems. And the most interesting thing is that no one responded, that the staff ignored the problem. This is good because it indicates a high level of service and a desire to do everything possible to make a positive impression. At the same time, more than half of tourists noted that problems with their own level of proficiency in a foreign language interfere. However, tourists faced other difficulties. About one fifth of the respondents reported that difficulties arose due to cultural differences, different laws and the lack of stable Internet. About 15 % did not notice any other problems. Interestingly, almost half of the tourists reported that they got into awkward situations due to misunderstandings. This may affect the perception of the country and the assessment of the travel experience. This is why travel agencies should send information memos. If a tourist knows what to do or expects certain reactions from the locals, then he is less unpleasantly surprised and leaves less negative feedback. And in conclusion, there was a question that helped to understand the essence of the problem a little more. About a fifth of the respondents reported that they also had difficulty communicating at vacation spots in their home country. Most likely, this is due to a shortage of staff and the recruitment of unskilled staff during the season. The ability to communicate is also a skill that needs to be learned, no matter what language.

In conclusion, I would like to say that the picture of tourists' satisfaction with the quality of communication has become better in recent years, but there is still much to improve. In addition, tourists still have difficulties learning languages, but they have adapted to the realities with the help of modern technologies. Successfully overcoming the language barrier requires joint efforts on the part of both tourists and service sector workers, as well as the continuous development of technological solutions in this area. The language of tourism is communication no matter what and between everyone.

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УДК 159.944.4

EMOTIONAL BURNOUT IN THE CONTEXT OF DIGITAL HYPERCONNECTIVITY: A SYSTEMIC ANALYSIS OF CHRONIC STRESS TRANSFORMATION

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Abstract. This article analyses the transformation of chronic stress into emotional burnout under conditions of digital hyperconnectivity, permanent availability, and hybrid work. Drawing on stress theories, WHO's ICD-11 classification, burnout assessment tools and survey data, the study argues that burnout is not an individual deficit but a structural phenomenon shaped by blurred work-life boundaries, productivity culture, information overload and technological pressure. The findings show that psychological awareness is outpaced by socio-technological stressors, requiring prevention at multiple levels rather than individual coping alone.

Keywords: emotional burnout, chronic stress, digital hyperconnectivity, systemic analysis, burnout prevention, organisational psychology, ICD-11, presenteeism.

ЭМОЦИОНАЛЬНОЕ ВЫГОРАНИЕ В КОНТЕКСТЕ ЦИФРОВОЙ ГИПЕРСВЯЗИ: СИСТЕМНЫЙ АНАЛИЗ ТРАНСФОРМАЦИИ ХРОНИЧЕСКОГО СТРЕССА

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Аннотация. В статье анализируется трансформация хронического стресса в эмоциональное выгорание в условиях цифровой гиперсвязи, постоянной доступности и гибридного формата работы. Опираясь на теории стресса, классификацию ВОЗ МКБ-11 (ICD-11), инструменты оценки выгорания и данные исследований, автор показывает, что выгорание является не индивидуальным психологическим дефицитом, а структурным феноменом, формируемым размыванием границ между работой и личной жизнью, культурой продуктивности, информационной перегрузкой и технологическим давлением. Результаты исследования свидетельствуют о том, что психологическая осведомленность не успевает за ростом социально-технологических стрессоров, поэтому профилактика должна включать многоуровневые меры и не

ограничиваться только индивидуальными стратегиями преодоления стресса.

Ключевые слова: эмоциональное выгорание, хронический стресс, цифровая гиперсвязь, системный анализ, профилактика эмоционального выгорания, организационная психология, МКБ-11, презентеизм.

Emotional burnout is increasingly conceptualised not as an individual psychological deviation but as a systemic outcome of prolonged exposure to chronic stress within demanding organisational and digital environments. The intensification of digitalisation, combined with escalating socio-economic demands, has fundamentally transformed the conditions under which individuals operate. Contemporary employees often work within a regime of continuous performance, availability, and self-optimisation. Within this framework, emotional burnout emerges as a structural phenomenon rather than an isolated psychological condition. It reflects difficulty sustaining long-term adaptation under conditions of chronic stress exposure. The central research problem can be formulated as follows:

Why does the prevalence of emotional burnout continue to increase despite the expansion of mental health awareness and interventions?

Stress, as originally conceptualised by Selye [1], represents a nonspecific physiological and psychological adaptive response to environmental demands. In its acute form, stress functions as a short-term regulatory mechanism that mobilises cognitive and physiological resources to meet immediate challenges.

Burnout, by contrast, constitutes a state of chronic maladaptation resulting from prolonged, unmanaged exposure to structural stressors. Critically, the World Health Organization classifies burnout in the ICD-11 (code QD85) not as a medical or psychiatric disorder but as an occupational phenomenon [2].

This classification underscores that burnout is a syndrome conceptualised as resulting from chronic workplace stress that has not been successfully managed, characterised by three core dimensions:

- feelings of energy depletion or exhaustion,
- increased mental distance from one’s job, or feelings of negativism/cynicism related to one’s work,
- reduced professional efficacy.

Thus, burnout should be interpreted as a systemic failure of long-term adaptive mechanisms rather than a mere extension or intensification of acute stress [3].

Burnout is closely connected with the structure of modern socio-economic systems.

Key determinants include:

Digital hyperconnectivity refers to the state of constant online availability shaped by the widespread use of smartphones, social media, corporate messengers, and remote communication technologies. In contemporary society, employees often remain connected to work-related tasks even outside official working hours. As a result, temporal and psychological boundaries between professional and personal life become increasingly blurred. This phenomenon reduces opportunities for emotional recovery, contributes to chronic cognitive activation, and creates a persistent feeling of being “always available.” Continuous digital engagement is associated with increased mental

fatigue, sleep disturbances, reduced concentration, and emotional exhaustion.

Hustle culture is a socio-cultural phenomenon that promotes constant productivity, self-optimisation, and professional achievement as indicators of personal value and success. Within this framework, rest and recovery are frequently perceived as signs of laziness or insufficient ambition. Social media platforms intensify this pressure by continuously presenting idealised images of success, efficiency, and career accomplishment. Consequently, individuals may internalise unrealistic productivity standards and develop guilt associated with rest or reduced performance.

Information overload refers to excessive exposure to large amounts of information that exceed an individual's cognitive processing capacity. In the digital era, this phenomenon is intensified by continuous news consumption, social media feeds, and constant notifications. A related concept is doomscrolling – compulsive consumption of negative or anxiety-inducing news content. Persistent exposure to emotionally distressing information increases background anxiety, emotional tension, and cognitive fatigue. Information overload reduces attentional control, impairs decision-making processes, and contributes to chronic psychological exhaustion.

The COVID-19 pandemic significantly transformed the structure of labour relations and professional interaction. The rapid transition to remote and hybrid work models created new psychological and organisational challenges. Hybrid work environments often lead to role ambiguity, unstable schedules, and difficulties separating professional responsibilities from personal life. Many employees experience increased emotional strain due to social isolation, reduced interpersonal communication, and the expectation of constant digital responsiveness. Post-pandemic adaptation has therefore become an important factor contributing to chronic stress and burnout.

Rapid technological development and the integration of artificial intelligence into professional environments have substantially increased cognitive demands placed on employees. Automation and AI systems accelerate workflows, increase performance expectations, and require continuous adaptation to new digital tools and processes. Employees are often expected to process information faster, multitask more efficiently, and maintain high productivity under conditions of constant technological change. This environment contributes to cognitive overload, emotional fatigue, and anxiety related to professional competitiveness and job security.

The analysis of the literature shows that emotional burnout in the digital era is intensified by several interrelated factors: digital hyperconnectivity, productivity-oriented culture, information overload, hybrid work uncertainty, and increasing cognitive demands shaped by technological change.

These factors collectively produce a state of chronic activation without sufficient recovery, which is the primary condition for burnout development.

Methodological Assessment in Contemporary Research

To ensure empirical validity, modern burnout research relies on standardised psychometric instruments that operationalise its multidimensional structure. The most widely cited tool is the Maslach Burnout Inventory (MBI) [4], which quantifies emotional exhaustion, depersonalisation, and reduced personal accomplishment through validated Likert-scale subscales. Complementary instruments include the

Copenhagen Burnout Inventory (CBI) [5], which differentiates between personal, work-related, and client-related exhaustion, and the Oldenburg Burnout Inventory (OLBI) [6], which assesses exhaustion and disengagement using balanced positive/negative item formulations to mitigate response bias. The consistent application of these validated scales across cited studies provides a robust methodological foundation for cross-organisational and cross-cultural comparisons, reinforcing burnout as a measurable, systemic construct rather than a subjective or anecdotal condition.

Burnout leads not only to exhaustion but also to changes in professional functioning.

Observed effects include:

- cognitive decline and decision-making errors
- emotional detachment and cynicism
- reduction in task engagement

A critical manifestation is presenteeism, defined as reduced productivity despite physical presence at work.

At the macro level, burnout contributes to:

- workforce inefficiency
- increased absenteeism
- organisational instability

According to WHO, depression and anxiety alone cause an estimated 12 billion lost working days annually, costing the global economy approximately US$ 1 trillion per year in lost productivity [7]. Although these figures do not refer to burnout specifically, they demonstrate the broader economic significance of mental health risks in the workplace. Despite high prevalence, help-seeking remains disproportionately low. This discrepancy is explained by:

- stigma
- normalisation of stress
- perceived professional risks

This gap indicates a systemic weakness of mental health integration within organisational and social structures.

According to Gallup, 76 % of employees experience burnout at work at least sometimes, while 28 % report being burned out very often or always [8]. In addition, Gallup's State of the Global Workplace 2024 Report indicates that 41 % of employees report experiencing a lot of daily stress [9]. These indicators confirm that chronic stress and burnout are not isolated individual problems, but widespread phenomena affecting a substantial proportion of the global workforce.

In creative sectors, high emotional investment and subjective evaluation increase vulnerability to burnout. In engineering and technical fields, high cognitive load and error intolerance may contribute to chronic mental fatigue.

In both domains, burnout is amplified by performance pressure combined with limited recovery opportunities.

The prevention of emotional burnout requires a comprehensive and multi-level approach, since burnout is determined not only by individual psychological factors but also by structural characteristics of the contemporary social environment [9].

Prevention and intervention strategies should be considered at individual, organisational and societal levels.

Prevention

Individual-Level Strategies

At the individual level, prevention should focus on restoring psychological and physiological resources. One of the key measures is the establishment of clear boundaries between work and personal life. In conditions of digital hyperconnectivity, employees often remain psychologically involved in work even outside working hours. Therefore, limiting work-related communication during rest periods is essential for emotional recovery.

Techniques such as mindfulness, physical activity, sleep stabilisation, and time management contribute to reducing chronic stress levels and improving adaptive capacity.

In addition, individuals should develop awareness of early burnout symptoms, including emotional exhaustion, cognitive fatigue, irritability, and loss of motivation. Early recognition allows intervention before severe psychological consequences emerge.

Organisational-Level Strategies

According to WHO recommendations, organisational interventions are among the most effective approaches to burnout prevention [10]. Employers should create working conditions that reduce excessive workload and chronic psychological pressure. This includes:

- realistic performance expectations;
- balanced distribution of tasks;
- flexible work arrangements;
- sufficient recovery time.

An important aspect is managerial training. Supervisors and team leaders should be able to recognise early signs of burnout and provide psychological support rather than reinforcing productivity pressure. Organisations should also reduce the normalisation of overwork culture. In many professional environments, chronic exhaustion is still perceived as a sign of dedication and responsibility. The implementation of corporate mental health programmes, psychological consultations, and burnout prevention training may significantly improve employee well-being and organisational stability.

Societal-Level Strategies

At the societal level, burnout prevention requires changes in cultural attitudes toward productivity and mental health [3].

Contemporary society often promotes the idea that constant activity and achievement are indicators of personal value. Social media intensifies this pressure by creating unrealistic standards of success and efficiency. Therefore, public awareness campaigns should emphasise the importance of psychological recovery, work–life balance, and emotional well-being. Another important direction involves reducing stigma surrounding psychological assistance. Many individuals avoid seeking professional help because of fear of judgment or perceived professional risks.

Improving access to mental health services and normalising psychological

support are essential components of long-term prevention.

Burnout should be recognised not only as an individual psychological issue but also as a consequence of socio-economic and technological conditions that continuously intensify emotional and cognitive demands. Consequently, sustainable prevention is possible only through the integration of individual coping strategies, organisational responsibility, and broader societal reforms aimed at protecting psychological well-being in the digital era.

Limitations and Future Research

This article employs an analytical-review methodology, synthesising established theoretical frameworks and secondary data from international health organisations, large-scale surveys, and peer-reviewed literature. While this approach enables a comprehensive macro-level analysis of burnout in the digital era, it does not involve primary empirical data collection, experimental design, or original statistical processing. Consequently, the findings are constrained by the methodological heterogeneity of cited sources, potential cultural biases in predominantly Western datasets (e.g., WHO, Gallup), and the rapidly evolving nature of digital work architectures. Future research should prioritise longitudinal studies tracking burnout trajectories across hybrid and fully remote work models, cross-cultural validation of assessment instruments in non-Western professional contexts, and randomised controlled trials evaluating the efficacy of organisational and policy-level interventions. Additionally, emerging domains such as algorithmic performance management, AI-driven workload distribution, and structured digital disconnection protocols warrant rigorous empirical investigation to refine evidence-based prevention frameworks.

Key Findings

The analytical review yields six principal conclusions that directly address the core research questions.

1. Systemic Nature of Burnout.

Emotional burnout in the digital era should not be interpreted as an individual psychological deficit. It represents a structural maladaptation to chronically embedded socio-technological stressors and therefore requires a conceptual shift from an individual to a systemic framework.

2. The Awareness–Prevalence Paradox.

Burnout continues to spread despite the expansion of mental health awareness and prevention initiatives. This indicates that awareness and individual coping strategies are insufficient when macro-level environmental and organisational demands continue to reproduce chronic exhaustion.

3. Qualitative Transformation of Stress.

Contemporary stress has shifted from an episodic adaptive response to a normalised background condition. Digital hyperconnectivity, information overload, hybrid work uncertainty, and the erosion of work–life boundaries create continuous cognitive and emotional activation.

4. Adaptive Mismatch Driven by Technological Acceleration.

The pace of digital and AI-mediated change increases communication speed, productivity expectations, and cognitive demands faster than individuals can

sustainably adapt. This creates a structural deficit of psychological recovery resources.

5. Degradation of Professional Functioning.

Chronic burnout manifests not only in emotional exhaustion but also in cognitive decline, emotional detachment, reduced engagement, and presenteeism. As a result, employees may remain formally present at work while becoming psychologically disengaged and less productive.

6. Need for Multi-Level Structural Intervention.

Sustainable prevention cannot rely on individual self-regulation alone. It requires integrated organisational and societal measures, including regulated digital availability, reasonable workload management, communication boundary policies, manager training, and cultural recognition of psychological recovery as a professional necessity.

Conclusion

The analysis conducted in this article demonstrates that emotional burnout in the digital era can no longer be interpreted exclusively as an individual psychological reaction to excessive workload. Instead, burnout reflects a structural transformation of chronic stress under the conditions of digital hyperconnectivity, permanent availability, and increasing socio-economic pressure.

The central paradox identified in this research is that emotional burnout continues to intensify despite growing public awareness of mental health. This suggests that awareness alone is insufficient when the environment itself remains fundamentally stress-producing. Contemporary stress is gradually losing its episodic character and becoming a permanent background condition integrated into everyday professional and digital routines. Constant notifications, hybrid work formats, information overload, and the expectation of permanent availability create a state of continuous cognitive activation, thereby reducing the possibility of full psychological and physiological recovery.

A critical finding of the study is the widening gap between technological acceleration and human adaptive capacity. Digital systems increase the speed of communication, productivity expectations, and cognitive demands at a pace that exceeds the limits of sustainable human functioning. Consequently, burnout emerges not as an individual weakness, but as a systemic indicator of the inability of modern social and organisational structures to provide conditions for long-term psychological stability.

The study also shows that burnout leads to a qualitative deformation of professional activity. This is reflected in the phenomenon of presenteeism, when an employee remains formally present at work but experiences psychological disengagement, reduced concentration, and declining productivity. Thus, burnout affects not only individual well-being but also organisational effectiveness.

In conclusion, the prevention of emotional burnout requires a transition from purely individual coping strategies to integrated systemic measures. Sustainable well-being in the digital era is impossible without organisational digital hygiene, clear communication boundaries, reasonable workload regulation, and a reconsideration of the productivity culture that currently normalises chronic overwork. Without these structural changes, emotional burnout will remain one of the defining psychological challenges of the twenty-first century, signalling a critical imbalance between technological progress and human mental ecology.

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УДК 37.091.64:004.946

RESEARCH TRENDS IN AUGMENTED REALITY AND 3D TECHNOLOGIES INTEGRATION INTO PRINTED EDUCATIONAL TEXTBOOKS

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Abstract. The paper presents a bibliometric analysis of research trends in augmented reality and 3D technologies in educational textbooks. The dataset includes 186 Scopus-indexed publications from 1996–2025. Bibliometric analysis and BERTopic topic modelling are used to identify thematic structures and publication dynamics. Results show a marked increase in research activity after 2018, particularly in augmented and virtual reality, immersive learning and interactive materials. Two main themes emerge: AR in education and digital interactive textbooks, reflecting growing integration of multimedia technologies in educational publishing.

Keywords: augmented reality, 3D technologies, educational textbooks, digital learning, interactive textbooks, immersive learning.

ТЕНДЕНЦИИ ИССЛЕДОВАНИЙ В ОБЛАСТИ ДОПОЛНЕННОЙ РЕАЛЬНОСТИ И 3D-ТЕХНОЛОГИЙ В УЧЕБНЫХ ИЗДАНИЯХ

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Аннотация. В статье представлен библиометрический анализ тенденций исследований в области дополненной реальности и 3D-технологий в учебных пособиях. Набор данных включает 186 публикаций, индексируемых Scopus, за 1996-2025 годы. Библиометрический анализ и тематическое моделирование BERTopic используются для определения тематической структуры и динамики публикаций. Результаты показывают заметный рост исследовательской активности после 2018 года, особенно в области дополненной и виртуальной реальности, иммерсивного обучения и интерактивных материалов. Появляются две основные темы: дополненная реальность в образовании и цифровые интерактивные учебники, отражающие растущую интеграцию мультимедийных технологий в издательскую деятельность в сфере образования.

Ключевые слова: дополненная реальность, 3D-технологии, учебные печатные издания, цифровое обучение, интерактивный учебник.

The rapid development of digital technologies has significantly transformed contemporary educational environments. Traditional printed textbooks are increasingly supplemented with interactive and multimedia elements aimed at improving student engagement, visualization and learning efficiency [1]. Recent studies emphasize the importance of multimodal integration in educational materials, particularly the interaction between textual and visual forms of representation in scientific learning environments [1]. Contemporary educational research also increasingly examines the relationship between printed and digital learning formats, including differences in reading perception, engagement and information retention [2]. Despite the growing popularity of electronic textbooks, discussions continue regarding their pedagogical effectiveness and long-term educational value [3]. Modern educational textbooks are expected not only to provide information but also to support interactive learning, visual communication and the formation of a unified educational environment [4]. Among these technologies, augmented reality (AR) and three-dimensional (3D) visualization tools have become particularly important due to their ability to combine printed educational materials with digital interactive content.

Augmented reality technologies make it possible to overlay virtual objects, animations and additional information onto physical textbook pages through mobile devices or specialized applications. Such integration expands the educational potential of printed publications and supports immersive learning experiences. Research comparing traditional printed and electronic textbooks highlights the growing importance of combined printed-digital educational environments and interactive learning approaches [5]. In educational practice, AR technologies are widely applied in science education, language learning, engineering, medicine and technical training, where visualization and spatial representation are especially important.

Recent studies demonstrate that augmented reality technologies can significantly improve student engagement, spatial understanding and visualization of complex educational content [6]. AR-based educational materials are increasingly applied in geometry, physics, engineering and language learning, where interactive visualization supports deeper comprehension of abstract concepts [7–9]. Researchers also emphasize the growing role of augmented reality textbooks and active digital learning systems that combine printed educational materials with multimedia and mobile technologies [10–12].

At the same time, the growing number of publications devoted to AR and 3D educational technologies creates the need for a systematic overview of existing research directions. Bibliometric analysis makes it possible to identify dominant themes, publication dynamics and emerging trends within a scientific field. In recent years, bibliometric approaches have increasingly been combined with topic modelling methods that allow researchers to reveal hidden thematic structures within large publication datasets.

The present study focuses on research trends related to augmented reality and 3D technologies in educational textbooks. The aim of the paper is to identify the main thematic directions and publication dynamics in studies devoted to the integration of interactive and immersive technologies into educational learning materials.

The study applies a bibliometric analysis combined with topic modelling in order to investigate research trends in augmented reality and 3D technologies related to educational textbooks. The dataset was retrieved from the Scopus database using the search query "3D" AND textbook.

The selected dataset included 186 English-language publications published between 1996 and 2025. The analytical corpus consisted of publication titles, abstracts and author keywords. The collected data were processed using BERTopic topic modelling, which combines semantic embeddings and clustering algorithms to identify groups of thematically related publications.

The modelling procedure revealed several thematic clusters associated with education, digital textbooks, medical visualization and engineering applications. Since the present study focuses on educational textbooks and learning environments, peripheral medical and technical topics were excluded from detailed interpretation. The final analysis concentrated on the two most relevant thematic directions related to educational applications of augmented reality and digital textbooks.

The study also included an analysis of publication dynamics, topic distribution and keyword frequency patterns. The obtained results were visualized through topic distribution charts, topic evolution over time and keyword frequency diagrams.

The analysis demonstrates that research activity related to augmented reality and 3D technologies in educational textbooks remained limited for many years. Between 1996 and 2015, only isolated publications appeared within the dataset. However, publication activity began to increase gradually after 2016 and accelerated significantly after 2018.

The most intensive growth was observed between 2020 and 2025 (fig. 1). The dominant educational topic increased from 7 publications in 2020 to 17 publications in 2025, indicating rapidly growing academic interest in immersive educational technologies, augmented reality and interactive learning materials. This tendency reflects the broader digital transformation of education and the increasing integration of multimedia technologies into traditional printed learning environments.

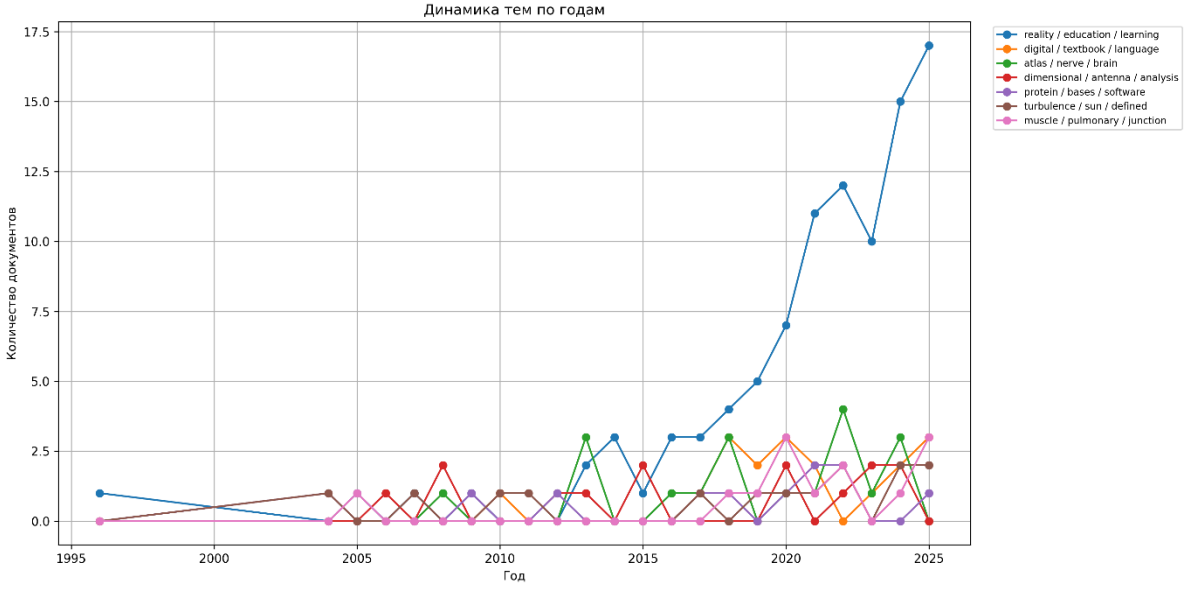


Figure 1. Publication dynamics of the main educational topics (1996–2025)

Figure 1 demonstrates a significant increase in publication activity after 2018, particularly within the topic related to augmented reality and educational technologies.

The growth of publications after 2020 may also be associated with the expansion of online and hybrid learning practices, which stimulated interest in interactive and digitally enhanced educational materials.

The topic distribution analysis revealed a strong dominance of the cluster labelled “reality / education / learning”, which included approximately 97 publications (fig. 2). This thematic group significantly exceeded all other identified clusters and represented the central research direction within the dataset.

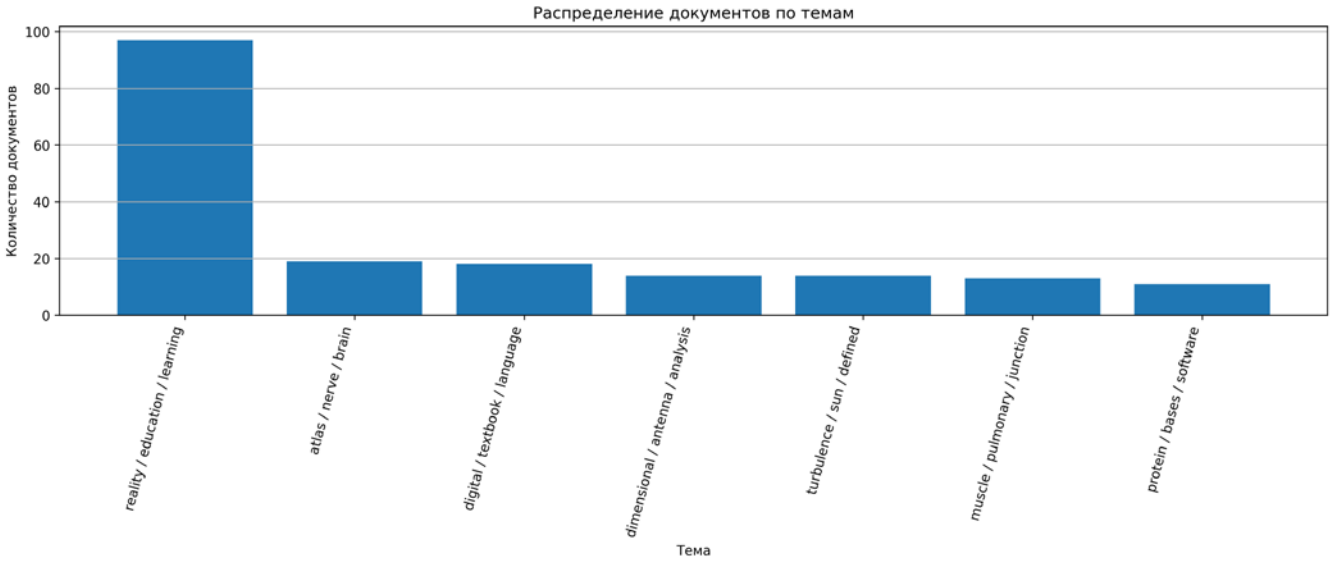


Figure 2. Distribution of publications across thematic clusters

A second relevant cluster, “digital / textbook / language”, included approximately 18 publications and focused on digital educational materials, interactive textbooks and language-learning technologies. Other automatically generated clusters were primarily associated with medical visualization, anatomy, biological modelling and engineering applications. Since these topics were not directly connected with educational textbook design, they were excluded from detailed interpretation. The main thematic directions identified through BERTopic modelling are presented in Table.

Table. Results of the thematic modelling

Topic	**Main keywords**	**Number of publications**	**Interpretation**
reality / education / learning	reality, education, learning, augmented, virtual	97	AR and immersive learning technologies
digital / textbook / language	textbook, digital, interactive, teaching, language	18	Digital and interactive textbooks

The first thematic direction focuses on augmented reality, immersive learning technologies and educational communication. The analysed publications demonstrate

that modern research increasingly views augmented reality not only as a visualization tool but also as an important component of digital pedagogy.

The second thematic direction focuses on digital textbooks, interactive educational interfaces and language-learning materials. The most frequent keywords in this cluster include textbook, digital, learning, language, interactive and teaching. The analysed publications demonstrate a transition from traditional printed textbooks toward hybrid educational materials that combine printed content with multimedia technologies, mobile applications and interactive learning tools. The most frequent keywords in this cluster include textbook, digital, learning, language, interactive and teaching. The analysed publications demonstrate a transition from traditional printed textbooks toward hybrid educational materials that combine printed content with multimedia technologies, mobile applications and interactive learning tools.

Several studies within this cluster address the development of active digital textbooks designed to support user interaction, adaptive learning and multimodal content presentation. Language-learning publications particularly emphasize phonetic visualization, communication tools and interactive educational interfaces.

Keyword frequency analysis additionally confirms the dominance of immersive-learning terminology within the dataset. Figure 3 demonstrates that the most frequent words include reality, education, learning, augmented, virtual, textbook and digital. Topic similarity and clustering visualizations reveal close relationships between augmented reality, digital textbooks and immersive learning environments, indicating that contemporary educational research increasingly integrates printed and digital formats into unified interactive learning systems.



Figure 3. Most frequent keywords in the analysed publication corpus

The conducted bibliometric analysis demonstrates that research devoted to augmented reality and 3D technologies in educational textbooks has developed into an actively growing interdisciplinary field. The most intensive publication growth was observed after 2018, particularly in studies related to augmented reality, immersive learning and interactive educational materials.

The analysis identified two dominant thematic directions: augmented and virtual reality technologies in education, and digital interactive textbooks. These directions reflect the broader transformation of educational publishing toward multimedia integration, visualization and hybrid printed-digital learning environments.

The results indicate that augmented reality technologies are increasingly considered an effective tool for improving educational communication, student

engagement and visualization of complex learning content. Modern printed textbooks are gradually evolving from static educational resources into interactive educational platforms connected with digital applications and multimedia systems.

The obtained findings may serve as a basis for further studies devoted to augmented educational publishing, interactive textbook design and the integration of immersive technologies into printed learning materials.

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УДК 37:001(536.2)

EDUCATION, MEDIA AND DIGITAL TRANSFORMATION IN UAE-RELATED STUDIES

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Abstract. The paper examines education, media and digital transformation in UAE-related studies based on 840 Scopus-indexed publications. The corpus includes English-language open access publications within arts and humanities, business and social sciences. The study applies a scoping review design and thematic modelling of titles, abstracts and keywords which identified 16 major topics structured around education, innovation, language learning, media communication, governance and sustainability. The findings provide a structured basis for further research on media design in the UAE educational and professional environment.

Keywords: UAE, media design, scoping review, thematic modelling, Scopus.

ОБРАЗОВАНИЕ, МЕДИА И ЦИФРОВАЯ ТРАНСФОРМАЦИЯ В ИССЛЕДОВАНИЯХ ОБ ОАЭ

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Аннотация. В статье на основе 840 публикаций, индексируемых в Scopus, рассматриваются вопросы образования, медиа и цифровой трансформации в ОАЭ. Включены англоязычные публикации открытого доступа в области гуманитарных, бизнес- и социальных наук. В работе используется обзор предметного поля и тематическое моделирование названий, аннотаций и ключевых слов, позволившее выявить 16 основных тем, связанных с образованием, инновациями, языковым обучением, медиакоммуникацией, управлением и устойчивым развитием. Полученные результаты создают структурированную основу для дальнейшего изучения медиа-дизайна в образовательной и профессиональной среде ОАЭ.

Ключевые слова: ОАЭ, медиа-дизайн, обзор предметного поля, тематическое моделирование, Scopus.

In recent decades, the UAE has strengthened its position as one of the leading centres of digital innovation in the GCC region. Government initiatives and investment in the technology sector have supported the expansion of digital infrastructure, educational platforms, media industries and creative digital services. Statista

characterizes the UAE digital market as a dynamically developing sector shaped by innovation, connectivity and the growing role of digital services [1]. The transformation of the media environment is closely connected with the high level of internet access and the active use of social media in the country. According to Statista, mobile internet penetration in the UAE is projected to reach 96 percent by 2025, while the average mobile internet speed is expected to exceed 86 Mbps [2]. The education system of the UAE is also actively adopting innovative digital formats. One of the most promising directions is the use of virtual and immersive learning environments. According to Statista Market Insights, the metaverse education market in the UAE is projected to reach US$17.28 million in 2026 and may increase to US$81.07 million by 2030, with a compound annual growth rate of 47.17 percent [3]. The development of the national digital environment is reflected in international indicators. According to Statista, the Digital Quality of Life Index for the UAE was 0.544 in 2025 [4]. This index characterizes the broader conditions for digital services, online communication, education and media ecosystems.

The study of education, media and digital transformation in the UAE is therefore relevant because the digital environment has become a key factor in the development of media ecosystems and the growth of creative industries. At the same time, the existing body of research on the UAE remains interdisciplinary and fragmented. A review is thus needed to identify the structure of the research field and determine the place of media design and digital communication within it. The aim of the study is to examine the thematic structure of UAE-related studies and to identify how education, media and digital transformation are represented in this research field.

To achieve this aim, the study sets the following objectives:

- to form a corpus of UAE-related publications indexed in Scopus;
- to analyse titles, abstracts and author keywords using topic modelling;
- to identify the major thematic areas represented in the corpus;
- to determine how the results can provide a structured basis for further research on media design in the UAE educational and professional environment.

The study was conducted as a scoping review combined with automated thematic modelling. The empirical basis consisted of 840 English-language open access publications indexed in Scopus. The search was limited to publications with “UAE” in the title and to the subject areas of arts and humanities, business, management and accounting, and social sciences. The data were then exported from Scopus and prepared for automated text analysis. Preliminary processing included screening, deduplication and preparation of textual data for topic modelling. Further processing was conducted in Google Colab using Python. Thematic modelling was performed with BERTopic, an algorithm that combines transformer-based text embeddings with clustering methods to group semantically related publications into thematic topics. The method was applied to identify recurring semantic patterns and reveal the internal structure of UAE-related studies.

The dynamics of publication activity show an uneven but generally increasing interest in UAE-related studies in arts and humanities, business and social sciences (Figure). From 2006 to 2015, the number of publications remained relatively low and in most years did not exceed ten papers. A gradual increase can be observed after 2016,

while the most intensive growth began after 2019. The number of publications rose from 45 in 2019 to 52 in 2020 and reached 71 papers in both 2021 and 2022. The highest values were recorded in 2023, 2024 and 2025, with 124, 142 and 176 publications respectively. The lower value for 2026, 65 publications, should be interpreted with caution, as the year was not complete at the time of data collection. Overall, Figure indicates the growing visibility of the UAE as a research object and reflects increasing academic interest in digital transformation, educational development, innovation, media communication and sustainability.

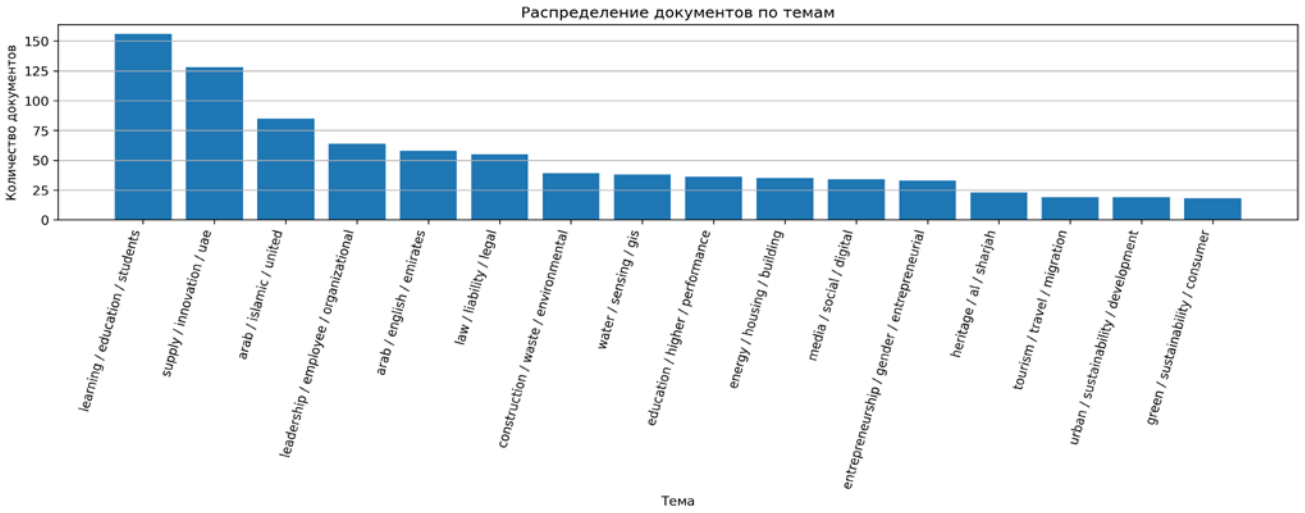
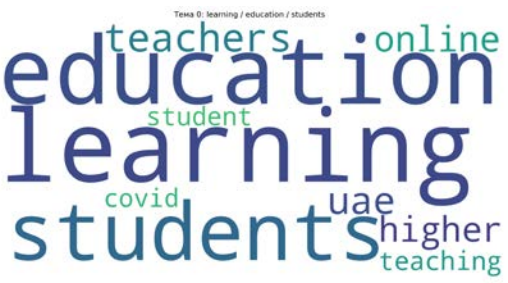
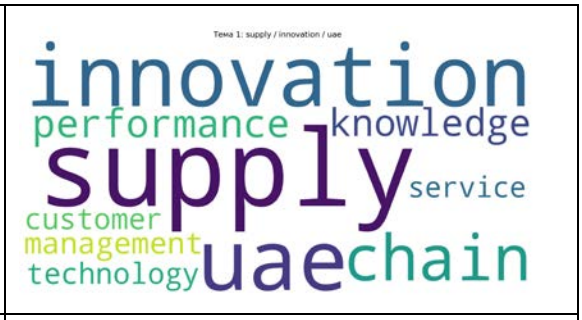
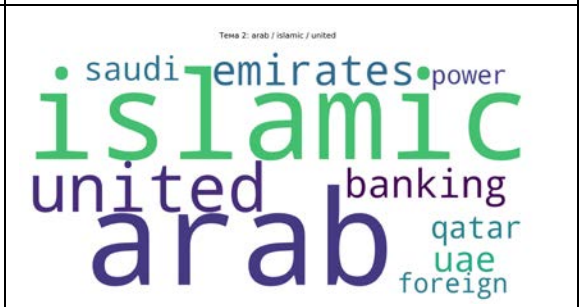
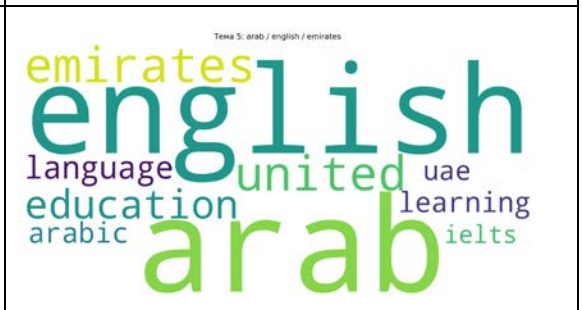


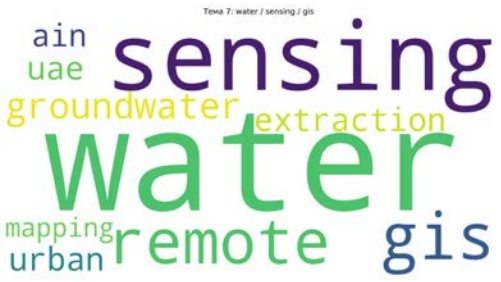
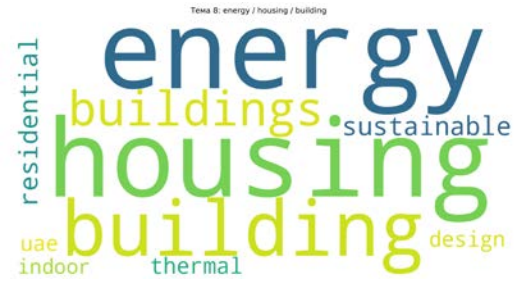
Figure. Dynamics of UAE-related publications in 2006-2026

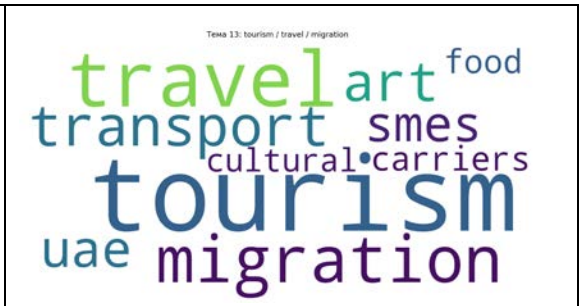
BERTopic modelling identified 16 major topics in the corpus (Table). Their distribution is uneven, which indicates the heterogeneous structure of UAE-related studies. The most represented areas are associated with education, learning, innovation, organizational development, language education and legal regulation. Media communication is also present in the corpus, although it appears as a more specialized direction. This distribution shows that the research field combines several thematic layers: educational, technological, managerial, communicative and socio-cultural.

Table. Results of the thematic modelling

Topic	Theme	Documents	Keywords
1	Learning, education and students	156	

2	Supply, innovation and UAE	128	
3	Arab, Islamic and United Emirates context	85	
4	Leadership, employee and organizational studies	64	
5	Arab, English and language education	58	
6	Law, liability and legal regulation	55	
7	Construction, waste and environmental management	39	

8	Water, remote sensing and GIS	38	
9	Higher education, performance and quality	36	
10	Energy, housing and building sustainability	35	
11	Media, social media and digital communication	34	
12	Entrepreneurship, gender and business development	33	
13	Heritage, Sharjah and archaeology	23	

14	Tourism, travel and migration	19	
15	Urban sustainability and development	19	
16	Green sustainability and consumer behaviour	18	

The results of BERTopic modelling show that the most relevant topics for further research on media design are connected with digital education, media communication, language learning and technology-based learning environments. These directions demonstrate how visual, digital and communicative practices are represented in UAE-related studies.

The largest topic, “Learning, education and students”, includes 156 publications and forms the educational core of the corpus. Among the most cited publications in this area are studies on metaverse adoption in UAE higher education [5], students’ intention to use mobile learning during the COVID-19 pandemic [6], the effectiveness of distance learning in higher education [7], e-learning interaction and student achievement [8], ChatGPT use among UAE university students [9], and educators’ digital competence [10]. These studies are relevant to media design because digital learning environments require visual interfaces, interactive content, user-friendly educational platforms and new forms of digital communication.

The topic “Media, social media and digital communication” includes 34 publications and is the most directly connected with the focus of the article. The most cited publications in this area examine journalism education in the digital age [11], high school students’ engagement with technology and media literacy [12], the spread of fake news through WhatsApp [13], and the representation of tolerance in UAE press media [14]. These studies show that media design in the UAE can be studied in relation

to digital content, social media communication, news production, visual storytelling and media literacy.

The topic “Arab, English and language education” also has relevance for media design, as it reflects the multilingual and multicultural character of the UAE educational environment. This is important for media design because digital content, educational interfaces and visual communication should be adapted to multilingual audiences.

The results show that media design is not yet represented as a separate large research topic in the analysed corpus. However, it is closely connected with several established areas: digital learning, social media, journalism education, language education, digital competence and AI-supported educational communication. Therefore, the next stage of the research should focus on a systematic review of publications related specifically to media design, digital media literacy, educational content design, visual communication and digital learning environments. It is important to note that the study is limited to open access publications indexed in Scopus, hence, the results do not provide a complete overview of all research on media design in the UAE.

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УДК 81'34

THE SOUNDING BODY AND THE SPEAKING VOICE: A HYPOTHESIS OF ISOMORPHISM BETWEEN PROSODY AND CHOREOGRAPHIC PHRASING IN CULTURES WITH DIFFERENT LINGUISTIC STRUCTURES

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Abstract. The article proposes and substantiates a hypothesis of structural isomorphism between the prosodic organization of language and the system of rhythmic-plastic organization of traditional dance. Drawing on embodied cognition theory and a multimodal approach, the author argues that speech prosodic patterns are embedded in the bodily experience of native speakers and reflected in choreographic phrasing. A comparative analysis is conducted on the material of Chinese, Russian, and English cultures.

Keywords: prosody, isomorphism, choreographic phrasing, language typology, embodied cognition, multimodal communication, entrainment, corporeality.

ЗВУЧАЩЕЕ ТЕЛО И ГОВОРЯЩИЙ ГОЛОС: ГИПОТЕЗА ИЗОМОРФИЗМА ПРОСОДИИ И ХОРЕОГРАФИЧЕСКОЙ ФРАЗИРОВКИ В КУЛЬТУРАХ С РАЗНОЙ ЯЗЫКОВОЙ СТРУКТУРОЙ

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Аннотация. В статье выдвигается и обосновывается гипотеза о структурном изоморфизме между просодической организацией языка и системой ритмико-пластической организации традиционного танца. Опираясь на положения теории воплощенного познания и мультимодального подхода, автор утверждает, что просодические паттерны речи закрепляются в телесном опыте носителей языка и отражаются в хореографической фразировке. На материале китайской, русской и английской культур проводится сопоставительный анализ.

Ключевые слова: просодия, изоморфизм, хореографическая фразировка, языковая типология, воплощенное познание, мультимодальная коммуникация, синхронизация, телесность.

For a long time, prosody remained something of a "stepchild" in linguistics – it was studied, but rarely placed at the center of theoretical constructs. Dance, in turn, was at best considered a striking but superficial metaphor for harmony. However, data accumulated in recent decades from neurolinguistics, cognitive psychology, and

anthropology compel a reconsideration of these views. A growing number of researchers agree that language does not exist in isolation from bodily experience, but is instead deeply rooted in it. As theorists of embodied cognition convincingly show, language arises from the interaction of body, brain, and environment, and prosody plays a key role in this interaction. The prosodic scaffold is today considered an evolutionary precursor of both language and music – ritualized group vocalizations combining affective and intonational aspects of prosody served as the common foundation from which two separate, though homologous, specializations later emerged.

In this paper, we advance a hypothesis that goes beyond these claims: there exists a deep structural isomorphism between the prosodic system of a language and the choreographic phrasing system of its speakers' traditional dance. This hypothesis has three important implications. First, it allows us to view traditional dance not simply as art, but as a bodily grammar – a system of nonverbal communication that reflects the basic rhythmic-intonational patterns characteristic of the thinking and speech of a given culture's members. Second, it opens the possibility of bridging the gap between linguistics and choreography – two fields of knowledge that have long developed in isolation from each other. Third, it has practical implications for foreign language teaching methodology and translation, enabling the use of bodily experience as a resource for acquiring non-native prosody.

Contemporary research on language evolution offers increasing evidence that language was not an exclusively vocal invention, but developed as an integrated multimodal system in which hand, head, body, and voice acted in inseparable unity. As S. Brown notes, vocal and gestural theories of language origin have long been opposed to each other, but it is far more reasonable to view vocalization and gesture as complementary communicative specializations [1, p. 1894].

A key mechanism linking speech and movement is entrainment – the natural human tendency to synchronize one's movements with the temporal regularities of external stimuli. As shown by Lidji and colleagues, listeners are able to entrain to rhythmic patterns of speech, and the nature of this entrainment depends on their native language: speakers of stress-timed languages demonstrate more regular entrainment than speakers of syllable-timed languages [2. p. 1040]. This ability to entrain underlies not only speech interaction – when interlocutors unconsciously adjust tempo, rhythm, and intonation to each other – but also dance coordination, when dancers synchronize movements, breathing, and rhythmic accents.

The most important empirical evidence supporting our hypothesis comes from the study by Türk and Calhoun [3, p. 15], which demonstrated on Turkish that gesture apexes synchronize with prosodic accents (71 % of cases) and with tonal markers of prosodic words (76 % of cases). These findings are of fundamental importance: they demonstrate that prosodic structure is not an exclusively acoustic phenomenon, but is rather expressed through multimodal signals as a composite signal. In other words, the "sounding body" and the "speaking voice" are not metaphors but fully real, empirically observable dimensions of human communication.

Russian belongs to the stress-timed language type with dynamic (stress) accent. Unlike, say, English, where prosodic structure is largely tied to grammatical function,

Russian stress exhibits considerably freer placement and plays an important distinctive role at the lexical level. The dynamic prominence of the stressed syllable makes Russian prosody more "percussive," with a clear contrast between stressed and unstressed syllables. Nevertheless, the Russian prosodic system also includes rich melodic contours, including rising tones for non-finality and falling tones for finality.

This prosodic system, it can be hypothesized, should produce a bodily habit of strong, accented, dynamically contrasted movements. Russian traditional dance – plyaska – is a vivid embodiment of this plastic aesthetic. Characteristic features of Russian folk dance include strong stamping rhythms (drobushki), sharp squats, active torso work, and spins that create a vivid dynamic pattern. The outstanding composer and folklorist M. P. Mussorgsky repeatedly emphasized that the rhythmic structure of folk dance and the rhythmic structure of Russian folk speech are deeply akin.

However, the most direct empirical confirmation of our hypothesis with respect to Russian comes from research on gesture-intonation clusters. In a study by Maria Esipova on polar responses in Russian, a gesture-intonation cluster used to express doubt about the validity of a prior speech act was identified [4, p. 5]. The crucial conclusion of this study is that gestures and intonational contours should be considered on par with each other. In other words, in Russian communicative culture, prosody and gesture form an inseparable unity, and consequently, dance as a hypertrophied, aestheticized form of gestural communication should inherit the same structural principles.

Significant data also come from studies of Russian gestural communication in the context of teaching Russian as a foreign language [5, p. 338]. In a study covering six years of observation of cross-cultural communication among students from different countries, it was found that formal situations are dominated by precise and controlled gestures, whereas informal settings reveal greater gestural variability, including expressive and emotional aspects. This differentiation of gestural behavior depending on the communicative situation has direct parallels in dance tradition, where, for example, the khorovod (a more restrained, ritual form) and the plyaska (a more expressive, improvisational form) demonstrate different degrees of gestural freedom.

Thus, in Russian culture, prosody, gesture, and dance are linked by a common principle: the accented, dynamically contrasted highlighting of significant elements in the acoustic stream finds its plastic counterpart in forceful, articulated accents in body movement.

Chinese represents a fundamentally different prosodic type. It is a tonal language: the same syllabic complex, uttered with different melodic contours, can denote completely different concepts. The prosodic structure of Chinese is organized not around stress but around the melodic contour of each syllable. In Mandarin, there are four tones (plus a neutral tone), each characterized by a specific tonal movement: high level tone (first tone) – a high, level contour; rising tone (second tone) – movement from mid to high; low dipping tone (third tone) – a fall followed by a rise; and high falling tone (fourth tone) – a sharp fall from high to low.

This prosodic system requires an extremely high degree of control over the melodic line throughout each syllable. Hypothetically, it should produce a bodily habit

of precise, differentiated, fine-motor movements – in other words, movements where the focus is not so much on amplitude and force as on the shape of the trajectory.

A direct empirical confirmation of this hypothesis is contained in Xueting Luo's research, which examined the influence of pronunciation characteristics and vocal pitch changes on the dancing body's movements [6, p. 231]. The results show that different pronunciation and acoustic changes in pitch elicit corresponding bodily reactions in dancers, suggesting an influence of acoustic features on the manner of movement and performance. The analysis of correspondences between sound, rhythm, vocal articulatory style, and the dancing body reveals an inner connection between language and bodily expression.

At the core of this investigation is the potential of Kunqu's embodied practice, which weaves together poetic voice and dance movement, to transcend mere aesthetic pursuits and become a conduit for spiritual experience, fostering self-awareness and a deeper connection with nature. Employing an interdisciplinary framework that combines theoretical insights with practical experience, this research examines the symbiotic relationship between voice and movement within Kunqu Opera.

Through critical analysis and eco-somatic practice, it addresses pivotal questions concerning the connection between poetry and Kunqu dance, the significance of poetic voice and the potential for a renewed practice that integrates poetic voice and Kunqu dance to facilitate a spiritual journey rooted in historical, philosophical and aesthetic foundations.

Moreover, researchers of Chinese music and dance have long noted a deep connection between the tonal system of the Chinese language and the pentatonic melodic structures of traditional Chinese music.

As noted in contemporary Chinese musicological literature, the pentatonic scale and the phonetic feature of tonal glide – "intonational coloring" – determine the aesthetics and character of Chinese musical thinking, which in turn is directly reflected in choreographic practice.

Thus, Chinese culture exhibits a different type of isomorphism than Russian: here, the dominant element is not dynamic stress but melodic contour, and this principle is traced both in the organization of speech and in the organization of dance movement.

English occupies a special place in our comparative framework. It is a stress-timed language in which the alternation of stressed and unstressed syllables creates a regular rhythmic pattern with roughly equal time intervals between stressed syllables. This rhythmic regularity makes English prosody particularly "musical" and, importantly, particularly convenient for studying the phenomenon of entrainment.

Studies by Lidji and colleagues have shown that native speakers of English demonstrate a tendency toward more regular entrainment of movements to rhythmic speech patterns than speakers of syllable-timed languages, and this ability is preserved in English-French bilinguals. This means that long-term experience with a stress-timed language shapes in humans a special rhythmic sensitivity – the ability not only to perceive but also to bodily reproduce regular rhythmic patterns.

In study by Liu examined whether three visual scaffolds – computerized visuals, beat gestures, and visual rhythm annotation – improve foreign language learners' comprehension of spontaneous conversational speech. Results suggest that prosody-

oriented scaffolds yield domain-specific gains under spontaneous input. This testifies to a deep integration of gestural and vocal channels in speech production. Pedagogically, listening instruction may be optimized by tailoring visual, embodied, and interactive supports to learner characteristics rather than applying a single scaffold uniformly [7, p. 21].

Applied to dance, these data mean that a culture using a stress-timed language with a regular rhythmic structure is more likely to develop dance forms in which rhythmic regularity and accentual hierarchy play a key role. The foxtrot, for example, as shown in the dissertation study by Andrews, exhibits a structure that can be analyzed using categories borrowed from linguistic prosody: dance steps are organized into prosodic units, and the sonority of movements follows a hierarchical principle analogous to sonority in language [8, p. 28].

Of particular interest is the fact that in English culture, the metaphor of dance has traditionally been used to describe prosody itself. In the poetic tradition, going back to the rhetorical practices of antiquity, verse rhythm is often likened to a dance step. Thus, in studies on Klopstock and Goethe, the idea of poetry as a kind of dance is traced. Klopstock conceived of poetry as dance, and his innovations in prosody consisted in intensifying the physical dimension of poetic speech. This tradition of understanding prosody through the bodily metaphor of dance is not a chance coincidence but a reflection of the deep isomorphism we are attempting to describe.

The data presented above allow us to assert that the hypothesis of structural isomorphism between prosody and choreographic phrasing has solid theoretical foundations and is supported by a number of empirical observations. However, its final confirmation requires a comprehensive methodological framework.

First, cross-cultural experimental studies are needed in which subjects – native speakers of different languages – are shown videos of traditional dances without sound accompaniment and asked to determine the emotional tone or "communicative intention" of the dancer. If our hypothesis is correct, native speakers of a given language should demonstrate higher accuracy in recognizing "their own" dances compared to "foreign" ones.

Second, physiological experiments using neuroimaging technologies are promising, in which neural activity during perception of speech in native and non-native languages and during perception of dance from the corresponding culture would be recorded. Our hypothesis predicts similar activation patterns in areas responsible for rhythm and movement perception (e.g., Broca's area and premotor cortex) when processing "own" prosodic and choreographic stimuli.

Third, ontogenetic studies are important: tracing how, as a child acquires their native language, not only speech but also dance preferences corresponding to the prosodic type of their culture develop.

Finally, the practical significance of our hypothesis for foreign language teaching methodology can hardly be overstated. If the isomorphism of prosody and choreographic phrasing receives final empirical confirmation, then traditional dance can be understood as a "bodily grammar" of culture – an additional channel for acquiring non-native prosody. For native Russian speakers learning Chinese, this would mean, for example, that mastering the tonal system could be facilitated through

plastic imitation of melodic contours with gestures – that is, through a kind of "dancing language". For learners of English, conversely, rhythmic exercises in which the accentual structure of an English phrase is practiced through claps, stamps, or other synchronized movements could prove useful.

The analysis conducted allows us to assert that the hypothesis of structural isomorphism between prosody and choreographic phrasing has solid theoretical foundations and is supported by a number of empirical observations from the fields of multimodal communication analysis, psycholinguistics, and dance studies.

At the theoretical level, the hypothesis rests on several independent lines of evidence. First, evolutionary and neurobiological studies indicate that vocal and gestural communication share a common origin and are deeply linked through entrainment mechanisms. Second, data on the synchronization of gesture apexes with prosodic events in speech demonstrate that prosodic structure is realized in a multimodal signal combining voice and body. Third, in each of the linguistic cultures examined – Russian, Chinese, English – systematic correlations are found between the prosodic organization of the language and characteristic features of dance movement: from the forceful accentuality of Russian plyaska through the melodic contouring of Chinese plasticity to the rhythmic regularity of English social dances.

At the practical level, the results open new perspectives for foreign language teaching methodology. If the isomorphism of prosody and choreographic phrasing receives final empirical confirmation, then traditional dance can be understood as a "bodily grammar" of culture – an additional, body-oriented channel for acquiring non-native prosody and the deep non-verbal logic governing communication. This means that foreign language teaching methodology could benefit from incorporating body-oriented practices in which prosodic patterns are acquired not only through auditory imitation but also through plastic embodiment.

Of course, the presented hypothesis is only a first approximation toward solving a complex interdisciplinary problem. Many questions remain open: about the dynamics of isomorphism formation during cultural evolution, about the role of cross-cultural contacts and borrowings in the transformation of prosodic-dance correspondences, about the possibility of a reverse influence of dance innovations on the prosodic habits of language speakers. Answers to these questions require further cross-cultural and neurobiological research. However, it is already clear that the intersection of linguistics and choreography, prosody and dance, opens a new field of knowledge in which the "sounding body" and the "speaking voice" cease to be poetic metaphors and become objects of rigorous scientific inquiry.

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УДК 72:7.05(669)

DESIGN RESEARCH IN NIGERIA: SUSTAINABILITY AND UNIVERSAL DESIGN

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Abstract. The paper examines design research in Nigeria based on 144 publications from Scopus. The study applies thematic modelling of abstracts to identify publication dynamics and major research areas. The results show that the field is structured around sustainable building design, energy-efficient architecture, health-oriented design, universal design and inclusive learning environments. The findings provide a basis for further research on accessibility and universal design in Nigeria.

Keywords: Nigeria, research, sustainability, accessibility, universal fesign, thematic modelling, scoping review.

ИССЛЕДОВАНИЕ ДИЗАЙНА В НИГЕРИИ: УСТОЙЧИВОСТЬ И УНИВЕРСАЛЬНЫЙ ДИЗАЙН

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Аннотация. В статье рассматриваются исследования в сфере дизайна в Нигерии на основе 144 публикаций из Scopus. Обзор основан на тематическом моделировании аннотаций для выявления основных исследовательских направлений. Результаты показывают, что поле структурируется вокруг устойчивого проектирования зданий, энергоэффективной архитектуры, дизайна в сфере здравоохранения, универсального дизайна и инклюзивной образовательной среды. Полученные результаты создают основу для дальнейшего изучения универсального дизайна в Нигерии.

Ключевые слова: Нигерия, исследования, устойчивость, доступность, универсальный дизайн, тематическое моделирование, обзор предметного поля.

Nigeria, as one of the fastest-growing economies in Africa, demonstrates dynamic development in the field of design. Nigeria is the most populous country in Africa, with a population exceeding 237 million people and a median age of approximately 19 years, it represents a demographically distinctive context for examining the social role of design [1]. More than 60 percent of the population is under the age of 25, which creates sustained demand for inclusive, accessible and environmentally responsive solutions.

The digital transformation of the country provides an important material basis for the expansion of design research and practice. As of early 2024, Nigeria had 103 million internet users, corresponding to an internet penetration rate of 45.5 percent, while the number of active mobile connections reached 205 million [2]. According to Statista projections, household internet penetration is expected to reach 64.07 percent by 2029 [3]. The growth of connectivity changes the conditions in which design is produced, distributed and consumed.

The World Bank projects economic growth at 3.7 percent in 2024 and 4.1 percent in 2025, linking these dynamics to reforms in fiscal, monetary and trade policy and to the expansion of service industries [4].

In this context, information and communication technologies are becoming one of the drivers of structural transformation which increases the importance of design competencies. Nigeria's engagement with design as a strategically significant area is also reflected in initiatives aimed at developing digital talent. The World Economic Forum notes that Nigeria launched the Three Million Technical Talent programme, described as the largest talent accelerator in the world, with the aim of training three million technical specialists by 2027 [5]. Among the twelve priority skill areas identified by the programme are user interface and user experience design and data visualisation [5].

The study of design research in Nigeria is therefore timely and necessary. The intersection of demographic scale, service-sector development and investment in digital skills creates conditions in which universal design acquires both theoretical and practical significance. A review is thus needed to identify dominant research directions and key authors as a starting point for research into Nigerian design.

The aim of the study is to examine the thematic structure of design research in Nigeria. To achieve this aim, the study sets the following objectives:

- to form a corpus of Scopus-indexed publications related to design and Nigeria;
- to analyse abstracts using thematic modelling;
- to identify the main research topics in the corpus;
- to determine the place of universal design and main publications for further study.

The review was conducted as a scoping review combined with thematic modelling. The empirical basis consisted of 144 English-language publications indexed in Scopus. The dataset was retrieved using the search query "NIGERIA AND DESIGN" in titles and keywords. The analysis was based on abstracts. The data were processed in Google Colab using Python. Thematic modelling was performed with BERTopic, which groups semantically related publications into topics on the basis of text embeddings and clustering methods. Topic names were formulated on the basis of high-frequency terms and the thematic content of publications within each group.

The thematic modelling of 144 Scopus-indexed publications identified four major directions in Nigerian design research: sustainable building design, healthcare-oriented design, universal design and inclusive learning environments, and renewable energy solutions.

Publication dynamics show that the field developed unevenly during the analysed period (Figure 1). Note that the number of publications recorded for 2026 is incomplete, since recently published articles require time to be indexed in Scopus. The number of publications in the field was relatively low and sporadic until 2016. Since 2017, there has been a clear and steady growth in research activity, reaching its peak in 2022-2024. The most dominant theme throughout the period is related to design, energy, and building performance (orange line), which consistently leads in the number of publications. Studies on health and care-oriented design (blue line) also show significant growth, especially after 2020. Research on universal design and inclusive learning environments (green line) demonstrates stable interest with a noticeable increase in recent years. Publications focused on solar and renewable energy in building design (red line) appear more periodically.

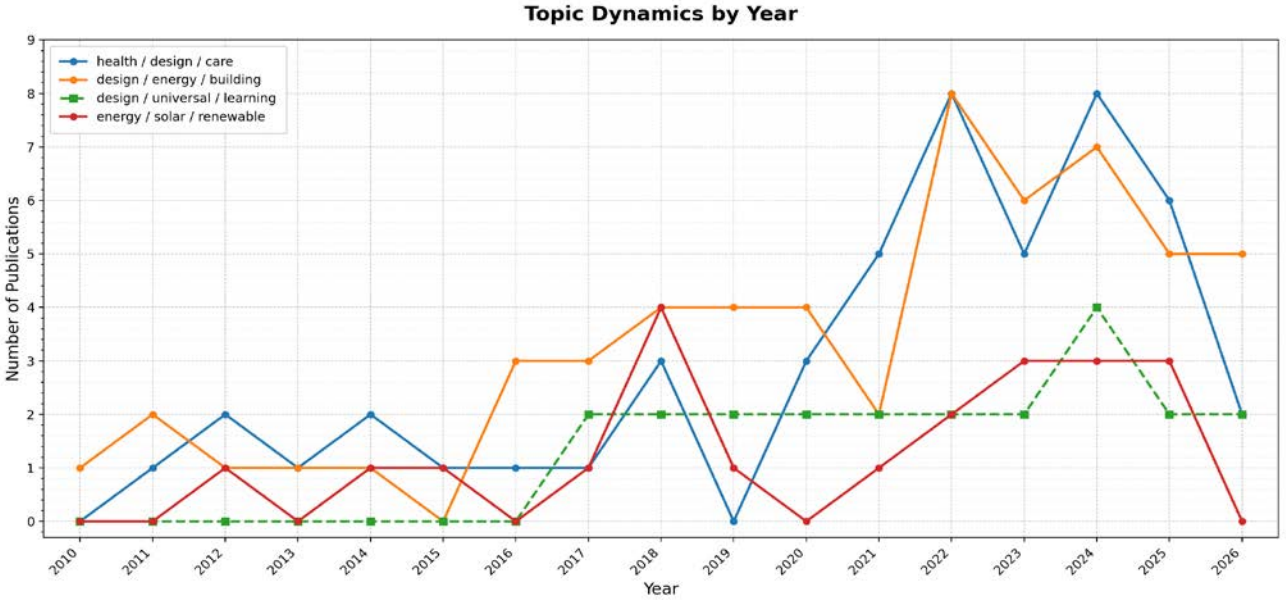


Figure 1. Dynamics of the main research topics by year (2010–2026)

The distribution of publications across the four topics is presented in Figure 2. The largest topic includes 56 publications and focuses on design, energy and building performance. It is followed by healthcare-oriented design, with 46 publications. universal design and inclusive learning environments form the third topic, with 24 publications, while solar and renewable energy solutions in building design account for 18 publications.

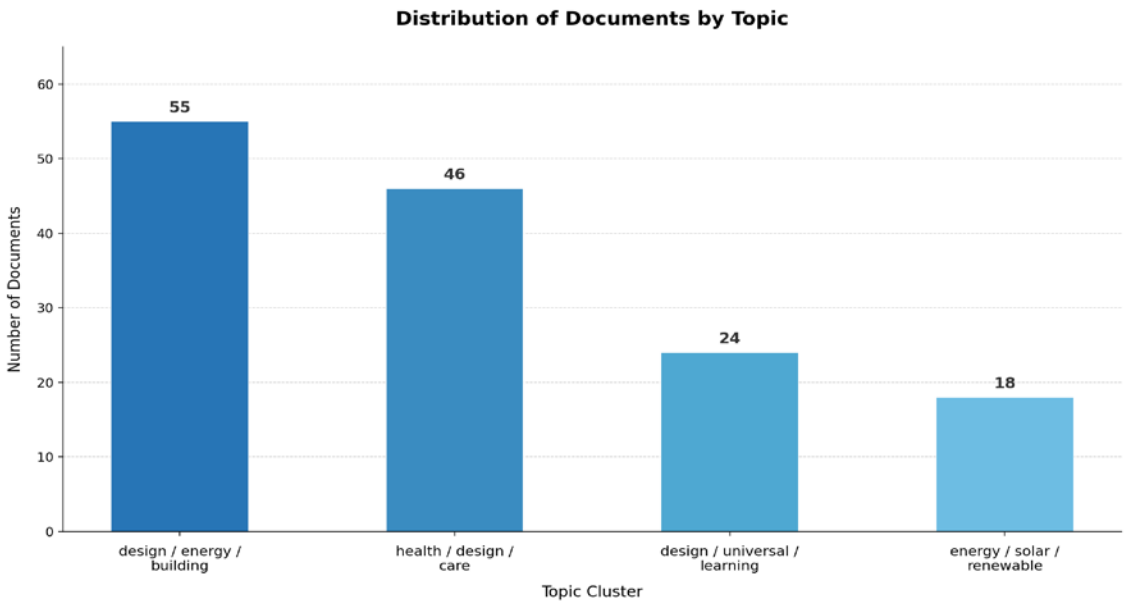
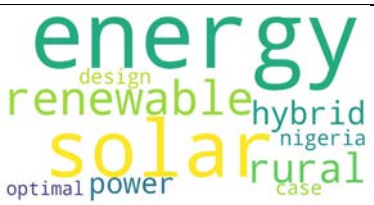


Figure 2. Distribution of publications across thematic topics

The thematic structure of the corpus is summarized in Table. The results indicate that sustainability and energy efficiency form the core of design research in Nigeria. At the same time, universal design appears as a smaller but socially significant direction, since it is connected with accessibility, inclusive educational spaces and the adaptation of buildings to different user needs.

Table. Results of the thematic modelling

Topic	Theme	Documents	Keywords	Most cited authors
1	Design, energy and building performance	56		Nwalusi et al. [6], Aduwo et al. [7], Bashir and Leite [8]
2	Healthcare-oriented design	46		Okonofua et al. [9], Rana et al. [10], Wright et al. [11]
3	Universal Design and inclusive learning environments	24		Ugah et al. [12], Adewale et al. [13], Sholanke et al. [14]

4	Solar and renewable energy in building design	18		Ohijeagbon et al. [15], Udoakah et al. [16], Okubanjo et al. [17]

Theme 1 focuses on design, energy and building performance. Nwalusi et al. examined climate-responsive design strategies for contemporary low-rise residential buildings in Enugu, Nigeria [6]. Aduwo et al. assessed workers' productivity through biophilic design in selected office buildings in Lagos State [7]. Bashir and Leite analysed the performance of aerogel as a thermal insulation material for sustainable residential buildings in tropical climates [8]. These studies show that this topic is mainly connected with sustainable architecture, energy efficiency, thermal comfort and building performance.

Theme 2 is associated with healthcare-oriented design. Okonofua et al. analysed interventions aimed at improving the quality of intrapartum care in Nigerian referral hospitals [9]. Rana et al. described the design of data visualization tools for nutrition monitoring in Nigeria [10]. Wright et al. examined the use of theories of change and responsive feedback in the design of a digital service business for patent and proprietary medicine vendors in Nigeria [11]. These publications demonstrate that design is applied not only to buildings, but also to healthcare services, communication tools and user-oriented systems.

Theme 3 focuses on universal design and inclusive learning environments. Ugah et al. evaluated universal design compliance in faculty of environmental science buildings in federal universities in South-west Nigeria [12]. Adewale et al. studied the effectiveness of the perceptible principle of universal design in shopping malls in Southwest Nigeria [13]. Sholanke et al. examined the compliance of vertical accessibility components in high-rise buildings with universal design strategies at Covenant University [14]. This topic is particularly important because it connects design research with accessibility, inclusive educational spaces and the needs of different user groups.

Theme 4 addresses solar and renewable energy in building design. Ohijeagbon et al. proposed an optimal hybrid renewable energy system for sustainable power supply to isolated-grid communities in North Central Nigeria [15]. Udoakah et al. presented the design of a photovoltaic system for an electrical laboratory at the University of Uyo [16]. Okubanjo et al. examined the optimal design of an off-grid hybrid renewable system with battery storage for the rural electrification of an academic community in Nigeria [17]. These studies confirm the role of renewable energy solutions in sustainable building design and infrastructure development.

Overall, the results show that the field is primarily shaped by sustainability, energy efficiency, healthcare needs and accessibility. The largest topic is connected with climate-responsive architecture, thermal comfort and building performance, which confirms the importance of environmental conditions for Nigerian design

research. Healthcare-oriented design demonstrates the social role of design in improving access to services, communication and user-oriented solutions.

Universal design is not the largest topic in the corpus, but it is the most relevant direction for further focused research. It is connected with accessibility, inclusive educational spaces, public infrastructure and the adaptation of buildings to different user needs. A future systematic review should therefore focus on Universal Design and accessibility in Nigerian educational and public infrastructure, with attention to barriers, design strategies, sustainability and user experience. The study is limited to Scopus publications, future research might consider national databases.

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УДК 008

LEGENDS AND MYTHS AS PART OF CULTURE

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Abstract. Modern man lives in a world where science reigns supreme. It would seem that after the discovery of DNA and flight into space, the place for myths should have disappeared. But this did not happen. In fact, we ourselves participate every day in creating new legends, and myths have penetrated deeply into cultural code. In this article explores the origin of myths and legends, why they do not disappear for millennia, and what important role mythology plays in the life of each individual and society overall.

Keywords: myths, legends, culture, mythology, philosophy.

ЛЕГЕНДЫ И МИФЫ КАК ЧАСТЬ КУЛЬТУРЫ

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Аннотация. Современный человек живет в мире, где царит наука. Казалось бы, после открытия ДНК и полетов в космос место для мифов должно было исчезнуть. Но этого не произошло. Более того, мы сами каждый день участвуем в создании новых легенд, а мифы глубоко проникли в культурный код. В данной статье изучается вопрос зарождения мифов и легенд, почему они не исчезают тысячелетиями и какую важнейшую роль они играют в жизни каждого человека и общества в целом.

Ключевые слова: мифы, легенды, культура, мифология, философия.

One of the key concepts in philosophy can be found in the works of the Neo-Kantian Ernst Cassirer. He believed that myth is not an illusion; myth is a part of a system of expressive forms that is closely linked with other forms. Myth occupies a special position among the symbolic forms of spiritual culture. Art and knowledge, morality and law, language and technology are closely bound up with the mythical; it is from this source that the fundamental epistemological concepts – such as space, time, number, and so forth – likewise emerge [1, p. 84].

According to E. Cassirer, myth is a symbol, and the symbol, in turn, is essential for the very existence of myth. The philosopher points out that mythological symbols are concepts created by humans themselves [2, p. 11].

Myths – narratives generated by folk or religious imagination, which provide a humanized, artistic-figurative explanation of various natural phenomena or offer an interpretation and justification of cultural phenomena and religious rites [3, p. 220].

A legend, meanwhile, is genre of folklore non-fairy-tale prose that conceptualizes miraculous events associated with the phenomena of animate and inanimate nature, the human world, and supernatural beings [4, p. 138].

The point is that myth is not merely a lie or a misconception. It is a specific form of thinking, a language in which a culture explains itself. Myth answers the questions to which science provides no emotional response: “How should I live?”, “What should I fear?”, “Why does suffering make sense?”.

The origin of myths is neither an accident nor a sign of foolishness among ancient people. It was an urgent necessity for survival. Imagine a primitive human standing at the edge of a forest. He hears a rustle, sees lightning, or finds the dead body of a fellow tribesman. The brain attempts to analyze what it sees but cannot explain the occurrences logically. At this precise moment, mythology is born.

The first reason for the emergence of myths is the struggle against chaos. The human brain cannot tolerate uncertainty. If the cause of a drought is unknown, the world becomes terrifying and unfamiliar. However, as soon as the drought is given a name (“the god Perun has grown angry”), a plan of action appears: if the god is angry, one must offer gifts. Myth makes the world predictable. This constitutes the first global function of myth – the ordering of the cosmos.

The second reason stems from the previous one: explaining the origin of the surrounding world. While knowledge remains insufficient to interpret the occurrence of rain or the changing of the seasons, the simplest method is to invent an explanation in order to satisfy human curiosity.

Legends, however, are born differently. They appeared in human culture after myths, serving as a uniquely transformed narrative. Unlike cosmic myths regarding the creation of the Sun, a legend is always tied to a real place, person, or event. There was a real fire in the city, a real battle, a real ruler. Decades pass, and the eyewitnesses die out. Oral transmission begins to accumulate fiction, and certain details become hyperbolized. The hero turns into a giant, the enemy into a demon, and an ordinary sword into a legendary blade.

For instance, the historical King Arthur most likely existed as a leader of the Britons. Yet, the narrative transformed him into the emperor of the entire island and the owner of the magical sword Excalibur. This is how a legend is born – out of the dust of real history, kicked up by the wind of folk imagination.

Real people are involved in these stories, that is why emotions frequently influence the transformation of the narrative. Even in everyday life, people tend to change the details of a story: certain moments may be erased while others are exaggerated, which allows us to witness the birth of legends – for instance, about public figures – even in modern times. Everyone has encountered a piece of news about a celebrity that ultimately turned out to be far from the truth. Moreover, the desire to spread a false story can be driven by one's feelings toward that specific individual.

But why do such narratives remain, even when people understand that they are fictional?

In the first place, the human brain is poor at retaining dry facts but highly effective at remembering stories. A legend acts as an “installer” of cultural memory. Memorizing the founding date of Rome is difficult. However, remembering the story of the brothers Romulus and Remus, suckled by a she-wolf, is easy. A legend encodes vital information into an engaging format that is transmitted orally across multiple centuries. While science explains how the world works, myth and legend provide humans with an answer to why they should wake up in this world. As long as the narrative lives, the culture survives as well.

Secondly, myths serve as a means of liberating individuals from the finitude of existence. They help people cope with the realities of life, including the inevitability of death, by acting as a form of psychological defense. Consider the myth that **“**after death, the soul passes into the realm of the ancestors**”** or that **“**heroes live on in eternal glory**”**. Legends of ghosts, house spirits, and guardian angels represent humanity's attempt to bridge the abyss of non-existence. People would rather believe in a terrifying but living otherworldly creature than in emptiness and silence.

An important aspect is the maintenance of social order. Any laws and moral norms are fragile; therefore, the myth that **“**evil deeds will be punished in the afterlife**”** or the urban legend that **“**a suicide drowned in this river and now drags swimmers down**”** serves as a highly powerful social regulator. Myths and legends govern behavior more effectively than the criminal code because they rely on shame and fear rather than logic.

While in ancient times myth substituted for science, today it fulfills different yet equally vital tasks. High-tech society suffers from **“**mechanization**”**. Myths restore magic and meaning to the world. Every country and every nation possesses it’s own folklore. Each story is unique, allowing individuals to feel a sense of belonging to something grand and mysterious – as though they belong to a secret society where esoteric legends have been revealed to them. Ultimately, legends shape national pride and unity.

Despite the fact that the topic of discussion centers on fictional stories, we must not forget the kind of world we live in today. Nowadays, a legend is a commodity. Not many people would know about an obscure lake in Scotland, and even fewer would remember it after a couple of months; however, if you mention that the Loch Ness Monster lives there, tourists will line up. **“**Cursed places**”**, **“**witches' cemeteries**”** and **“**dancing forests**”** – modern legends broaden the horizons of young people in this unconventional way. While a young person reads about a cursed castle, they simultaneously learn about the dynasty that lived there, and who built it and why. Without a myth, a place is just coordinates on a map. With a myth, it becomes a “spot of power”.

Let us be honest: a life built solely on numbers and dry facts would be melancholic. This is precisely why art exists in the world, a domain to which folklore undoubtedly belongs. After all, folklore also serves as a source of inspiration for artists, producers, and writers. Legends and myths are reworked to create something beautiful, perhaps even grand. Therefore, society requires mystery. By listening to stories about the ghost in the Mikhailovsky Castle or reading about the enigmatic sphinxes near the Academy of Arts, individuals escape from reality into a world where statues come alive

and curses exist. Myths and legends also reflect the political, social, and cultural life of a city. They act as an invisible yet vital dimension of reality, providing a prism through which one can understand a city more deeply. Consequently, a tourist can decipher the cultural code of their destination. These seemingly childish tales reveal the populace's attitudes toward emperors – disclosing whom they respected and whom they ridiculed – as well as which historical events had the most profound impact on the transformation of the population. Such diversity speaks volumes, as the myths of every nation possess a distinctive aura. Therefore, studying a country through this lens should not be underestimated.

Naum Sindalovsky, a prominent researcher of St. Petersburg folklore, discusses the multifaceted nature and value of urban legends in an interview with a **"**Rosbalt**"** correspondent: "Saint Petersburg is a city that writes; one only needs to read and extract". He argues that folklore represents the highest form of spiritual culture, differing cardinally from gossip in that it possesses a sense of completeness and a structure as in a literary work [5].

Mary Midgley highlights, particularly in **"**Science as an Inadequate Mythology**"**, that myth is a universal way of overcoming everyday limitations, which is available to all people, and not just primitive cultures. We can not see myths in our daily life, because they are woven into our daily lives: **"**Our myths are hard to see because they are constitutive of our thinking: they give the foundation, the tools, the (subconscious) concepts by which we think**"** [6, p. 34].

According to F. Nietzsche, every culture loses its healthy creative nature without myth - only myth makes culture complete [7, p. 174].

Now then, we have figured out that myths and legends are not a "relic of the past", but a foundational part of culture in any era. They arise from the desire to explain the unknown, persist due to their psychological utility, and are essential for us to feel like part of something grand and meaningful. If we remove myths from culture, we will be left with a society of robots who know physics but do not know why they should wake up in the morning. We will be left with nothing but dry dates and soulless instructions.

However, as long as there are stories transmitted around campfires, passed down by word of mouth, or shared in internet comment sections, culture remains alive. Myths and legends must be perceived not as an ideal reality in another dimension, but as a part of everyday life that actively influences it. For instance, in his work **"**The Dialectics of Myth**"**, philosopher Alexey Losev rejects the attitude toward myths as something inferior or childish:" Mythology provides that initial material for science upon which the latter will subsequently perform its abstractions**"** [7].

Myth is not a fiction, but the most real of all realities, governing our actions, hopes, and fears. Whoever controls a people's legends ultimately controls the people themselves.

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УДК 659.1:316.77

NARRATIVE REVIEW OF CULTURAL CODES IN CROSS-CULTURAL ADVERTISING COMMUNICATION

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Abstract. International advertising relies on symbols whose meanings vary across cultural contexts. The article examines how linguistic, visual and national symbols shape consumer perception and influence the interpretation of advertising messages. The review shows that effective international brand communication requires not only translation, but also semiotic and cultural adaptation of images, slogans, values and communication strategies. The findings may be useful for specialists in brand management.

Keywords: cross-cultural communication, advertising, semiotics, symbols, localization, brand management.

ОПИСАТЕЛЬНЫЙ ОБЗОР КУЛЬТУРНЫХ КОДОВ В МЕЖКУЛЬТУРНОЙ РЕКЛАМНОЙ КОММУНИКАЦИИ

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Аннотация. Международная реклама опирается на символы, значение которых меняется в разных культурных контекстах. В статье рассматривается, как языковые, визуальные и национальные символы формируют восприятие потребителей и влияют на интерпретацию рекламных сообщений. Показано, что эффективная международная бренд-коммуникация требует не только перевода, но и семиотической и культурной адаптации образов, слоганов, ценностей и коммуникативных стратегий. Результаты исследования могут быть полезны специалистам в области бренд-менеджмента.

Ключевые слова: межкультурная коммуникация, реклама, семиотика, культурные символы, локализация, бренд-менеджмент.

The global advertising industry has become one of the most dynamic areas of contemporary communication. According to DataReportal, worldwide advertising expenditure reached almost USD 1.1 trillion in 2024, increasing by USD 75 billion compared with 2023 [1]. Digital formats account for a major part of this growth and have substantially changed the ways in which brands address audiences across

countries, languages and media platforms.

The international relevance of this field is also associated with the expansion of creative services. According to UNCTAD, global exports of creative services reached USD 1.4 trillion in 2022, while exports of creative goods amounted to USD 713 billion [2]. Advertising, branding, design, digital media and communication services form part of this broader creative economy. As these services move across borders, promotional messages increasingly require interpretation in relation to specific cultural contexts.

A colour, image, gesture, slogan or brand symbol may produce a positive response in one society and an ambiguous or negative reaction in another. The same campaign can therefore be effective in one market and unsuccessful in another if it does not correspond to local symbolic systems. This issue is particularly significant in digital media, where verbal and pictorial signs circulate rapidly through social networks, online platforms and algorithmic recommendation systems.

The aim of the article is to identify and describe studies on cultural codes and symbols in cross-cultural advertising communication. To achieve this aim, the article reviews publications selected from Scopus, summarizes the main research approaches represented in this field and describes how linguistic, visual and national symbols are examined in relation to advertising perception and international brand communication.

The study is based on a narrative review of Scopus-indexed publications. The search query was formulated as follows: (“cross-cultural advertising” OR “intercultural advertising” OR “international advertising”) AND (“cultural code” OR semiotic OR symbol*). The search resulted in 22 publications available in open and restricted access. Five open access papers were analysed in full text, while the remaining publications were examined on the basis of their abstracts and bibliographic data. A narrative review was selected because the purpose of the article is to identify and describe key theoretical and thematic lines in the study of symbolic meaning in advertising communication.

The reviewed publications demonstrate that advertising should not be analysed only as a commercial message. It functions as a system of culturally specific signs that shape consumer perception, brand evaluation and audience response.

Alcántara-Pilar, Sánchez-Duarte, Rodríguez-López and Abarkane Abdel-Lah examine the symbolic function of foreign languages in multilingual advertising. Their 2025 experiment involved 405 respondents who evaluated the same fictitious message translated into seven foreign languages. The findings indicate that each language evoked different associations and that these associations could be transferred to the advertised product [3]. This work is significant because it treats language not only as a verbal code, but also as a symbolic marker of prestige, authenticity, attractiveness and country-of-origin meanings.

A related publication by Alcántara-Pilar, Sánchez-Duarte, Bermúdez-Martínez and Rodríguez-López considers the effect of foreign languages on company image and word-of-mouth. The authors used a between-subjects experimental design with five languages: Italian, Turkish, Russian, English and French. Native Spanish-speaking participants listened to an audio-only commercial and evaluated the company. Language recognition significantly influenced both company image and willingness to recommend the brand [4]. The results suggest that the symbolic value of language can

affect consumer attitudes even when the verbal content is not fully understood.

Guidère analyses advertising translation as a specific form of intercultural transfer. The article argues that international advertising has turned translation into a key element of global business communication. The author emphasizes that promotional translation differs from ordinary linguistic transfer because it requires attention to communicative effect, semiotic structure and cultural context [5]. This position supports the claim that global campaigns require adaptation of meaning rather than literal translation.

Corrius and Espasa develop this problem through the concept of transcreation. Their article examines the English subtitling of Estrella Damm's campaigns, especially the materials associated with Barcelona and Mediterranean culture. The authors demonstrate that transcreation involves creativity, semiotic adaptation and cultural recontextualization [6]. Their conclusions are relevant because they show that promotional translation often requires the recreation of emotional and cultural meaning in another language.

Petitimbert applies Greimasian semiotics to transcultural advertising texts and contexts. The article analyses creative projects prepared for an international television campaign for a major food brand in France, Germany and the United Kingdom. The author uses a semiotic grid developed through the examination of completed advertisements from neighbouring food categories. The proposed model helps evaluate how different creative concepts function across cultures [7]. This source is particularly relevant because it treats campaigns as structured systems of meanings, values and rhetorical patterns.

Singh also presents semiotic analysis as a practical instrument for cross-cultural strategy. The author argues that culture influences the clarity of communication and that communicative "noise" increases when messages cross cultural borders. Singh criticizes the assumption that standardized campaigns can be equally effective across markets and shows that consumers may reject products or messages that conflict with their cultural beliefs [8]. This conclusion confirms that semiotic analysis can help brands identify culturally specific meanings before entering foreign markets.

Phillips and McQuarrie examine visual rhetoric in international advertising. Their chapter discusses whether pictures can function across national markets more easily than words. The authors note that images may appear universal, but their interpretation still depends on product knowledge, advertising literacy and cultural background [9]. Their argument suggests that pictorial ambiguity can be useful in global campaigns only when it is strategically controlled.

Lick studies multimodality in Canadian print advertising and compares English and French consumer magazines. The research focuses on functional connections between headlines and images. French-language advertisements used analogy and hyperbole more frequently than English-language ones, and the author concludes that they tended to stimulate a higher level of cognitive elaboration [10]. This finding demonstrates that verbal and pictorial elements may interact differently even within one country.

An analyses localization strategies in web advertising by comparing Korean and U. S. local websites of 33 multinational brands. The content analysis reveals cross-

cultural differences in creative strategies, information cues and the representation of individuals or groups [11]. The study confirms that glocalization is visible in practical web communication: multinational brands adapt not only language, but also information structure and representational patterns.

Michaelidou, Micevski and Halkias examine consumer culture positioning strategies across countries and product categories. Their research analyses how advertisers use global, local and foreign positioning in print advertisements from Austria, Hungary and Turkey. The authors focus on country-of-origin cues as symbolic resources [12]. The findings demonstrate that global, local and foreign cultural references are strategic instruments in international advertising.

Akaka and Alden review global consumer culture positioning and perceived brand globalness. They define global consumer culture as a system of shared signs understood by consumers in urban markets across countries. Their analysis suggests that international advertising contributes to the construction of transnational consumer culture by circulating brands, lifestyles and symbolic meanings [13]. This perspective is useful for understanding how global brands create a sense of modernity, cosmopolitanism and belonging to a wider consumer community.

Lwin, Stanaland and Williams examine the use of American and local symbols in international advertising under conditions of consumer ethnocentrism and U. S.-focused animosity. Their article focuses on the relationship between national symbolism, consumer attitudes and political-cultural perception [14]. The study is relevant because it shows that national signs are not neutral. They can strengthen brand identity, but may also provoke resistance when associated with political tension or negative country-of-origin attitudes.

Mundel, Nieves-Pizarro, Wickham and Aiello study patriotic appeals and national symbols in Argentine and English newspaper advertisements during the Malvinas/Falkland Islands War. Their corpus includes 3,707 advertisements from La Nación and The Times published between April and December 1982. The authors analyse appeals, products, cultural values and code-switching. The findings indicate that the war produced only marginal changes in advertising, while national symbols remained relatively scarce [15]. This suggests that even during political conflict, market logic and media conventions may limit the direct use of patriotic imagery.

Waitt critically examines representations of Indigenous Australians in international tourism advertising by the Australian Tourist Commission. The author analyses verbal and pictorial texts using semiotic techniques. The study shows that Indigenous peoples were represented through images of ecotourism, escape to a “primeval” world and adventure on an untamed frontier. Waitt concludes that these representations helped differentiate Australia as a tourist destination, but also reproduced colonial myths [16]. This article demonstrates how advertising may construct cultural identity through simplified or stereotyped imagery.

Kutlu and Gündüz analyse female nudity in print advertising from a cross-cultural perspective. The authors note that visual elements are often treated as easier to standardize than verbal text because they do not require translation. However, their analysis shows that body images and erotic stimuli operate as culturally marked signs [17]. The study is relevant because it confirms that pictorial content cannot be assumed

to have universal meaning. Body representation, gender roles and sexuality require cultural sensitivity.

Sauvage and Karsaklian compare advertising campaigns for French Champagne in foreign markets. One campaign is designed for China, while another targets global markets excluding China and France. The authors show that legal restrictions and cultural expectations influence how Champagne is represented. Their analysis reveals different cultural imagery in the two campaigns and confirms that luxury, tradition and celebration may be encoded differently depending on the target audience [18].

Kasianova and Kovács examine the advertising strategies of Volkswagen and Fiat on social media, focusing on German and Italian audiences. The article analyses linguistic solutions, cultural values and online engagement. The authors show that successful communication with potential customers requires adaptation to the values and communication styles of the target audience [19]. This publication connects cross-cultural advertising with social media communication and demonstrates how linguistic choices are used to engage culturally specific audiences.

Yuan analyses the influence of core nodes of visual communication symbols in cross-cultural advertising network communication. The article is more technical than semiotic, but it is useful for understanding digital circulation. Yuan examines account status, account neighbours and historical communication data in the Sina microblogging system. The author uses WEKA, feature selection algorithms and classification methods to identify influential nodes in large-scale networks. The reported accuracy reaches 95 percent [20]. For the present article, the most important conclusion is that digital advertising symbols should be examined not only through their content, but also through the network structures that determine their visibility and circulation.

Belk's review of qualitative advertising research is methodologically important for the present study. The author argues that qualitative research remains necessary despite the growth of big data, online experiments and surveys. The review discusses observation, interviews, projective methods, focus groups, netnography and videography, together with semiotics and reader-response theory [21]. This position is significant because symbolic meanings and cultural codes require interpretation rather than only numerical measurement.

Bambauer-Sachse studies dimensions of brand globalness in advertising. The article focuses on how global brands build value and credibility through global promotion. The author argues that such brands may symbolize cosmopolitanism, modernity and belonging to a global consumer segment [22]. This supports the idea that international campaigns should balance global recognition with local cultural relevance.

The review indicates that cultural codes in advertising are studied through language symbolism, semiotics, visual rhetoric, localization, national imagery and digital circulation. The selected studies show that cross-cultural advertising cannot rely on universal interpretation of signs: its effectiveness depends on the adaptation of verbal and pictorial elements to cultural expectations, symbolic associations and communication styles.

The study confirms that cultural codes shape how consumers interpret brand

messages, evaluate products and respond to promotional appeals. Effective international brand communication therefore requires more than linguistic translation; it depends on cultural adaptation, awareness of local values and understanding of how advertising signs circulate in digital environments.

Online platforms and artificial intelligence make cross-cultural advertising more complex. They create opportunities for personalization and rapid adaptation, but also increase the risk of cultural misunderstanding, as symbolic content can spread quickly across different audiences.

The study is limited by its narrative review design and by the fact that only five open access papers were analysed in full text. The remaining publications were examined on the basis of abstracts and bibliographic data, which limits the depth of source interpretation.

Future research may include a narrative review of Russian-language publications in national databases and university library resources, followed by a systematic review of international and Russian studies. Further empirical work may compare advertising campaigns of different brands, product categories and regional markets.

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УДК 82.0

LITERATURE: THE LITERARY WORD AS A DRIVER OF MEANING

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Abstract. In this article examines literary language as a driver of meaning in PR and business communication. Using Eugene Onegin, Dracula and Harry Potter, it analyses avoidant, manipulative and coordinating communicative models and relates them to BBC Creative's Dracula campaign, the Pepsi Refresh Project and Dove's Real Beauty campaign. It argues that rhythm, suggestion and metaphor help messages cut through information noise, while sustainable memorability emerges when an ethical strategy and poetic form interact.

Keywords: literary word, business communication, PR strategies, Eugene Onegin, Dracula, Harry Potter, rhythm, suggestion, metaphor.

ЛИТЕРАТУРА: ХУДОЖЕСТВЕННОЕ СЛОВО КАК ДРАЙВЕР СМЫСЛА

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Аннотация. В статье рассматривается литературный язык как фактор смыслообразования в PR и бизнес-коммуникации. На материале романов «Евгений Онегин», «Дракула» и «Гарри Поттер» анализируются избегающая, манипулятивная и координирующая модели коммуникации и сопоставляются с кампаниями BBC Creative Dracula, Pepsi Refresh Project и Dove Real Beauty. Показано, что ритм, суггестия и метафора помогают преодолевать информационный шум, а устойчивая запоминаемость возникает при взаимодействии этичной стратегии и поэтической формы.

Ключевые слова: литературное слово, бизнес-коммуникация, PR-стратегии, Евгений Онегин, Дракула, Гарри Поттер, ритм, суггестия, метафора.

Introduction

In the context of increasing information noise, traditional PR tools are losing some of their effectiveness. Rational arguments, facts and figures are often lost in a flow of competing messages. Audiences, overwhelmed by information, develop psychological filters and may fail to perceive messages. In this situation, literature can be considered a laboratory in which both successful and failed communication

strategies have already been modelled.

This article considers the literary word as a driver of meaning in business communication and PR. By the "driver of meaning" we mean a linguistic or psychological mechanism that not only transmits information, but also triggers the formation of intended associations, values and long-term attitudes in the addressee's mind.

The hypothesis of the article is that this driver arises not from the behavioural patterns of literary characters or from poetic techniques separately, but from their interaction.

To test this hypothesis, the article addresses three objectives:

1. To analyse the communication strategies of three contrasting literary heroes – Onegin, Dracula and Harry Potter – as matrices of successful and failed roles.

2. To identify the mechanisms of poetic speech that help messages cut through information noise.

3. To explain how the interaction of behavioural patterns and rhythmic organisation of speech creates an effective communication tool applicable to PR practice.

Section 1. Literary Heroes as a Matrix of Communication Strategies

Long before the advent of PR and corporate communication, literature had modelled the main types of interaction between people. Characters in novels often act in conditions similar to those faced by modern business communicators: uncertainty, conflict and lack of information. Analysing their successful and failed strategies allows us to form a practical typology that can be transferred to PR campaigns, negotiations and crisis communication. Three contrasting characters were selected for this purpose: Eugene Onegin, Dracula and Harry Potter.

Table 1. Communication Strategies of the Three Literary Heroes

Character	**Communicative model**	**Key characteristics**	**Result**	**PR/business analogy**
Eugene Onegin	Avoidant	Ignores Tatiana's letter and chooses a duel instead of dialogue	Failure of communication, Lensky's death and the personal collapse of the hero	Formal press releases instead of responsive crisis dialogue
Dracula	Manipulative	Hypnotic speech and suppression of will	Short-term success followed by collapse	Short-term conversion followed by reputational risks
Harry Potter	Coordinating	Listens, unites others and creates shared values	Sustainable success through teamwork	Crisis PR: recognise the problem, involve people and speak the language of values

As the table shows, the successful strategy represented by Harry Potter relies on dialogue and coordination. The failed strategy represented by Onegin is based on avoidance of direct contact. The dangerous strategy represented by Dracula is based on suggestive suppression.

However, the question “How can communication cut through information noise?” remains open. This issue is addressed in the second section, which focuses on poetic mechanisms.

Section 2. Poetry as a Technology for Reducing Noise

The first section showed how literary characters establish a matrix of communication strategies: what to do, what to avoid and what risks suggestion carries. However, this typology does not fully answer the question of memorability. Poetry offers a set of formal techniques that bypass psychological filters and increase the transmission of meaning [1, p. 33]. Three mechanisms are particularly important: rhythm, metaphor and suggestion.

2.1 Metaphor as a Shortening of Meaning

A rational argument requires proof. A metaphor, by contrast, offers a ready-made image that carries an evaluation and an attitude. For example, when we say, “Our company is a ship in a storm,” the listener instantly grasps the implication: instability, danger and the need to trust the captain. In Bram Stoker’s novel Dracula, metaphors of blood, night and eternity work faster than any direct reasoning about immortality [2]. In PR, metaphor is especially useful when time and communication channels are limited. A single image can replace an entire paragraph of explanation and ensure long-term memorability [1, p. 57].

2.2 Suggestion as Influence Without Direct Resistance

Suggestion is a psychological influence that leads the recipient to accept beliefs or attitudes without critical evaluation. In business communication, suggestion works where the listener is emotionally involved or weakened. Short rhythmic phrases that are repeated throughout a campaign may gradually cease to be evaluated rationally and begin to be perceived as self-evident. This is effective, but ethically risky. It raises the issue of ethical boundaries – a central concern in PR practice. In the absence of ethical restrictions, suggestive techniques transform into manipulation, which in the long run leads to a loss of audience trust.

2.3 Rhythm

Rhythm in poetry is not merely an alternation of stressed and unstressed syllables. Rhythm creates expectation, and the brain unconsciously anticipates continuation. When a speaker creates rhythmic inertia, for example through short phrases of three or four words, the listener begins to predict the continuation. This reduces cognitive load and increases the credibility of the message [1, p. 88].

In PR, rhythm works in slogans, headlines and the structure of public presentations. It is one of the most subtle but important filters: it can work even when metaphor and suggestion are less visible.

Thus, metaphor, suggestion and rhythm are not merely decorative elements of a text, but technological filters that increase the probability that meaning will reach the addressee. They are neutral in themselves: their effectiveness depends on the

behavioural strategy into which they are embedded. The third section explains how the intersection of poetic techniques and communicative roles creates the main driver of meaning.

Section 3. The Intersection of Strategies and Poetics: How to Speak in a Memorable Way

The first section examined the communicative strategies modelled by literary characters: avoidant, manipulative and coordinating. The second section considered poetic mechanisms – metaphor, suggestion and rhythm – that help reduce information noise. The answer to the question of memorability lies in the intersection of these two lines. Long-term memorability arises not from strategy or poetic form alone, but from the way poetic devices strengthen and stabilise a behavioural model.

3.1 Onegin: How Not to Communicate

Onegin's strategy is to avoid direct dialogue and move into formality or conflict. An important clarification is necessary here: Onegin speaks in verse, like all the characters in the novel. His speech is rhythmically organised, because Eugene Onegin is written in iambic tetrameter, but this does not save him from communicative failure [3]. The problem is not the absence of poetic form, but the position of the hero himself.

Onegin chooses pragmatic distance, dry rationality and a rejection of emotional involvement, especially in comparison with Lensky and Tatiana. In the scene of his explanation with Tatiana, he speaks plainly and almost matter-of-factly, explaining that he is not meant for happiness [4, p. 225]. His communication rejects the emotional and metaphorical potential of poetic speech. As a result, Tatiana remembers the act of refusal rather than the words themselves. The duel is remembered as an event, not as the outcome of a meaningful dialogue.

The PR lesson is clear: formal correctness and rhetorical order are not enough. If communication avoids emotional involvement, dialogue and shared values, the audience may remember the fact of the message, but may not accept its meaning.

3.2 Dracula: Memorability Without Trust

Dracula's strategy is manipulative and suggestive. His poetic technique is rhythmic hypnosis, repetition and the symbolism of blood, night and eternity [2]. His speech is memorable, but this memorability is connected with the suppression of will. As soon as the hypnotic effect disappears, memory begins to work against him: Dracula is remembered as a threat rather than as an authority.

The PR lesson is that aggressive suggestion and rhythmic repetition may create quick memorability, but they also destroy trust. The audience may remember the message, but it may not want to return to it voluntarily. In the long term, such a strategy creates reputational risks.

3.3 Harry Potter: The Coordinating Model

Harry Potter represents a coordinating strategy: he listens, names shared values and assigns roles. In Harry Potter and the Order of the Phoenix, the creation of Dumbledore's Army is a clear example of this model. Harry does not present himself as an unquestionable hero. Instead, he builds communication around a shared threat and a shared need for protection [5]. In Harry Potter and the Deathly Hallows, the Battle of Hogwarts also demonstrates the distribution of roles: Hermione performs analytical functions, Neville embodies courage and resistance, and the professors provide

institutional protection [6].

Harry's strategy inspires trust through vulnerability. He does not hide his fear; this honest vulnerability – unlike Onegin's cold distance and Dracula's false omnipotence – inspires confidence. His strategy can be connected with Bakhtin's idea of dialogic communication, where meaning is co-created between speaker and listener rather than imposed from above [7, p. 134].

The poetic device associated with this model is a metaphor of shared values and a simple rhythm of natural speech. Such communication is memorable because metaphor creates a ready-made image, rhythm reduces the effort of memorisation, and the coordinating strategy creates emotional connection. The audience remembers not isolated words, but a rhythmically organised image of itself as part of a team with the hero.

3.4 Three Real Cases: Dracula, Onegin and Harry Potter

The literary models discussed above can also be observed in real PR practice. The following cases show how avoidant, manipulative and coordinating strategies appear in brand communication.

A striking example of visual suggestion is BBC Creative's 2020 campaign for the premiere of the series Dracula. The billboard consisted of a white surface covered with wooden stakes. During the day, it looked like an abstract composition. However, as darkness fell, the shadows cast by the stakes formed the recognisable profile of Count Dracula with protruding fangs. This visual effect is shown in Figure. Next to the billboard, there was a glass display case with the inscription "Break in case of vampires" and a wooden stake inside [8].



Figure. BBC Creative's Dracula billboard based on shadow and visual suggestion. Source: D&AD, 2020

The advertisement does not directly encourage viewers to watch the series, does not explain the plot and does not list the actors. Instead, it creates an experience: viewers notice how shadows turn into a vampire, feel slight tension and draw their own

conclusion that the series is worth watching. Information enters consciousness without a direct rational argument. This is why the case demonstrates the power of suggestion and visual metaphor [8].

The Pepsi Refresh Project can be interpreted through the avoidant model represented by Onegin. In 2010, Pepsi decided to abandon traditional Super Bowl commercials and redirect millions of dollars to a social grant project. People proposed local initiatives, voted for them, and the winning ideas received funding [9]. The project received professional attention, but it did not create a sufficiently clear connection between social activity and the product. MediaPost later argued that the project did not help sell more cola and was closed against the background of declining market share [10]. In this sense, the case demonstrates the risk of social communication that is not clearly connected with brand identity.

The Dove Real Beauty campaign can be compared with the coordinating model represented by Harry Potter. Launched in 2004, the campaign replaced standard advertising images with ordinary women of different ages, sizes and appearances. It was based on research showing that only a small minority of women considered themselves beautiful [11, 12]. Dove did not avoid dialogue and did not rely on aggressive suggestion. Instead, the company addressed an emotional problem directly and connected the brand with shared values: confidence, self-acceptance and a broader understanding of beauty. The campaign helped Dove associate its brand with self-acceptance and long-term audience engagement.

3.5 The Final Formula: How to Speak in a Memorable Way

Analysing the intersection of behavioural models and poetic techniques, we can formulate an empirical model of effective memorisation: a stable communicative effect is achieved when a coordinating strategy is combined with a rhythmically organised, semantically compressed and emotionally precise form of presentation.

The main answer to the question “How can one speak in a memorable way?” is the following: speak in the rhythm of shared values. Use metaphor not instead of argument, but as a way to compress and strengthen it. One rhythmic image is often remembered better than several paragraphs of logic. Poetry teaches a PR specialist to synchronise what is done (strategy) with how it is communicated (form). Only then can a message both cut through the noise and remain in memory.

The main results of the comparison can be summarised as follows.

Table 2. Summary of Literary Models and PR Lessons

Character	Communicative model	PR lesson	Ethical status
Eugene Onegin	Avoidant	Avoidance without dialogue leads to communicative failure.	Negative
Dracula	Manipulative	Suggestion without trust produces only a short-term effect and creates reputational risks.	Ethically problematic
Harry Potter	Coordinating	Coordination combined with poetic rhythm and shared values creates sustainable communication.	Constructive

Thus, the literary word becomes a true driver of meaning only when poetic form is combined with an ethical communicative strategy aimed at trust, dialogue and shared understanding.

Conclusion

The study confirms that classical literature is not merely a collection of stories, but a structured field of communicative archetypes. Returning to the initial hypothesis, the "driver of meaning" arises not from behavioural patterns or poetic techniques alone, but from their interaction. The analysis makes it possible to draw four practical conclusions for PR and business communication.

First, different literary characters offer ready-made matrices of communicative roles. The avoidant model represented by Onegin leads to failure because it lacks empathy, dialogue and emotional involvement. The manipulative model represented by Dracula can provide short-term success, but it destroys long-term trust. The coordinating model represented by Harry Potter creates a more sustainable result through dialogue, shared values and audience involvement.

Second, poetry functions as a technological layer of communication. Rhythm, suggestion and metaphor act as filters that help a message cut through information noise and reduce the audience's cognitive load. As a result, the message becomes easier to perceive, remember and emotionally accept.

Third, the main communicative driver is formed at the point of synthesis, when an appropriate communicative role is combined with a rhythmically organised, semantically compressed and emotionally precise form. A PR specialist can learn from poetic discipline: to check phrases by ear, maintain rhythmic consistency and compress complex meanings into vivid metaphors.

Fourth, the study reveals a critical ethical boundary. Synthesis without dialogue becomes manipulation, as demonstrated by Dracula. Poetic packaging without an effective communicative role remains an empty form, as shown by Onegin. The literary word becomes a true driver of meaning only when it serves not to suppress critical thought, but to create understanding, trust and shared interpretation.

This study has certain limitations. It is based on only three literary characters and three PR cases and does not claim to be comprehensive. Future research could explore other communicative archetypes, for example Sherlock Holmes or Jay Gatsby, or test the proposed model experimentally in real PR campaigns.

Ultimately, bridging literary analysis with strategic communication offers a human-centred framework for navigating modern information overload. In an era where attention is scarce and trust is fragile, poetic discipline does not merely embellish communication; it helps structure meaning so that it can be remembered, trusted and shared.

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При написании статьи были применены технологии искусственного интеллекта.

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УДК 004.056.5

SOCIAL ENGINEERING AS ONE OF THE MAJOR THREATS TO INFORMATION SECURITY

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Abstract. The technique where a hacker attacks not a computer but a person working with it is called social engineering. Social hackers are people who know how to “hack a person” by programming them to do the right thing. The article describes seven phases of social engineering attack and provides some examples of such attack techniques.

Keywords: manipulating, information, social engineering, attack, protect, cybersecurity, control.

СОЦИАЛЬНАЯ ИНЖЕНЕРИЯ КАК ОДНА ИЗ ОСНОВНЫХ УГРОЗ ИНФОРМАЦИОННОЙ БЕЗОПАСНОСТИ

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Аннотация. Прием, когда хакер атакует не компьютер, а человека, работающего с ним, называется социальной инженерией. Социальные хакеры – это люди, которые знают, как можно «взломать человека», запрограммировав его на совершение нужных действий. В статье описаны семь этапов атаки с помощью социальной инженерии и приведены некоторые примеры техник подобных атак.

Ключевые слова: манипулирование, информация, социальная инженерия, атака, защита, кибербезопасность, контроль.

Currently, humanity is actively moving from industrial to post-industrial. In it, the main factor of production is knowledge (information), and the main method of labor is computerization. In this regard, the number of cyber attacks will increase, and information security is becoming of great importance.

At its core, information security (or InfoSec) is the practice of protecting data from unauthorized access or breaches, whether the data is in physical form or digital. Information security spans various disciplines, covering everything from protecting physical files stored on-site to encrypting digital data stored in cloud environments. The primary goal is to protect data from internal and external threats while ensuring that employees and systems can access the information they need without unnecessary delays or barriers. Information security requires a blend of policies, tools, and

technologies to secure sensitive data, maintain privacy, and uphold trust between an organization and its stakeholders.

The importance of information security has surged in recent years due to the rising prevalence and sophistication of cyber threats. Malware attacks, phishing schemes, and ransomware incidents have reached all-time highs, often targeting small to large organizations alike. These attacks are not only increasing in number but are becoming more sophisticated, leveraging automation and artificial intelligence to adapt to defenses. For example, ransomware attacks, which lock organizations out of their data until a ransom is paid, have been especially damaging. Organizations are faced with a dual threat: evolving tactics by attackers and the rapid proliferation of data and interconnected devices, both of which create more vulnerabilities to be managed.

More than 70 % of cyber attacks are carried out using social engineering.

What is social engineering?

The best and easiest definition of the term social engineering is: social engineering is lying to people to get information.

Social engineering is an act of manipulating a person to take any action that may or may not be in "target's" best interest. This may include obtaining information, gaining access, or getting target to take a certain action. It is art of manipulating and misleading people [1].

Social engineering is a psychological manipulation technique used to trick individuals into divulging confidential information, performing specific actions, or granting unauthorized access to systems and physical locations. Unlike traditional hacking that targets software vulnerabilities, social engineering exploits human behavior

Emotions used to perform social engineering attack are as follows: fear, greed, curiosity, helpfulness, etc.

- Fear – Malicious actors commonly use fear to manipulate victims because it is one of the most powerful of human emotions. For example, a phony email stating that your online bank account has been compromised and requires a new password will likely elicit fear.
- Greed – Let's face it, most of us have had a few greedy moments. It's only human. For this reason, social engineers find it a successful tool. A good example is the notorious "419 Nigerian scam," in which cybercriminals claiming to be a Nigerian official promise a large reward for a small sum of money. Even today, the lure of easy money causes people to fall for the ancient con.
- Helpfulness – From a young age, most of us are taught to be helpful and obedient. This willingness to help others is used against victims by social engineers. For example, criminals seek out customer service agents because their helpful mindset makes them easy targets.
- Curiosity – Curiosity is exploited when attackers promise something of interest to deceive victims. It might be as simple as an email saying, "Your Amazon purchase for $825 is ready to ship; click here to view your order".

There are seven phases in a total of social engineering attack.

- Identifying the goal – first phase consists of attack formulation and in accordance, identifying target necessary to fulfill goal.

– Information gathering – in this phase, social engineers assess and identify potential information sources and begin information gathering and assessment.

– Preparation – in this phase, social engineers analyze information and develop an action plan and methodology to begin approaching the target.

– Establishing a relationship – in this phase, social engineers establish a line of communication and begin to build a relationship.

– Exploit the relationship – in this phase, the target is “prepped”. The exploitation stage uses different methods of misleading to evoke right type of emotions and prime the target to right emotional stage.

– Debrief – in this phase, social engineer returns to victim and maintains desired emotional state. The goal is that the victim will not feel like anything in relationship was odd, and they will not understand that they have been under attack.

– Goal satisfaction – after a successful social engineering attack, social engineers will exploit information they have gathered. After social engineering attack, the social engineer will either return to the victim for more information or slowly close relationship [2].

History of social engineering

Tricking users into divulging sensitive information is nothing new in the world of cybersecurity. The only thing that’s changed is the method of attack, the stories used to obtain information, and sophisticated attacks from organized groups incorporating threats. The term social engineering was first used in 1894 by Dutch industrialist JC Van Marken, but it’s been a method of cyber attacks since the 1990s.

In the 1990s, social engineering involved calling users to trick them into divulging their credentials or providing the dial-in landline number that connected a threat actor to an internal corporate server [3].

Here are some examples of social engineering attack techniques.

Baiting

With baiting, false promises are made to targeted individuals to lure them into a trap. The most common form of baiting uses strategically located USB drives to disperse malware when unsuspecting users insert them into their computers. Other baiting approaches promise an individual a reward, something enticing for free, or a special offer for sharing information or to lead them click on malicious links [4].

Business email compromise

A business email compromise (BEC) occurs when an executive’s (e.g., CEO or CFO) email is used to trick individuals into giving an attacker their target, which is usually sensitive information, money, or other valuable assets.

Phishing

The leading malware infection vector, phishing, is a widely used social engineering technique that is executed in several ways. Regardless of the type of phishing attack, the outcomes are usually the same – individuals unwittingly share sensitive information or download a malware payload.

Bulk email phishing

Bulk phishing emails are sent to many recipients and usually appear to be sent by a recognizable, reputable business or organization (e.g., bank, online store, or phone company). The emails are designed to mimic the organization’s branding, and the

messages are carefully written to make users think they are legitimate requests.

However, the senders' requests lead users to a security breach, such as sending credit card information in response to a request to update it or sharing bank account information to update an account at an online store.

Some other examples of social engineering attack techniques are: short message service (SMS) phishing, or smishing, spear phishing, vishing, pretexting, quid pro quo, scareware, tailgating, watering hole attack, and the list is growing very fast [5], [6].

Short message service (SMS) phishing, or smishing is phishing via text message.

A spear phishing attack is a well-researched phishing exploit that targets specific individuals or organizations. The messages use details about the organization or people to make the email appear more authentic.

Vishing involves the social engineering perpetrator leaving urgent or menacing voicemails in an attempt to coerce the recipient into falling for the ploy.

Pretexting is when a social engineering attacker assumes the identity of a trusted, important entity such as a bank, utility, or health care representative to drive the target into the trap.

Quid pro quo social engineering scams lure targets by promising something in exchange for information. For instance, they might tell someone that they have won a prize and require them to provide personal information to claim it.

Scareware makes users think something is wrong with their system. Threats are sent to users, telling them about the alleged issue and explaining that the only way to resolve it is to fill out a form, which requires sharing personal information or other sensitive data.

Tailgating, also referred to as piggybacking, is a form of physical social engineering. Unauthorized individuals follow authorized team members into restricted areas under false pretenses, such as picking up a special delivery, explaining that they lost their keycard, or having their hands full and being unable to handle the door.

A watering hole attack is derived from the term "to poison the watering hole". What it means to users is that an attacker creates fake sites to attract users to sites with malware or infects existing websites that the target group is known to visit.

It is extremely important to be able to recognize social engineering attacks.

One should be very wary of any unsolicited advice or help, particularly if it requires action from a person, such as clicking on a link or downloading a file. Any requests for passwords or personal information is very likely a social engineering attack.

It is necessary to take caution if one receives a call from anyone claiming to be tech support or get an unscheduled "inspection". Tech support are busy enough that they're unlikely to look for new problems and inspection visits are likely attempts to install software like keyloggers on your computers.

Also, one should stay away from anything that creates a false sense of urgency as they use this to trick a person so that he doesn't use better judgment, and be wary of any sob stories or other forms of psychological manipulation.

Be sure to always cross-reference and double-check. If a person receives a suspicious email or phone call or anything asking him to disclose information or perform a task, it is necessary first to verify that it is legitimate before taking action.

It is important to know how to stay protected against social engineering if a person is in charge of an organization. One should consider taking the following steps:

- reduce and control admin rights among regular users;
- create frequent cybersecurity training sessions and spread awareness;
- perform staff exercises and get penetration testing;
- prepare for incident management as well, not just prevention;
- activate spam filter. Because email is used for a lot of social engineering, the easiest way to protect against it is to block spam from reaching inbox;
- don't respond to scammers. By doing so, a person demonstrates that his email address is legitimate, and they will simply send more mail;
- have a robust cybersecurity solution in place [7].

Social engineering is widely used by cybercriminals because it is a highly effective way to bypass complex and cumbersome cybersecurity systems (e.g., anti-virus software, firewalls, intrusion detection systems, and intrusion prevention systems), allowing them to access protected systems. Compared to these cybersecurity systems, people are an easy target because human error cannot be completely eliminated. In this regard, it is necessary to educate people about social engineering techniques and ways to prevent such cyber attacks [8].

In fact, people are considered the weakest link in an organization's security. So no matter how good one's IT team is at protecting a company from cyberattacks, a person can never completely eliminate the risk of someone trying to get into the system through social engineering methods. That's why it's so important to train employees about identifying phishing emails and other types of social engineering attacks.

So, in today's digital age, one of the most underestimated threats isn't found in a computer virus or a sophisticated piece of malware – it's in the mind. Social engineering is a calculated psychological manipulation aimed at exploiting the most fundamental aspects of human behavior. It is the art of manipulating individuals to divulge confidential information or perform actions that compromise security.

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МАТЕРИАЛЫ
XIX Международной научно-практической конференции
на английском языке
«ДИАЛОГ КУЛЬТУР»

2026 ● Часть I

PROCEEDINGS
of the XIX International Scientific and Practical
conference in English
“DIALOGUE OF CULTURES”

2026 ● Part I

Редактор и корректор А. А. Чернышева
Технический редактор М. А. Баранова

Научное электронное издание сетевого распространения

Системные требования:
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Дата подписания к использованию 30.07.2026. Изд. № 5279/26

Высшая школа технологии и энергетики СПбГУПТД
198095, СПб., ул. Ивана Черных, 4.