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Manuscript

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METHODOLOGICAL ASPECTS OF APPLICATION OF END-TO-END DIGITAL IMMERSIVE TECHNOLOGIES TO INCREASE LABOR PRODUCTIVITY AT INDUSTRIAL ENTERPRISES

Speciality: 5.2.6 - Management

ABSTRACT

Of the dissertation for the degree of Candidate of Economic Sciences

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Relevance of the research topic. In the context of sanctions pressure and the structural restructuring of the Russian economy, labor productivity is becoming a key development factor, with Russia lagging behind industrialized countries by a factor of 1.5 to 3. The dominance of extensive growth and the low level of digitalization of industry exacerbate this problem (only 20-30% of processes are covered). To overcome external economic shocks and build a sustainable national economy, activate the country's internal reserves of labor productivity, and ensure technological leadership and growth, in accordance with Decrees of the President of the Russian Federation No. 204 of May 7, 2018, and No. 309 of May 7, 2024, the national projects «Labor Productivity and Employment Support» and «Data Economy and Digital Transformation of the State» were adopted, as well as Government Resolution No. 317 of April 18, 2016, on the implementation of the National Technology Initiative (NTI).

As part of the commitment to technological sovereignty, end-to-end digital immersive technologies have been identified as priority end-to-end technologies (Decree of the President of the Russian Federation dated June 18, 2024, No. 529). Their implementation is critical for industrial enterprises to reduce operational losses and transition to intensive growth.

However, despite the proven effectiveness of end-to-end digital immersive technologies in optimizing business processes, there are no methodologies in domestic practice for their specific application to increasing labor productivity. The development and implementation of productivity management tools using technological solutions, including immersive technologies, are becoming a critical factor in ensuring economic and industrial growth. These circumstances determine the relevance of developing methodological aspects of the application of end-to-end digital immersive technologies to improve labor productivity at industrial enterprises.

Research topic coverage. The theoretical framework for this study is formed by the Systems Management School of Charles Bernard and David Forrester, which examines the integrity of economic entities. This framework is complemented by

the theoretical developments of Thomas Schultz and Henry Becker (human capital theory), Karl Marx (classical labor theory of value), Fred Davis (theory of technological adoption), and David Acemoglu (theory of resource allocation).

The theoretical and methodological foundations of labor productivity management were laid by David Ricardo, Adam Smith, and Karl Marx, who described the factors of productivity growth from a political economy perspective. Based on these studies, the founders of scientific management, Francis Taylor and Henry Emerson, defined the principles of labor productivity management from a management theory perspective.

The Soviet school of productivity and scientific organization of labor studied the integrated consideration of human, organizational, and technological factors in labor productivity. The greatest contributions to the development of this school were made by A.K. Gastev and O.A. Ermansky. Productivity factors were studied by G.M. Krizhizhanovsky, S.G. Strumilin, and G.P. Shchedrovitsky. Methodologies for improving labor productivity were developed by N.A. Bernstein, E.G. Liberman, M.M. Syrkin, A.I. Rosenblum, P.M. Kerzhentsev, A.A. Bogdanov, and G.A. Prudensky.

Post-Soviet and contemporary Russian academic discourse on labor productivity has been characterized by a shift in focus to institutional factors, digital transformation, and the macroeconomic context, as well as a comprehensive analysis of productivity constraints and reserves in the Russian economy. These aspects were covered in their works by S. Glazyev, S. Bodrunov, A. Frenkel, A. Sosnilo, A. Buzgalin, V. Sadovnichy, V. Ardzinov, A. Fedyunina, Z. Mkrtychan, N. Karamnova, I. Ilyina, I. Voskoboinikov, E. Balatsky, E. Bassovskaya, N. Ekimova, R. Kapelyushnikov, and others. The following works are devoted to the study of the practical application of tools and methods for increasing labor productivity with the aim of improving operational efficiency at the level of economic entities: J. Liker, N. Hayashi, T. Ono, S. Shingo, M. Vader, D. Jones, J. Shook, M. Imai, G. Niva, I. Adizes, D. Hobbs, Ch. Marchvinsky, A. Osterwalder, T. Shook, M. Kuzyk, and others. A significant contribution to the comprehensive E. Mayo, M. Porter, R.

Solow, P. Drucker, M. Follett, F. Hertzberg, D. McGregor, M. Weber, A. Fayol, J. Mooney, and L. Urwick contributed to the study of labor productivity and aspects of performance management.

Labor productivity in the context of digitalization was examined by V.F. Ukolov, V.V. Cherkasov, A.E. Zavyalov, V.Ya. Afanasyev, J. Wagner, A.V. Trachuk, L.S. Nabokova, Yu.A. Kolesnikov, M.V. Vladyka, L.V. Lapidus, and others.

Innovation project management issues were addressed in the works of V. Popov and N. Kremlev. O. Zyablikova, K. Khomkin, V. Pervushin, M. Romanenko, N. Azarov, F. Yaroshenko, and others.

The theoretical understanding of the potential for using immersive augmented and virtual reality technologies in the industrial sector is the subject of works by J. Sutherland, P. Milgram, F. Kishino, R. Yang, J. Vince, E. Krokos, A. Seiberfeldt, O. Danielson, N. Kunkel, Sh. Ngok, V. Selivanov, P. Kikin, E. Komissarov, A. Nikolaev, P. Kokhno, and others.

However, despite the significance of existing research, issues of labor productivity management in the context of digitalization remain unresolved. In particular, the theoretical and practical aspects of using augmented and virtual reality technologies to improve labor productivity in the industrial sector have not been addressed.

The purpose of this dissertation is to develop methodological aspects of applying end-to-end digital immersive technologies of augmented and virtual reality as a tool for increasing labor productivity at industrial enterprises in the face of current challenges.

To achieve this goal, the following objectives were required:

1. To identify, based on a systematic study of current theory and practice and an analysis of empirical data, the significance, potential, and application of end-to-end digital immersive technologies as a means of managing labor productivity in the context of the new industrial revolution and current socioeconomic challenges;

2. To operationalize methods for applying end-to-end digital immersive technologies in the business processes of industrial enterprises to increase labor productivity to ensure an appropriate selection of implementation targets;

3. To develop a proprietary methodology for implementing immersive technologies of augmented and virtual reality in the business processes of industrial enterprises;

4. Develop and test an organizational and economic mechanism for transforming the enterprise management system when implementing immersive technologies, confirm the economic efficiency, validity, and reliability of the developed methodological aspects.

The object of research are production systems and business processes of enterprises requiring the use of end-to-end digital immersive technologies to improve productivity.

The subject of research is the use of end-to-end digital immersive technologies in augmented and virtual reality to improve productivity at enterprises.

Conformity of the dissertation to the passport of the scientific specialty. The dissertation was completed within the framework of the Passport of the scientific specialty of the Higher Attestation Commission of the Ministry of Education and Science of the Russian Federation 5.2.6 «Management»: paragraph 4. «Management of economic systems, principles, forms and methods of its implementation. Theory and methodology of change management in economic systems»; paragraph 6. «Methods and criteria for assessing the effectiveness of management systems. Results-based management»; paragraph 16. «Theory and methodology of project management. Processes, methods, models and tools for project and program management. Risk management (risk management)»; paragraph 17. «Operations management. Management of production systems. Management of the operational efficiency of an enterprise and an organization»; paragraph 19. «Innovation management. Innovative capabilities of a firm. Management of organizational and technological innovations. Interorganizational forms of innovation management»; paragraph 26. «Organization management in the

context of digital transformation. Strategies and methods for digital business transformation».

Theoretical and Methodological Framework of the Study. The theoretical basis of the study is formed by the works of Russian and international authors focused on the study of factors affecting labor productivity management and the application of virtual and augmented reality in industry. The study utilized methods of systematization, classification, description, construction of theoretical propositions, induction, statistical, economic, and comparative analysis.

The information base of the research is based on statistical and analytical materials from the Russian state statistics authorities (Rosstat) on the state of national accounts, digitalization of industries, and the use of digital technologies in the Russian economy, data from the International Labor Organization (ILO) and the Organization for Economic Cooperation and Development (OECD) on the dynamics of labor productivity and the digitalization of industry, research materials from research organizations (HSE University, Moscow State University, etc.), analytical materials from the Russian Academy of Sciences (RAS) and its branches, materials from meetings, roundtables, annual reports from executive bodies of the Russian Federation and subordinate organizations whose powers include direct or indirect management of labor productivity, stimulation of growth in labor productivity and the use of digital technologies, and materials from industrial companies.

Validity and reliability of research results. The validity of the research results submitted for defense is confirmed by the analysis and correct use of official statistical information collected, verified, and published in state statistical and information systems, as well as the results of a large body of research by domestic and international scientists published in peer-reviewed scientific journals.

The reliability of the obtained scientific results is confirmed by their implementation in Russian organizations. The author's operationalization of application methods and methodology for implementing end-to-end digital immersive technologies has been used by the Moscow Foundation for Inhabited Area Renovation to reduce the design time for capital construction projects,

visualize architectural planning and urban design solutions, and verify design and working documentation received from general designers and general contractors.

The scientific novelty of this dissertation research lies in the systematic and substantiated solution to the current scientific and practical problem of developing methodological aspects of managing the implementation of end-to-end digital immersive technologies of augmented and virtual reality in the business processes of industrial enterprises to increase labor productivity, resolving the scientific and methodological problem expressed in the lack of a holistic approach to the integration of these technologies into business processes, their operationalization and practical transformation of theoretical potential into specific management tools within the framework of management theory.

During the dissertation research, the following **scientific provisions and results**, which are novel, were obtained and are submitted for defense:

1. The article identifies relevant methods of managing labor productivity. Among them, along with traditional intensive and extensive methods, the use of end-to-end digital technologies is becoming a categorical imperative in the context of the fourth industrial revolution and the new industrial policy of the Russian Federation to accelerate economic growth, achieve national goals and solve strategic development tasks. These technologies include: big data; neurotechnologies and artificial intelligence; distributed ledger systems; quantum technologies; new (customized) production technologies; industrial internet of things; robotics components and sensors; wireless communication technologies; immersive technologies of virtual and augmented reality. It is substantiated that the implementation of end-to-end digital technologies ensures increased competitiveness, reduced resource consumption and increased labor productivity, depending on the choice of technological alternatives and the availability of a scientifically developed implementation methodology. Immersive virtual and augmented reality technologies have been identified as having significant potential for managing labor productivity growth. These innovative means of visualizing and augmenting the real world with digital objects have been identified, enabling change

management by transporting users into artificially simulated scenarios. These technologies are evolving from process automation to the cognitive integration of humans and machines, where gestures and gazes serve as natural interfaces for control. Immersive technologies are inherent in «human-centricity» (technology enhances, rather than replaces, humans)—a priority principle for the next stage of industrial development, industrial policy, and the new technological paradigm. (Chapter 1, § 1.1-1.3, Chapter 2, § 2.1, Item 4, Passport of the scientific specialty VAK 5.2.6. «Management»);

2. The author has developed and presented an operationalization of the use of end-to-end digital immersive technologies of augmented and virtual reality by enterprises in industrial sectors, which makes it possible to identify and specify the areas of their appropriate use. A classification of functions, roles and possibilities of applying end-to-end digital immersive technologies of augmented and virtual reality within business processes to improve labor productivity is presented, including modeling of the production environment, quality control of operations, development of human capital, information visualization and process development. Methods of industrial application of virtual and augmented reality are formulated and systematized, the feasibility of integrating these technologies at the business process level is substantiated. (Chapter 2, § 2.1.-2.3, Chapter 3, §3.1.; clause 17. Passport of the scientific specialty HAC 5.2.6. «Management»);

3. A proprietary methodology for implementing end-to-end digital immersive technologies of augmented and virtual reality into enterprise business processes has been developed. The methodology is aimed at increasing the operational efficiency and sustainability of production systems through the integration of complementary technologies. The methodology is a six-stage iterative process that provides a systematic approach: (1) assessing the level of labor productivity, innovation, and personnel engagement, including an analysis of the current state of business processes based on operational metrics; (2) diagnostic identification of dysfunctions and codification of strategic operations in the production flow, focusing on identifying critical areas (maintenance, logistics, etc.) using value stream analysis

methods; (3) forming a structural diagram for implementing augmented and virtual reality trajectories, which also provides for the development of an improvement plan with a quantitative assessment of productivity reserves; (4) operationalization of AR/VR trajectories in the business process, ensuring monitoring of time frames and change execution. (5) implementation of a methodology for procedural quality control of AR/VR technology implementation, aimed at verifying the implementation of improvements using post-implementation data; (6) assessment of the impact on the release of labor productivity reserves.

A distinctive feature of the proprietary methodology from existing approaches is its systematic elimination of the ignorance of the principle of complementarity, which has traditionally been used to treat AR/VR as isolated tools, significantly reducing synergistic effects. The methodology enables the identification and classification of problem areas within the enterprise, which helps focus on key production areas and business processes requiring optimization and implementation of digital immersive technologies, and enables in-depth multi-level analysis.

The scientific innovation in the field of project management provided by the developed methodology lies in its ability to overcome the fragmentation of traditional approaches to the implementation of end-to-end digital technologies. Unlike the common practice of treating AR/VR solutions as isolated IT projects or automation tools, the author's six-step methodology represents a holistic project-process approach to project management. It systematically links strategic productivity improvement goals (macro level) with tactical tasks of operationalizing technologies in specific business processes (micro level). Its novelty lies in the integration of change management methodologies (at stages 1, 3, and 6), innovation risk management (stage 2), and continuous improvement (the PDCA cycle, embedded in the iterative nature of stages 4-5) into a single management framework (Chapter 1, §1.3; Chapter 3, §3.2; paragraphs 16 and 19 of the Higher Attestation Commission's Scientific Specialty Passport 5.2.6. «Management»);

4. An organizational and economic mechanism was developed and a transformation of the project management system and organizational structure of the

organization was tested during the implementation of immersive technologies. The mechanism developed by the author includes: (1) institutional adaptation of the management structure, integrating complementary AR/VR trajectories into existing business processes (performance assessment, dysfunction diagnostics); (2) operational monitoring and procedural control procedures synchronized with the stages of operationalization and verification of improvements; (3) a financial model based on ROI and economic efficiency calculations.

As part of the development of the organizational and economic mechanism, the author substantiated the need and proposed a model for creating a specialized project office (PO) with expanded functionality, which serves as a key element in the transformation of the management system. Unlike a classic project office, which focuses on coordination and methodology, the proposed model is endowed with a strategic and integrative role. Its key functions include: (1) managing a portfolio of AR/VR initiatives based on their contribution to strategic performance KPIs; (2) coordination of the project's interdisciplinary ecosystem, synchronization of the actions of internal departments (production, IT, HR, occupational health and safety) and external partners (integrators, vendors); (3) support of the full implementation cycle according to the proposed six-stage methodology - from diagnostics to impact assessment; (4) centralized knowledge and competency management, including the development of adaptation programs, training, and the development of internal expertise in immersive technologies. This project office acts as an institutional core, ensuring sustainability, scalability, and systematic risk management during the integration of immersive technologies into business processes, transforming disparate innovative projects into a manageable digital transformation program.

The economic efficiency, validity, and reliability of the developed methodological aspects, including the operationalization of application methods and the methodology for implementing immersive digital technologies, have been confirmed by their testing and practical implementation at the Moscow Housing Renovation Fund to reduce the design time for capital construction projects, visualize architectural planning and architectural urban planning solutions, and

verify design and working documentation received from General Designers and General Contractors. The use of augmented and virtual reality technologies at the Moscow Foundation for Inhabited Area Renovation has reduced the design and verification time for incoming documentation by 14%, increased the operational efficiency and productivity of project teams by 8%, redistributed the workload, and freed up 3 hours per month of useful employee time. (Chapter 3, §3.3; Item 6, Item 26. of the Passport of the scientific specialty VAK 5.2.6. «Management»).

The theoretical significance of this study lies in the development of a theory for managing the business performance of enterprises and increasing labor productivity through the use of digital technologies. Factors hindering and stimulating productivity growth (resource constraints, human capital quality, and digital maturity level) are systematized, and a classification of efficiency reserves for industrial enterprises is developed. The theoretical and scientific contribution lies in the theoretical justification of end-to-end digital immersive technologies of augmented and virtual reality as a tool for improving the efficiency of production cycle management, including models of their interaction with traditional management practices.

Practical significance of the study. The study addresses the problem of the fragmented implementation of end-to-end digital immersive technologies of augmented and virtual reality, proposing a transition from isolated solutions to a comprehensive transformation of operational management. The results of the study enable the implementation of end-to-end digital immersive technologies of augmented and virtual reality in industry to optimize personnel training, quality control, and process modeling; and the use of universal scenarios for integrating immersive technologies into business processes to increase labor productivity; adapt the proposed recommendations to the specifics of enterprises, including an assessment of their impact on key indicators.

The conclusion of the research thesis. The results, conclusions, and practical recommendations of the study were presented and approved at scientific and

practical conferences, the materials of which reveal the problems of increasing labor productivity through the use of information and communication technologies.

The research results were tested at the following scientific and practical conferences: the Second Moscow Marxist Forum «Social Sciences in the USSR and Their Role in the 21st Century (Dedicated to the 100th Anniversary of the USSR)» (Moscow, Russia, 2022); the 10th All-Russian Scientific Conference «Speransky Readings. Socioeconomic Development of Russia in the Context of Reformatting the World Order» (Moscow, Russia, 2023); the 5th International Scientific and Practical Conference «Science, Technology, and Society: Interaction and Prospects» (Moscow, Russia, 2024). «Modern Trends and Priorities of Sustainable Development of Regions» (STPR23), dedicated to the 300th anniversary of the Russian Academy of Sciences (Makhachkala, Russia, 2023); the IX International Scientific and Practical Conference «Science and Education: Achievements and Prospects» (Saratov, Russia, 2024); the XVIII All-Russian Scientific Conference of Young Scientists «Science. Technology. Innovation» (Novosibirsk, Russia, 2024), the III International Scientific and Practical Conference "Modern Trends and Practical Solutions in Science» (Moscow, Russia, 2024).

List of the author's publications. Ten scientific papers were published as part of the study, including three articles in peer-reviewed journals that should publish the main scientific results of dissertations for the degree of candidate of sciences and the degree of doctor of sciences, approved by the Higher Attestation Commission.

Dissertation Research Structure. The dissertation research consists of an introduction, three chapters, a conclusion, a list of references and bibliography, and appendices. The dissertation is 197 pages long and contains 188 references, 11 tables, 20 figures, and 2 appendices.