Economics of knowledge-intensive and high-tech enterprises and industries. Management in organizational systems

Экономика наукоемких и высокотехнологичных предприятий и производств. Управление в организационных системах

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RESEARCH ARTICLE

Planning of reproduction processes in electronics for a strategic perspective

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Abstract
Objectives. The work sets out to develop new approaches to strategic planning methodology in the electronics industry that take into account the current global multi-vector economic transformation and corresponding acceleration of technological changes. The most general framework for the further development of the electronics industry is outlined along with a discussion of its likely impact on the socioeconomic structure of future society.
Methods. Along with classical methods for studying socioeconomic relationships pertaining to complex systems such as the electronics industry, systems analysis, foresight technologies, production process modeling, and strategic planning methods are applied. In order to evaluate the explanatory power of different development models, particular attention is given to the multiple comparison method.
Results. The study identifies a need for a radical restructuring of economic and industrial sectors in which the electronics industry is accorded a leading role as a result of its development transcending traditional economic rationalizations to acquire a civilizational character. The establishment of the electronics industry as the main driving force for the entire economy, along with a corresponding restructuring of personnel training, thus represents a key strategic element in Russia's continuing development.
Conclusions. In the ongoing race for technological (and therefore economic, military, and political) sovereignty, the creation and continuous development of a strategic planning and management system for the electronics industry acquires a strategic character. The establishment of a genuinely independent national macroeconomic region can be achieved by ensuring self-sufficiency in both the production and consumption of electronic products.

Keywords: electronics industry, strategic planning, digitalization, artificial intelligence (AI), technological singularity, production processes, digital transformation

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НАУЧНАЯ СТАТЬЯ

Планирование воспроизводственных процессов в электронике на стратегическую перспективу

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Резюме

Цели. Цель работы – разработка новых подходов к методологии стратегического планирования в электронной промышленности с учетом глобальной многовекторной трансформации экономики и ускорения технологических изменений. Настоящее исследование показывает наиболее общие рамки дальнейшего развития электронной промышленности и рост ее влияния на социально-экономическое устройство будущего общества.

Методы. Наряду с классическими методами исследования социально-экономических отношений сложной системы, которой является электронная промышленность, применялись системный анализ, форсайт-технологии, моделирование производственных процессов и методы стратегического планирования. Особое внимание уделялось методу множественного сравнения для оценки объяснительной способности различных моделей развития.

Результаты. Проведенное исследование объективно подводит к необходимости новой реструктуризации отраслей экономики и промышленности с особым статусом для электронной промышленности, т.к. ее развитие выходит за рамки экономической рациональности и приобретает цивилизационный характер. Постановка электронной промышленности в качестве локомотива всей экономики наряду с реструктуризацией подготовки кадров – это залог стратегического успеха развития нашей страны.

Выводы. Создание и непрерывное развитие системы стратегического планирования и управления электронной промышленностью – единственная возможность «срезать углы» в развернувшейся гонке за технологическим, а значит экономическим, военным и политическим суверенитетом. Особое стратегическое значение приобретает необходимость построения собственного макрорегиона, самодостаточного как с точки зрения производства, так и потребления электронной продукции.

Ключевые слова: электронная промышленность, стратегическое планирование, цифровизация, искусственный интеллект, технологическая сингулярность, производственные процессы, цифровая трансформация

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INTRODUCTION

Fundamental transformations occurring in the contemporary market economy are driven in part by changing consumption patterns and the crisis in the existing financial system. These developments present both challenges and new opportunities for the development of Russia's electronics industry. On January 22, 2026, the President of Russia, Vladimir Putin, held a meeting dedicated to the development of the Russian electronics industry, including issues related to the development and production of electronic component base and integrated circuits.[1] Following that meeting, the President of Russia decreed the creation of an interdepartmental commission to improve the efficiency of managing the development of the Russian electronics industry, which is headed by First Deputy Prime Minister D. Manturov and Presidential Aide A. Fursenko. Due to the strategic focus of the decisions to be adopted, executive bodies involved in developing the Russian economy will create a tiered planning system for the timely adjustment of strategic plans in light of scientific and technological achievements, which in practice emerge faster than strategic forecasts and foresight studies.

The key indicators reflecting the current state and development trends of the Russian electronics industry can be summarized in a few parameters. The gross output of the radio-electronic industry (REI) reached RUR 3.5 trillion in 2025. Despite a 34% increase in production, Russian electronics continued to lag behind major competitors by 25–35 years in terms of key technological characteristics. The most significant factor hindering the industry's development is a significant shortage of skilled personnel.

THEORETICAL FOUNDATIONS OF STRATEGIC PLANNING IN THE ELECTRONICS INDUSTRY

Methodological framework of the study

The contemporary economy is a multifaceted phenomenon characterized by a high degree of interconnectivity among its structures and components, including its supersystem, comprising the aggregate of natural factors and civilizational socioeconomic relations in their broadest sense. Thus, the wider economy serves as a supersystem relative to the electronics industry, which in turn is composed of various subsystems and subsectors. Therefore, a systemic approach to strategic planning and management of production processes in the electronics industry requires a coordinated analysis of the following factors: the crisis of the existing financial system, the regionalization of the economy, the formation of new economic blocs, changes in trade routes, the decline in effective demand, mass migration, the struggle for resources, etc. The necessity for—and approaches to—adapting production to these objective processes will be analyzed below.

A systems approach to the study of complex systems reveals the full set of their parameters, including interactions along the "supersystem–system–subsystems" axis. Since the fundamental task of strategic planning and management consists in monitoring the state of a complex system over time and responding proactively to challenges and changes, a multiple comparison method should be applied both to the entire set of parameters characterizing the system and to its dynamics. The essence of this approach consists in comparing selected parameters of the controlled system, which do not always have a strictly metric form, in a vector format at set intervals, such as a month, quarter, or year. With this approach, not only is the resulting indicator visible—such as changes in the industry's gross revenue or the dynamics of the topological component of the designed electronics—but also the factors that determined the overall change. These may include changes in the number of enterprises in the industry, the structure and physical volumes of output, price changes, etc. System analysis using the multiple comparison method can be effectively combined with artificial intelligence and big data technologies.

The rapid pace of change in both the hardware infrastructure of electronics, along with the constantly improving algorithms used to control it, underscores the critical importance of strategic foresight research, including both established and entirely new technological trends.

Current changes in strategic planning and management methodology can be summarized in comparison to established methods in several key areas. Since the digitization of management processes will become comprehensive in the very near future, the accuracy of forecasts and risk assessments can be expected to experience dramatic improvements. The widespread implementation of artificial intelligence systems will free management personnel from performing routine operations and significantly reduce the risk of errors. Meanwhile, the use of big-data technologies will allow decision-makers to operate not merely with selective aggregate indicators, but also taking into account primary production parameters available to sensors and cyber-physical systems in real time. Thus, with the optimization of industry-specific processes, management professionals will need to focus instead on solving new heuristic problems that arise.

[1] Meeting on the development of microelectronics. Vladimir Putin chaired a meeting on the development of Russian integrated electronics. http://www.kremlin.ru/events/president/transcripts/79027. (In Russ.). Accessed April 01, 2026.

Trends and factors driving the development of the electronics industry

The global transformation unfolding before our eyes is heightening the role of geostrategic factors that affect every aspect of civilized life. Among the most significant developments, particular attention should be paid to the global transformation of the division of labor and expertise, as well as the emergence of cooperation on the scale of large regional technology hubs. Compounding all this is the rapid development of digital technologies and their penetration into every aspect of socioeconomic relations.

Most experts agree that these changes have already begun [1]. The current economic crisis is objective and irreversible due to the market model of self-reproducing capital and aggressive financing having reached growth limits on a global scale. This is evident in the gradual dismantling of the global fiat dollar system. Today, money with its classic five functions no longer exists. As well as depriving Russia of the ability to use so-called reserve currencies, sanctions have revealed their fiat nature to other countries. Due to sanctions, Russia cannot settle payments using its sovereign funds, which it had placed with counterparties to diversify risks. Meanwhile, many friendly countries have been presented with incontrovertible evidence of the unsustainability of a global financial system controlled from a single country. As a result, regional payment systems are actively developing.

This, in turn, creates objective conditions for the regionalization of the real economy. While the global division of labor that emerged in the global electronics industry was economically efficient, it proved to too fragile to cope with systemic shocks. The emergence in the global economy of relatively self-sufficient currency-technology zones implies a clustering into separate macroregions, in which resources, markets, production, and technologies are starting to be concentrated. This process is accompanied by the practice of strict moratoriums on the export of high-tech solutions outside their zones. Since it is already clear that global international cooperation in the field of high technology, including electronics, is effectively impossible, the only viable way forward involves increased reliance on domestic strengths and cooperation models, including with reliable regional partners.

Thus, the strategic goal of Russia and its partners consists in the creation of a macroregion based on existing natural resources and domestic scientific expertise, as well as creative and industrial potential, that is maximally self-sufficient in terms of utilizing productive resources, and in which the population produces and consumes its own goods. Meanwhile, the Western approach to regional transformation is being implemented in an increasingly aggressive, forceful manner. This includes claims to the resources and markets of Latin America, Mexico, Canada, Greenland, and the Middle East, as well as ongoing attempts to maintain a military-monopolistic global hegemony.

Conversely, the framework of our Eurasian region is being shaped on a fundamentally different basis. This involves recognizing the objective interdependence of the economies of various countries and seeking avenues for integration based on the principles of mutual benefit, including strategic predictability and security. The Shanghai Cooperation Organization and BRICS[2] has shown itself to be capable of coordinating harmonious relations among the member states of these international associations to shape a new landscape of relations and create the necessary conditions for the emergence of independent macroregions (currency-technology zones) by leading countries (e.g., Russia, India, and China).

Forms of mutually beneficial cooperation are aimed at mitigating negative socioeconomic changes, such as a global decline in demand, the inevitable decline of the mass production model, the growing scarcity of all types of resources including even drinking water, as well as widespread environmental pollution. The formerly dominant market-based system of reproduction centered on mass consumption, the short life cycle of consumer goods, and the race for ostentatious status symbols, is clearly in the final stages of its existence. From the ruins of its gigantic globalist model, a new world and a new economy are already emerging.

A careful consideration of these factors along with other macroeconomic and geostrategic developments, which include changed migration patterns, includes a reassessment of the direction and depth of technological trends. Information and communication technologies in general—and microelectronics in particular—have already become a prerequisite for establishing a sovereign macroeconomic zone. However, the negative impact of geostrategic factors on the markets for new scientific and technological fields, such as neural networks, new communication technologies, and unmanned transport systems, continues to hold back their development as compared to the more optimistic predictions of experts [2, 3].

However, this can be explained in terms of new approaches to modeling production processes not yet having reached their full potential. Having accustomed themselves to operating under the conditions of fierce international competition, it is economically and psychologically difficult for manufacturers to shift toward cooperation. While competition according to

[2] BRICS—an acronym for Brazil, Russia, India, China, and South Africa—is an informal group of countries with rapidly growing economies.

the winner-takes-all approach has led to significant overconsumption of resources, cooperation, especially when combined with planning and coordination aimed at integrating various actors to achieve a synergistic result, can be applied to ensure reliable and effective industry connectivity. As a result, the private autonomy of manufacturers is increasingly giving way to transparency and traceability of the life cycle of electronic devices, from design and production to their sale, disposal, and subsequent recycling. This will be facilitated by the decision to mandate the labeling of all Russian electronic products, which will enable real-time visibility of the entire process.[3]

As experts from the Club of Rome[4] warned as early as the last century [4], the extensive phase of the market economy's development has now reached its limits. The top priority in the transition to a new, intensive economic model for the country consists in formulating strategic goals for the electronics industry and the economy as a whole. However, the formulation of such strategic goals involves several factors inherent in objective processes of production intensification.

The inevitable shift in production paradigms that is currently underway involves a movement away from large-scale, mass-market assembly-line production of electronic goods, which was focused on the mass consumer and the rapid obsolescence of electronic devices, towards flexible, reconfigurable automated systems and durable devices built on the principles of platform-modular architecture.

The paradigm shift involving the emergence and development of a qualitatively new socioeconomic model was described in detail in the works of the Soviet scholar N.D. Kondratiev [5]. The new post-capitalist paradigm must introduce a number of fundamental changes into the reproductive process. Industrial mass-production technologies should be replaced by those inspired by nature that improve the quality of life of citizens, including the production of high-quality goods that retain their consumer properties for a long time to ensure the rational and efficient use of resources at the same time as respecting the natural environment [6].

The strategic trend toward standardizing products and technologies based on open architectures must become a priority for government agencies. Such an approach will enhance the sovereignty of our future macroregion, strengthen cooperative ties, and significantly reduce the full lifecycle costs of the products being developed.

It is already clear that a revolution is also on the horizon in the refinement of manufacturing processes. While hundreds of operations are currently required to go from crystal growth to a finished electronic product, the transition to manufacturing finished electronic modules using various additive processes, as well as 3D printing of blocks and assemblies, is already being developed through research and development efforts by industry leaders and leading global research centers.

Electronics form the foundation of digital technologies, which in turn influence every stage of industrial production process, from strategic planning to the design of specific products. The development of digital technologies can be viewed as an intrinsic catalyst for the advancement of the electronics industry and electronic products.

An integral aspect of these and other objective socioeconomic processes consists in a concomitant transformation of consumer behavior. The ongoing economic crisis is exacerbated by various negative social shifts, including mass immigration, which in many countries has already become unmanageable and may turn out in the long term to be fatal. This includes a massive decline in the well-being of the so-called middle class and the general population. As purchasing power declines, manufacturers must shift to more flexible technologies that are responsive to scaling back production in line with actual effective demand. Meanwhile, mass immigration and the fierce global struggle for resources create conditions of social oppression and apathy, which have deleterious economic consequences.

The importance of the reputational assets of electronics manufacturers is rapidly growing. Given the global nature of world trade, rational consumer choice based on price-quality criteria is complemented by the equally important criterion of trust in the quality, durability, and efficiency of competing brands—or, more broadly, technological platforms. The strategic success of manufacturers will ultimately depend on consumer choice and their trust. Currently, competition is rapidly developing among several international technological platforms, which are backed by states forming sovereign technology zones. All of these platforms will need to become self-sufficient across the entire value chain, from the production of materials, chemicals, and design and manufacturing tools, to the development of digital intelligent technologies for collecting, processing, transmitting, storing, and analyzing information. Such challenges can be effectively addressed by the development of electronics products.

Meanwhile sanctions, local military conflicts, and artificially created tensions in various regions of the

[3] On Confirmation of Production of Russian Industrial Products. Resolution of the Government of the Russian Federation of July 17, 2015, No. 719. http://government.ru/docs/all/102816/. (In Russ.). Accessed April 01, 2026.

[4] The Club of Rome is an international public organization uniting representatives of the world's political, financial, cultural, and scientific elite.

world have disrupted supply chains, in some cases bringing production and consumption to a standstill. While this is a large, independent topic that requires separate consideration, we outline it here as a factor in the systematic understanding of current global trends.

Russian President Vladimir Putin's remark to journalists from the Financial Times[5] in 2019 that the liberal idea had outlived its purpose turned out to be prophetic: the currently unfolding global political crisis has compounded the already latent economic and social crises. Strategic planning in Russia must be based on the assumption that the economic, social, and political world will never be the same.

TECHNOLOGICAL ASPECTS OF STRATEGIC DEVELOPMENT OF THE ELECTRONICS INDUSTRY

The presented analysis confirms the necessity to develop new approaches to the technological aspects of production. Despite the rapid pace of technological development, the physical structure of global microchip consumption has remained virtually unchanged over the past five years, with the share of traditional solutions at the 350-nm level and above still standing at approximately 50%. The advanced level (below 28 nm) currently occupies approximately 16% of the market, which share has remained virtually unchanged since 2019. By 2030, it is projected to increase to only 17%. Thus, currently and in the coming years, most practical problems have been—and will continue to be—solved using topological standards of 350 nm and above. This, in turn, will impact the structure and quality of the industry's productive forces.

The increase in the average microchip production cycle is indicative. Up until 2020, the average cycle was approximately 30 days. However, with the decision to move beyond topological standards below 7 nm, the cycle began to lengthen to reach 69 days in 2025. This is evidence not only of the complexity of advanced technologies, but also their inherent instability.

Some experts believe that the minimal fabs concept developed by Shiro Hara [7] make it possible to compete with electronics giants, including by reducing the size of wafers. Such approaches are expected to gain momentum and become more competitive. This is due to the fact that the cost of modern giant silicon fabs, which focus on increasing wafer diameters and reducing design topology standards, reaches tens of billions of dollars and continues to rise. As products become more miniaturized, the cost of photomasks and lithographic processing equipment for wafers also increases. The cost of developing process technologies for new submicron technologies is also growing at an accelerated pace. At the present stage, a new superfab needs to sell wafers worth almost USD 20 million weekly for 10 years to ensure a return on investment. According to analysts at PricewaterhouseCoopers[6], the average cost of a chip created using 3-nm technology is 8 times higher than that of a 45-nm chip.

Since the Russian electronics market, especially under the conditions of sanctions, currently lacks the potential for global sales, a promising solution for the Russian electronics industry could involve the creation of low-cost and flexible production lines for processing wafers with diameters of 100–200 mm. Reducing the wafer diameter will lead to reduced fab productivity and increased processing costs per unit of wafer area. However, such solutions are becoming highly competitive for medium- and small-scale production, which currently does not fit into the superfab concept, as the cost of the line itself is reduced by orders of magnitude.

This type of production requires equipment that is modular and can operate in one or two shifts rather than continuously, which provides significant investment and operational savings. Currently, the uptime of advanced lithography systems from the Dutch company ASML[7] is approximately 50–60%, the remainder of the time being spent on maintenance and repairs. Since the cost of such machines is approximately USD 300–400 million, production costs are significantly impacted.

The mini-factory concept significantly lowers the barrier to entry, making this solution potentially attractive for export-focused development. Equipment for assembling integrated circuits and semiconductor devices in various package types can be easily integrated into the wafer production cycle. This results in highly efficient and flexible production systems, including a track for applying and developing photoresists, the corresponding test and measurement equipment, and a range of photoresists, developers, and anti-reflective coatings, to enable a complete cycle from wafer to packaged device. Accordingly, materials and chemistry, as well as design tools and other necessary industrial software, should be included in a packaged proposal for establishing such a facility, along with standard design and engineering solutions.

At the same time, electronic devices themselves are acquiring a platform-modular architecture, which enhances the competitiveness of such factories. As such

[5] http://www.kremlin.ru/events/president/news/60836. (In Russ.). Accessed April 01, 2026.

[6] International network of audit and consulting firms. https://www.pwc.com/gx/en.html. Accessed April 01, 2026.

[7] Manufacturer of lithographic equipment for the microelectronics industry. https://www.asml.com/en. Accessed April 01, 2026.

hardware solutions evolve, their workload becomes more predictable.

Electronic engineering, which became a strategic priority in 2021, already provides the foundation of the productive forces of the Russian electronics industry. For example, in 2024, testing of the first 350-nm projection lithography system, which was created in partnership with the Belarusian company Planar[8], was successfully completed. Two contracts for serial deliveries of these machines have already been signed. The next generation of 130-nm topology lithographs that use a Russian excimer laser should be ready by the end of this year. Meanwhile development of a 90-nm lithograph is already planned. In 2025, development of cluster plasma-chemical etching and deposition machines capable of handling 300-mm-diameter wafers was completed. The industrial strategy, which can be summarized as technology–equipment–chemistry–material, provides the foundation of the sovereignty of the Russian electronics industry.

Particular attention is being paid to the recycling of end-of-life products. The development of technologies for the renewal and recycling of resources holds significant promise. For example, the value of valuable materials recovered from electronic scrap could reach up to RUR 350 billion per year. The advantages of this form of organizing electronic production are significantly greater, and all of them must be considered within the context of strategic planning. The gradual digitalization of all production and management processes has entered the phase of industrial application of artificial intelligence and the creation of smart, adaptable production systems. Such technological breakthroughs are complemented by very significant organizational phenomena.

While artificial intelligence [8] is currently only a new, more advanced form of algorithmic processing of the accumulated knowledge of mankind, the prospects for its future application in production processes are difficult to fully imagine. It can become a comprehensive navigator, freeing specialists from processing already known facts and solutions, and opening up space for creative human activity. A striking historical analogy is the Luddite movement against the use of machines. However, history teaches that it was not machines that "crushed" workers, but workers who began to use machines for the purposes of improving their well-being. A similar situation is now developing with robotics. While the introduction of a fourth element—the "control device"—into the classical structure of the machine, consisting of engine, transmission device, and working element, also alarms many with prospect of the loss of their jobs, it is already clear that the robotization of production processes in the real sector of production will free up "human capital" for to create innovative solutions to the problems of human development arising within the sixth technological paradigm [9] or in Industry 4.0 [10].

A clearer understanding of the difference between artificial and "natural" human intelligence has now emerged. Artificial intelligence has received the adjective "artificial" because it currently processes the vast amounts of information accumulated by humanity in an efficient manner. Human natural intelligence, which has also been forced to engage in this routine work, has sought to obtain synergistic results from existing knowledge. While natural human abilities are already far inferior to computer algorithms in inductive fields, individual scientists have from time to time used deductive reasoning, which relies on an understanding of the subject of research in its entirety and diversity, to penetrate areas of fundamentally new and previously unknown knowledge. The geniuses of scientific history such as Hermes Trismegistus [11], Aristotle, Plato, Kepler, Einstein, Mendeleev, lay in their formulation of such insights in the familiar language of formulas and three-dimensional models. This example clearly demonstrates the division of functions between artificial and natural intelligence.

Thus, the strategic goal of electronics development can be formulated as the comprehensive development of computational and analytical computer programs for artificial intelligence to expand the scope of human creative activity while maintaining absolute control over the algorithms being created [12]. This technological trend will lead to a qualitatively new level of automation of the full cycle of production processes that optimizes the potential of cooperative links within the industry and between related industries. Overall production efficiency will increase thanks to multiparameter forecasting of both technological development and the market for final electronic products. Modern digital technologies and product labeling practices will lead to a leap in the quality of electronic products. Future "intelligent" self-reproducing systems will lead to the transformation of not only production, but also the entire set of socioeconomic relations.

STRATEGIC OBJECTIVES OF INDUSTRY MANAGEMENT TODAY

The methodological challenges of addressing strategic technological development objectives for the electronic industry are detailed in a dedicated monograph [12]. In practice, however, a tremendous amount of work lies ahead, the goal of which is to transform the industry management system into

[8] A developer of specialized technological equipment for the implementation of technologies in microelectronics. https://planar.by/. (In Russ.). Accessed April 01, 2026.

a system that can be broadly described as "Digital Twins of Enterprises and Organizations in the Electronic and Radio-Electronic Industries on the Platform of the Digital Twin of the Electronic Industry."

Modern digital information and analytical systems operate as network-centric systems with a distributed data storage protocol. This information exchange structure has proven its relevance and effectiveness. The ultimate goal of developing a system for collecting, storing, and processing information for the needs of government agencies should be the gradual creation of digital twins of enterprises and organizations in the real economy and digital twins of complex products on the industry digital twin platform. In such a system, all recurring information processes will be automated using the M2M (machine-to-machine) protocol, i.e., machine-to-machine communication.

It should be immediately noted that the transition to digital twin technologies in no way diminishes the importance of highly qualified managers. The Digital Twins hardware and software complex will undoubtedly free up a significant amount of time that managers currently have to spend on routine operations, ranging from collecting primary information to verifying and structuring it for the purpose of developing management decisions. Modern managers are sorely lacking this time to implement a comprehensive, all-encompassing optimization of industry reproduction and the formation of dynamic plans for solving the industry's strategic problems, such as eliminating the technological lag of Russian production, effective import substitution, and the timely implementation of the results of applied research and development, etc. In this area of work, neither the dominance of artificial intelligence nor the danger of technological singularity is visible. Without the participation of highly qualified managers, the management system at the mesolevel [13] will be nonviable.

At the base of the management pyramid will be digital twins of enterprises and organizations in the industry. Both human managers and digital twins will operate with arrays of production, business, and financial information on production in the electronics industry. Moreover, if we compare the arrays of information available for processing even by the most qualified managers with the arrays of information that a digital twin can handle, they are incomparably larger. And the gap will grow exponentially, but this is not a problem; in fact, it will be quite beneficial for decision makers, as they will be increasingly freed from routine tasks.

Previously, the object of strategic planning was the country's national economy. The reproduction cycle was calculated in two main aggregate formats: sectoral and territorial. This enabled, without the need for significant computational power, the calculation of two planned vectors of economic indicators, the comparison of which enabled for the verification or refinement of the methods and source data used. Repeated iterative recalculations were conducted, ultimately yielding an acceptable and plausible version of the strategic goal in specific indicators. This methodology was necessitated by the lack of modern digital tools. Currently, a significantly wider range of reproduction relations can be selected as the object of strategic planning. In its most general form, such an object can be called the "Electronics and Radioelectronic Industry Ecosystem."

The REI ecosystem can be conceptualized as a complex network of software-based and digitized actors, processes, technologies, and infrastructure that interact to create, produce, and distribute electronic products, including electronic components and REI. The ecosystem includes companies, research organizations, government institutions, suppliers, consumers, and other stakeholders.

A digital twin of an industrial sector, in this case the REI, is a computer model that enables planning, modeling, and optimization of the operations of enterprises in the industry and their interactions, including technological competition and production and business cooperation, and also ensures the dynamic formation of new supply chains for the fulfillment of complex orders [14, 15]. In computer terms, this is a platform that is formed on a powerful hardware and software complex, onto which digital twins of control objects are integrated.

A digital twin of a controlled object is a cyber-physical system augmented by a computer model of the controlled object, reflecting its state at any given moment and synchronized with the actual state of the physical object. A digital twin of a controlled object can be used for proactive planning and forecasting of the object's future behavior, as well as for modeling the object's behavior under any scenario. Types of digital twins of controlled objects are rapidly evolving from digital shadows of a real statistically monitored object to the formation of cognitive digital twins of enterprises and REI organizations, built on the basis of big data and artificial intelligence technologies.

A digital twin of an enterprise is an ontological twin of a real enterprise or organization, based on an ontological knowledge base.

Real electronics factories and their digital twins are linked into technological production chains, beginning with raw materials and ending with finished products. In the digital version, such chains should be represented as product graphs. This is a cybernetic object that digitally represents the relationships between product components located at the graph's vertices (objects) through edges (production and business relationships). The introduction of comprehensive labeling of electronic products[9], coupled with the construction of product graphs, will not only enable quality control of the final product but also immediately identify those responsible for defects. This approach will enable the rapid integration of partial results of completed research and development (R&D) projects within product graphs, greatly accelerating the technological development of the industry and guaranteeing the quality of the REI products.

Thus, the digital system for preparing industry management decisions can be broadly termed the "Digital Model of the REI," which includes three interconnected modules: an information and reference system, an analytical simulation modeling unit, and a digital "intelligent" voice interface. As this system develops, intensive and extensive improvement processes are implemented.

This model is now generally referred to as a cyber-physical system. It is a computer system that integrates tools for obtaining primary data from databases and sensors; computing tools for performing computer calculations, transmitting and processing data, and controlling physical processes using actuators; and communication tools for interaction with users and decision-makers.

ORGANIZATIONAL CHANGES

Strategic planning for such a specific industry as the electronics industry has another important aspect. Russian industry is an extremely complex reproduction system, and traditional manual management methods do not provide a synergistic increase in efficiency or a reduction in the complexity of management information flows. Therefore, quantitative changes have accumulated that must be transformed into a qualitative leap in the meso- and macroeconomic management system [16].

Within the complex Russian economy, distinct sectors (transportation, communications, finance, etc.) have cross-cutting functionalities across the entire economy. The electronics industry has similar functions, but it is integrated into the conglomerate known as industry and trade.

The macroeconomic role of electronics has increased immeasurably compared to the 1990s, when it was consolidated into an independent ministry. In the strategic perspective, electronics will become a dominant factor in all spheres of government. These trends indicate the need to separate the REI into an independent industry, as was done in the Soviet Union's economy in the 1960s. At that time, this organizational measure, coupled with the development and approval of the General Plan for the Development and Allocation of Productive Forces for the Strategic Perspective, allowed the country's economy to achieve parity with world leaders in electronics [17]. This experience should not be neglected.

Industry self-determination of the electronics industry will enable, within the framework of big data technology, the creation of dynamically updated classifiers, starting from a closed list of enterprises and organizations of the REI, as well as classifiers of equipment, personnel, and products both in a subindustry context and with an understanding of the localization of their production thanks to the product labeling system currently being deployed.

SOME ASPECTS OF STRATEGIC PLANNING AND MANAGEMENT METHODS

Data collection and processing system

The implementation of such a large-scale management system must be preceded by a full-scale inventory of enterprises and organizations in the industry [18]. As a reliable database and knowledge base are created in the industry, a digital twin of the REI should be created and approved for training. As REI enterprise managers master digital management technologies, REI enterprises and organizations of all types of ownership and legal entities will be connected to this platform. The synergistic effect of such organizational transformations will be achieved already at the stage of creating a system incorporating 50–100 of the largest enterprises in the industry, and will increase as the management and information integration of REI enterprises progresses.

In existing regulatory documents defining the foundation of economic management, the concept of information, which is the starting point of any management decision, is used too generally, without a strict topology (the format of each indicator) and metrics (attributes reflecting the volume or dynamics of the processes characterized by a specific indicator). Therefore, it is necessary to clarify that information for the purposes of modeling decision-making processes in the industry must be *reliable*, *comparable*, and *equatable*, and the methodology for obtaining information from the primary source must be the same for all aggregated indicators [19].

[9] Resolution of the Government of the Russian Federation of November 28, 2025 No. 1954 "On approval of the Rules for marking certain types of radio-electronic products with identification means and the specifics of the implementation of the state information system for monitoring the circulation of goods subject to mandatory marking with identification means, in relation to certain types of radio-electronic products." http://publication.pravo.gov.ru/document/0001202511290036. (In Russ.). Accessed April 01, 2026.

Without fulfilling these basic mandatory conditions, the aggregation of indicators of enterprises and organizations into general industry indicators is inadequate from a scientific point of view and contains systemic errors, the multiplication of which makes information aggregated from several noncomparable indicators unreliable.

Without delving into the intricacies of statistical science, we will highlight only the most general, yet absolutely essential, requirements for the collected production, economic, and financial information. Primary information is information obtained directly from the object of statistical observation. Previously, it was collected by the relevant departments of enterprises and primary statistical offices throughout the country. Now, it is possible to automate the collection of any primary production, economic, and financial information using so-called cyber-physical agents.

Only aggregated information that can be verified based on the primary data obtained directly from the object of statistical observation can be considered *reliable*. For the needs of industry management, primary information is aggregated into summary indicator formats, but the "ancestral trail" of each summary indicator can always be traced back to the enterprise or organization level. An aggregated industry indicator must be equal to the sum of similar indicators for enterprises and organizations within the industry, down to the last decimal point. If a deviation occurs, a special review of the causes of the discrepancy is required. This is possible. Therefore, the indicator is called aggregated, not summary. However, the deviation and its causes must be rigorously statistically assessed and, if necessary, adjusted.

Aggregated information obtained using a unified methodology for collecting and processing primary data can be considered *comparable*. It is strictly forbidden to aggregate, for example, indicators obtained directly through statistical observation and indicators obtained through an analytical method or a random survey method. This creates systematic statistical errors, which are unacceptable when making management decisions in general and strategic decisions in particular.

Comparability of information characterizes the inherent properties—the quality of the information itself—while comparability of aggregated information demonstrates the admissibility and correctness of comparing similarly named indicators in a time series. This is necessary for recognizing extensive and intensive factors influencing aggregated indicators. For example, the number of electronics companies changes from year to year, and the performance of each change. Therefore, it is necessary to identify the parts of the indicator change (increase or decrease) associated with changes in the number of objects of statistical observation and with the factor of improvement or deterioration in the performance of enterprises. Furthermore, all aggregated indicators must be recorded on the same date of receipt of the primary information and accounted for a comparable accounting period. These are only the most general, unavoidable requirements for management information. More precise statistical settings require a more thorough analysis of the primary indicators.

Statistical observation has many other important limitations and criteria, which we will leave to specialists. Here, we will simply highlight the problem that for planning, especially at a strategic depth, the indicators, and indeed all information used in the simulation model, must be as relevant as possible to the actual state of each enterprise and the industry as a whole, in both metric and dynamic terms.

Knowledge base and ontologies

The ability of modern algorithms (so-called large language models) to recognize and process not only numbers but also text is based on the scientific method of information ontology. This is a methodology for the ontological description of the qualitative parameters of phenomena, processes, or structures, such as equipment, enterprises, and organizations in the REI, with an emphasis on key properties in the form of actors, collections, structure, and attributes, which are used in subsequent modeling [20].

Agents of a multiagent model

Digital technologies make it possible to consider an ever-increasing number of factors, parameters, external disturbances, etc., integrating them into a strategic planning model by connecting an ever-increasing number of modules (agents). An agent (module) is autonomous software capable, within the framework of its assigned functions, of analyzing collected information, optimizing decisions, interacting and negotiating with other agents (M2M), informing decision-makers of the results of its actions, issuing recommendations, and incorporating feedback from all human and automated counterparties. An agent is capable of not only performing once-programmed tasks but also of continuously learning. Digital technologies make it possible to automate the entire cycle of routine and repetitive factors and, through combinatorial analysis, calculate a multitude of possible final values.

Visualization tools

Having almost all the metric and ontological information about the reproduction process in the industry, the control subsystem can generate visual graphs that will also be used in the procedures of strategic management of the REI.

ANTICIPATED RESULTS

As a result of the phased implementation of the digital twin of the REI, the following results are expected:

1. The system will be secure thanks to a layered user authorization subsystem.
2. A digital industry corporate platform will be created for interaction between all authorized participants in reproduction in electronics, which can be collectively referred to as the State Information System of Industry Electronics (SISIE).
3. A dynamically maintained digital classifier of REI enterprises will be created, whose relevance will be continuously maintained by an "intelligent" agent.
4. A digital classifier of REI will be created, broken down into the main subsectors, and linked to the mechanism for labeling products and their components.
5. A classifier of REI technologies will reveal the relative technological levels of Russian and foreign manufacturers and their dynamics online.
6. A dynamically supported classifier of REI personnel will be created, linked by digital algorithms to existing systems for training personnel, improving their qualifications, and personal career plans.
7. A reliable and comprehensive statistical database on REI will be created, along with a tool for its "intelligent" verification, processing, and visualization.
8. A digital "intelligent" agent will be put into operation, which will verify all information in the system online 24/7.
9. The analytical unit in the format of a digital twin model of the REI will calculate all possible consequences of management and technological decisions and propose several scenarios of strategic actions to optimize the final result.
10. Thanks to digitalized product graphs, the digital twin model of the REI will continuously record the balance/imbalance not only for the industry as a whole, but also for individual production items.
11. Product graphs will not only enable the current competitive cost of REI products to be maintained through strict alignment of physical production proportions, but also support online cost-effectiveness analysis of price versus quality, which will reduce the burden on the budget.
12. By expanding the digital twin model of the REI to function as a general plan for the development and deployment of productive forces, a layered linkage of R&D and production over a time horizon of 10–15 years will be facilitated.
13. All industry aggregated indicators will be programmatically linked to the actual primary indicators of enterprises and organizations of the REI. This will enable the targeted identification of those responsible for production failures and the elimination of the causes.
14. A comprehensive, general indicator of the efficiency of the electronic product reproduction cycle will not only include production, but also the entire socially significant chain of "product development (resource and material support for its reproduction) that best meets consumer requirements, including operational and repair support, as well as environmentally safe disposal."

CONCLUSIONS

Following its implementation, the conceptual version of the presented strategic planning and management model developed in Russia, which proactively responds to emerging risks and challenges, will provide a means for overcoming the technological backwardness of Russian electronics, enable the development of the industry, tackle the shortage of highly qualified personnel, and move away from dependence on imports of critical electronics in the context of sanctions aggression.

The general plan for the development and deployment of REI's productive forces will enable effective R&D and the development of in-house technologies that are integrated with the training of qualified personnel focused on new technological advances. It will create conditions for the formation, development, and strengthening of a macroeconomic region of friendly countries, facilitating the emergence of alternative production and supply chains, and thereby increasing the scale and efficiency of production. The described model for the digitalization of industry has the potential to be scaled up for the purposes of managing the entire economy.

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