

From ESG to EICSG (Environment, Intelligent, Cyber, Social, Governance) strategic management in Industry 5.0

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Abstract. The article develops strategic recommendations for improving the management practices of integrating modern scientific achievements into the processes of sustainable development of industrial ecosystems, adapted to the requirements and challenges of Industry 5.0. The concept of industrial EICSG-ecosystem in the context of Industry 5.0 is developed, combining elements of environmental (E - environmental), intellectual (I - intelligent), cyber-social (CS - cyber-social) and governance (G - governance) resilience. The conceptual components of effective development of industrial EICSG ecosystems, which form the organisational basis of Industry 5.0, are proposed. The prerequisites of strategic management of the industrial EICSG ecosystem of Industry 5.0 are defined.

1 Introduction

Industry transformation is taking place at all levels. At the macro level, a fundamentally new cyberinformation, complex, integrated mechanism of public-private, program-targeted management of strategic and tactical-operational development is being formed. At the meso-level, new forms of structural and functional organization and institutional self-regulation are rapidly emerging and replicated. It should be particularly noted here that industries are beginning to share the place of leadership with fundamentally new meso-organizational aggregates. The latter include EICSG-ecosystems (environmental, intelligent, cyber-social, governance), into which industrial cyber-social clusters are being transformed. The process is conditioned by the objective necessity of industry's transition to the principles of fundamental integrativity and bimodality.

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The newly emerging industrial EICSG-ecosystems designed to provide the organizational foundation of Industry 5.0 are new meso-organizational aggregates of industry. They are being formed today as leaders of a new integral cyberinformational mode of production and the integral cyberinformational society of the same name.

2 Literature review

Strategic management of effective development of industrial EICSG-ecosystem in the context of Industry 5.0 is a multidimensional task.

Meshcheriakova and Chernyaev [1] emphasize the need to form an industrial enterprise ecosystem adapted to the conditions of ESG-transformation. Malevskaia-Malevich [2] investigates the possibilities of green finance to support sustainable development of industrial ecosystems of smart cities in the context of circular economy. Zhu et al [3] analyze the two-way effects of ESG commitments by industrial firms affecting green innovativeness. Guo et al. [4] investigate the effect of industrial agglomeration on corporate ESG performance. Litvinova et al [5] examine the integration of ESG principles into the management practices of agro-industrial enterprises. Liu et al [6] propose to use graph neural networks to analyze the impact of ESG ratings on industrial chains. Degtyarev [7] emphasizes the peculiarities of forming a digital ecosystem of industrial enterprises to ensure their sustainable development. Chang and Lee [8] and Kao [9] investigate the impact of ESG activities on the value of companies and the evaluation of industrial park management efficiency. Sun and Saat [10] analyze how smart manufacturing affects the ESG performance of manufacturing companies.

However, as the empirical analysis of databases of scientific publications shows, there is an almost complete absence of works, where the object of research is not just the Industry 5.0 ESG-ecosystem, but the intelligent cyber-social industrial ESG-ecosystem (in the author's interpretation - EICSG-ecosystem). Attempts to conceptualize such a new object were made at the end of 2023 by the consulting company EY in a discussion report [11] dedicated to the convergence of artificial intelligence and ESG factors. The said report recognizes that the convergence of artificial intelligence and environmental, social and governance (ESG) factors is a key development in today's rapidly changing business landscape. The report's authors conducted an in-depth analysis of the symbiotic relationship between artificial intelligence and ESG, critically assessed the impact of artificial intelligence on ESG metrics, and offered practical recommendations to mitigate potential issues. By integrating artificial intelligence into risk management and ESG strategies, industrial ecosystems can not only achieve their sustainability goals, but also open up new opportunities to drive sustainability and organizational innovation.

3 Methods

The use of methods of classification, logical-structural analysis and synthesis, object and structural-logical modeling, as well as generalization allowed us to propose a number of conceptual theoretical and theoretical-practical models and mechanisms useful for the organization of industrial EICSG-ecosystems as an organizational basis for the formation of Industry 5.0.

4 Results

4.1 Conceptual EICSG-framework in Industry 5.0

The most important stage on the way to the transition to the new reality of the integral cyberinformation society is the phenomenon of the emergence and accelerated evolution of the Industry 5.0 industrial EICSG ecosystem, which expands the scope of the classical understanding of ESG development to include environmental (E), intellectual (I), cybersocial (CS) and governance (G) components. In other words, the emergence and rapid development of the EICSG industrial ecosystem within Industry 5.0 represents a paradigm shift beyond the traditional understanding of ESG development. This new concept incorporates environmental, intelligence, cybersocial and governance components to form a complex convergent system in which these elements interact synergistically to promote sustainable development of industrial systems in the emerging realities of Industry 5.0 [12].

The Industry 5.0 industrial EICSG-ecosystem is a complex convergent system in which environmental sustainability, human and artificial intelligence capabilities, cybersocial integration, and good governance interact to create a new level of co-evolution, synergy, and emergence to achieve sustainability and resilience of industrial systems under Industry 5.0 conditions. In the context of Industry 5.0's industrial EICSG-ecosystems, the environmental component emphasizes the pursuit of minimizing environmental impacts and actively using the principles of various sustainability concepts (circular economy, green economy, blue economy, cradle-to-cradle, efficient economy, biomimicry, eco-innovation concept, regenerative design, industrial ecology, industrial symbiosis, bioeconomy concept, etc.) to create closed cycles of production and consumption. This approach not only solves environmental problems, but also improves resource efficiency and preserves the natural capital necessary for long-term industrial prosperity. The intellectual pillar emphasizes the key role of human capital, innovation and knowledge. It involves harnessing the collective (natural and machine) intellectual potential to improve efficiency and competitiveness through research and development, application of artificial intelligence, machine learning and big data analytics. It is about creating an ecosystem that is constantly learning and evolving, utilizing intellectual resources to create breakthrough innovations and adaptive solutions. Cybersocial inclusion, a component of CS, reflects the unique merging of digital technologies with social processes to improve the well-being of the population, enhance the quality of life and ensure inclusiveness in access to information resources and technologies. It implies the creation of a digital environment that fosters collaboration, knowledge sharing and community engagement, thus strengthening the social fabric of the industrial ecosystem. Finally, the G dimension of governance emphasizes the need to change traditional governance approaches to accommodate the dynamics of the cyber-social economy. It requires the creation of transparent, flexible and adaptive governance structures that can effectively respond to changes in the external environment and ensure stakeholder participation in decision-making processes [13].

Thus, the EICSG ecosystem in Industry 5.0 is an intelligent infrastructure that combines technological advances with environmental and social management, underpinned by robust governance mechanisms. It is a model that promotes sustainability, adaptability and growth, ensuring that industrial activities contribute to the well-being of society and the environment while harnessing the transformative potential of the digital age.

The authors systematized the conceptual components of effective development of industrial EICSG-ecosystems (Fig. 1), consisting in the creation of an integrated, intellectually rich and flexibly managed system that is able to function and develop effectively in the dynamic environment of Industry 5.0.

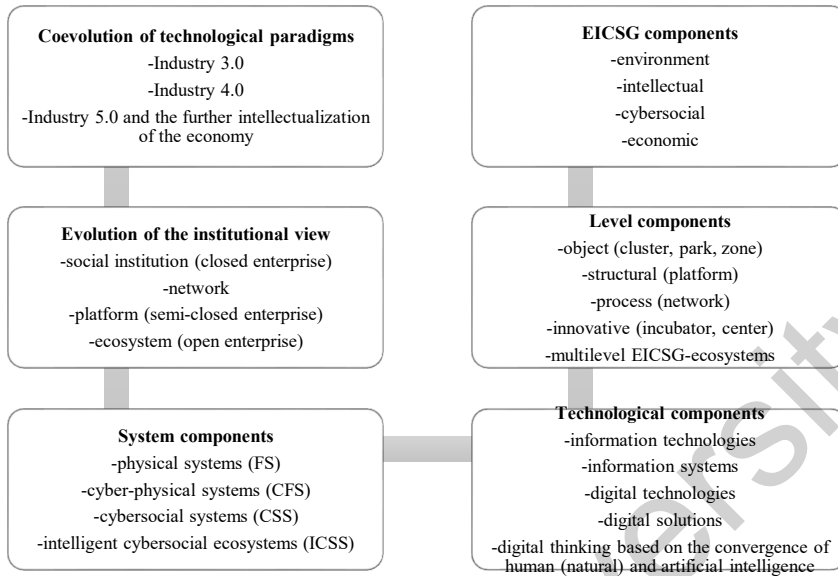


Fig. 1. Conceptual components of effective development of industrial EICSG-ecosystems under Industry 5.0 conditions

The essence of the conceptual approach presented in Figure 1 is the co-evolution of technological paradigms, where the leap from Industry 3.0, Industry 4.0 to Industry 5.0 means not just gradual technological progress, but a comprehensive intellectualization of the economy. This intellectualization is also characterized by an evolutionary shift in the institutional view of enterprises: from social institutions encapsulated in closed systems to open ecosystems that are dynamic, interconnected and expansive. Networks and platforms serve as intermediate stages, representing semi-closed enterprises that gradually move towards the open enterprise model characteristic of ecosystems. The system components of EICSG ecosystems include a spectrum from physical systems that form the physical infrastructure, to cyberphysical systems that combine physical operations with computational processes, and further leading to cybersocial systems that combine social interactions with cyber networks. The pinnacle of this evolution is the intelligent cybersocial ecosystem that utilizes advanced computing capabilities, data analytics, and machine learning to create a self-aware and self-improving industrial environment. At the core of these systems are technological components: information technologies that serve as the foundation for data and communication, information systems that provide a structured framework for operations, and digital technologies that pave the way for innovation. From this technological foundation, digital solutions emerge, fueled by digital thinking, which embodies the convergence of human intelligence with artificial intelligence, resulting in smarter, more responsive and efficient industrial ecosystems. Tiered components further dissect the EICSG ecosystem into its constituent parts, including entities such as clusters, parks, and zones that define the physical space of industry. Structural components, such as platforms, enable the integration and interaction of the various ecosystem actors, while process components, such as networks, facilitate the flow and exchange of information and resources. Innovation components, including incubators and hubs, provide a breeding ground for new ideas and technologies, fostering an environment where innovation is not only encouraged but also systematically implemented. Finally, the EICSG components themselves represent the pillars of sustainability and resilience of the industrial ecosystem. The ecological component ensures environmental stewardship, the intellectual component promotes knowledge creation and

application, the cyber-social component enriches community and digital interaction, and the economic component guarantees the financial viability and market competitiveness of the ecosystem. Each of these components intertwine with each other, working in concert to create a robust, sustainable, and future-proof industrial ecosystem that is well-prepared to meet the challenges and opportunities of Industry 5.0 [14].

4.2 Prerequisites for the strategic management of the Industry 5.0 industrial EICSG ecosystem

The industrial EICSG ecosystem, given the inherent complexity and breadth of its constituent components, requires strategic management that is forward-looking and adaptive. Such strategic management must recognize the interdependencies within the ecosystem and actively seek to balance and harmonize environmental sustainability, intelligence, cybersocial integration and governance.

Compliance with modern environmental norms and standards requires strategies that not only mitigate anthropogenic pressures but also actively promote environmental health. Such strategies must be based not only on regulatory compliance, but also on a strategic commitment to innovation in sustainable practices - eco-innovations such as the development and deployment of clean technologies, waste reduction and energy efficiency. The intelligence component of industrial EICSG eco-systems emphasizes the integral role of artificial intelligence and machine learning in shaping the future of Industry 5.0. I-component management strategies must take into account the enhanced cognitive capabilities of artificial intelligence systems that can process vast amounts of data, learn from patterns, and make autonomous decisions to improve efficiency, innovation, and adaptability of industrial processes. The cybersocial dimension requires strategic oversight of digital transformation processes based on digital strategizing, data management, and ethical use of technology to ensure that digital advances contribute positively to the overall maturity of the ecosystem. Governance in the industrial EICSG ecosystem is not only about internal corporate governance, but also about how the ecosystem as a whole interacts with external stakeholders and responds to macroeconomic trends and policy changes. Strategic management here needs to be inclusive, transparent and aligned with broader societal goals.

The industrial EICSG ecosystem thus requires a multi-dimensional approach to strategic management that incorporates advanced analytics, stakeholder engagement, and a deep understanding of the dynamic interactions between different components. Such an approach should be able to guide the ecosystem to meet the challenges of Industry 5.0, capitalizing on opportunities for growth while ensuring sustainability and resilience.

5 Conclusion

As a result of the study, strategic recommendations were developed to improve management practices, integrate modern scientific achievements and educational resources into the processes of sustainable development of industrial ecosystems, adapted to the requirements and challenges of Industry 5.0. The key achievement was the identification and detailed description of the conceptual foundations for the effective development of EICSG-ecosystems, which implies not only technological renewal, but also the transformation of managerial, educational and scientific practices. A unique concept of industrial EICSG-ecosystem is developed, which appears as an organizational foundation of a new industrial era, conditioned by deep integration of digital, physical, biological and social technologies. Special attention is paid to the prerequisites of strategic management and the most important characteristics of the transition to an integral cyberinformation society, which emphasizes the

need for coordinated work of all elements of the system in the conditions of the new economic and social reality.

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