DOI: https://doi.org/10.32782/2524-0072/2025-78-113

UDC 336.5.02:005.935

COST MANAGEMENT SYSTEMS AND BUSINESS PROCESS CONTROL: HISTORICAL AND METHODOLOGICAL PRINCIPLES AND TRANSFORMATION VECTORS IN THE CONTEXT OF INDUSTRY 4.0

СИСТЕМИ УПРАВЛІННЯ ВИТРАТАМИ ТА КОНТРОЛЬ БІЗНЕС-ПРОЦЕСІВ: ІСТОРИКО-МЕТОДОЛОГІЧНІ ЗАСАДИ ТА ВЕКТОРИ ТРАНСФОРМАЦІЙ В КОНТЕКСТІ ІНДУСТРІЇ 4.0

Bikulov Damir
Doctor of Science in Public Administration, Professor,
Zaporizhzhia National University
ORCID: https://orcid.org/0000-0001-9188-7310

Veritova Olga
PhD in Pedagogical Sciences, Senior Lecturer,
Zaporizhzhia National University
ORCID: http://orcid.org/0000-0001-7365-701X

Petrova Kateryna
PhD in Public Administration, Associate Professor,
Zaporizhzhia National University
ORCID: https://orcid.org/0009-0007-0352-7907

**Бікулов Дамір Тагірович, Верітова Ольга Сергіївна,
Петрова Катерина Володимирівна**
Запорізький національний університет

The purpose of the study is to analyze cost management systems and business process control from historical and methodological perspectives and to identify key vectors of their transformation in the context of Industry 4.0. The relevance lies in combining the stability of classical accounting with the flexibility of digital platforms to adapt to national practices and real-time requirements. An evolutionary overview of the development stages of cost accounting has been carried out, from classical approaches to digital transformation and ecosystem-based management. The research methodology relies on historical-system analysis, international case studies, theoretical synthesis, and modeling of future transformations in cost management and business process control within the framework of Industry 4.0. The stages of system development and the impact of tools (IoT, Big Data, AI, digital twins, blockchain) have been identified. The international experience of companies such as Toyota (Lean/Kaizen, JIT), Siemens (digital twins), Bosch (5S, Poka-Yoke, IoT), GE (predictive maintenance), Nestlé (ERP/BI), and Amazon (robotization, ML) has been studied, which made it possible to outline adaptive strategies and approaches for different levels of technological maturity, industries, and the Ukrainian context. The results of the study have both practical and strategic significance, as they reconstruct the evolution of cost accounting systems and provide practical steps for adapting Industry 4.0 technologies to cost management, with further identification of their development vectors.

Keywords: cost management, business process control, Industry 4.0, international experience, evolutionary development, digital transformation, planning, dynamic budgeting.

Мета даного дослідження полягає у аналізі систем управління витратами та контролю бізнес процесів з історико методологічних позицій і виявлення ключових векторів їх трансформації в умовах Індустрії 4.0. Актуальність роботи постає у поєднанні методологічної стійкості класичного обліку з функціональною гнучкістю цифрових платформ, яка особливо важлива для адаптації до національних практик і вимог реального

часу. У роботі було виконано історико-методологічний огляд ключових еволюційних етапів розвитку обліку витрат починаючи від класичних підходів системи обліку і калькулювання до більш сучасної аналітично-цифрової трансформації в умовах Індустрії 4.0 та еволюційно адаптивного і екосистемного управління витратами. Методика дослідження спирається на систематично-історичний аналіз, компаративний огляд міжнародних кейсів, синтез теоретичних джерел і концептуальне моделювання майбутніх векторів трансформації систем управління витратами та контроль бізнес-процесів в контексті Індустрії 4.0. У результаті було виділено послідовні етапи розвитку систем управління витратами, проаналізовано вплив інструментів Індустрії 4.0 (інтернет речей, великі дані, штучний інтелект, цифрові двійники і блокчейн). Додатково було виконано порівняльний аналіз міжнародного досвіду на прикладі компаній Toyota (операційна оптимізація витрат на основі Lean/Kaizen і JIT), Siemens (впровадження цифрових двійників і кібер-фізичних рішень), Bosch (візуалізувати виробничі процеси шляхом впровадження 5S і Poka-Yoke у поєднанні з локальними IoT-рішеннями і створенням навчально-практичних центрів), General Electric (програми передбачувального обслуговування), Nestlé (уніфікацію фінансового й операційного обліку через впровадження ERP/BI), Amazon (роботизацією складів і застосуванням ML-алгоритмів прогнозування попиту), що дозволило виокремити адаптивні стратегії, підходи для різних рівнів технологічної зрілості, галузевої специфіки та національного контексту України. Виділено, що отримані результати у рамці даного дослідження мають прикладне і стратегічне значення, через реконструкцію історико-методологічних розвитку систем обліку витрат і наданих практично-орієнтованих рекомендаційних кроків адаптації технологій Індустрії 4.0 до систем управління витратами і подальших майбутніх векторів їх розвитку.

Ключові слова: управління витратами, контроль бізнес-процесів, Індустрія 4.0, міжнародний досвід, еволюційний розвиток, цифрова трансформація, планування, динамічне бюджетування.

Formulation of the problem. In the context of rapid digitalization of business processes and the growing influence of Industry 4.0 on management practices, the modernization of cost control and planning systems becomes a decisive factor for the competitiveness of enterprises and their integration into global economic networks. Despite the fact that Industry 4.0 tools create conditions for effective budgeting, real-time monitoring, and platform-based coordination of costs, the practical transition from classical accounting models to ecosystem-based digital solutions is hindered by the lack of step-by-step adaptation of international experience in the national context and the absence of digital initiatives capable of transforming cost management at a systemic level. This situation leads to inefficient implementation of digital initiatives, limits the multiplicative effect of investments, and reduces the resilience of enterprises to external risks.

Analysis of recent research and publications. A historical review of cost management systems demonstrates an evolution from rigid regulation to flexible models. Classical works by Wildman J. R. [1] and Harrison [2] laid the foundation for systematization of costs and variance analysis. In the 1940, Paton W. A. and Littleton A. C. [3] emphasized the role of standard costing as a key tool for cost management. The next stage was the introduction of activity-based costing, initiated by Cooper R. and Kaplan R. S. [4] and confirmed in contemporary reviews by Sánchez-Rebull M. V., Niñerola A., and Hernández-Lara A. B. [5], which allows more accurate attribution of overhead costs. In the 1980-1990, Lean/Kaizen approaches (works by Ohno T. [6], Imai M. [7], Womack J. P., Jones D. T., Roos D. [8]) shifted the focus toward optimizing business processes and eliminating waste. The integration of information systems (ERP) in the context of cost management was reflected in the findings of Davenport T. H. [9], who argued that ERP platforms unify finance, logistics, and cost accounting, thereby increasing operational transparency. In the context of Industry 4.0, researchers highlight digital technologies such as the Internet of Things, Big Data, artificial intelligence, cloud computing, and blockchain, which together create a new predictive logic of management as a driver of transformation. In particular, contemporary studies by Schwab K. [10] and Dai J., Vasarhelyi M. [11] emphasize that Industry 4.0 enables the shift in cost modeling approaches from post-factum analysis to forward-looking forecasting. Important benchmarks include the works of Nakamoto S. [12], Tapscott D. and Tapscott A. [13], Parker G., Van Alstyne M., Choudary S. [14], and Asadi S. K. M. [15], which demonstrate that blockchain and platform architectures form ecosystem-based models of cost management and ensure intercorporate transparency and trust. However, issues related to the historical and methodological foundations and transformation vectors of cost management and business process control systems in the context of Industry 4.0 have not yet been sufficiently addressed.

Highlighting previously unresolved parts of the overall problem. Despite the existence

of a thorough analysis of the historical and methodological stages and traditional approaches to cost management, several key issues remain unresolved in the academic literature, which are becoming particularly relevant in the context of digital transformation. First, the direct impact of Industry 4.0 technologies on cost management systems and business process control mechanisms has not been sufficiently studied, which limits their practical application for enhancing transparency and efficiency. Second, there is a lack of systematic developments aimed at summarizing and adapting international experience in cost management and business process control, particularly in the form of step-by-step implementation measures and practical recommendations for Ukrainian enterprises, which hinders the formation of an effective transformation model in the national environment. Third, comprehensive vectors of future transformation of cost management systems and business process control in the context of Industry 4.0 have not been formulated. Such vectors should integrate organizational prerequisites, digital tools, and human competencies into a unified development framework. Addressing these aspects will make it possible to move from descriptive characteristics to the creation of a holistic methodology that ensures process discipline alignment, data standardization, and the implementation of adaptive cost management models in the digital economy.

Formulation of the article's objectives. The purpose of the work is to analyze cost management systems and business process control from historical and methodological perspectives and to identify the key vectors of their transformation in the context of Industry 4.0. Within the framework of the study, existing approaches to the organization of cost control and accounting will be summarized, the impact of modern digital technologies will be assessed, and international experience will be considered in accordance with the concepts of the «intelligent enterprise» and the «circular economy», as well as conclusions will be drawn regarding the adaptation of these solutions in the Ukrainian economic context. **The tasks of the work** are as follows: 1. to identify the key evolutionary stages and approaches in cost management; 2. to examine the impact of Industry 4.0 technologies on cost management systems and business process control; 3. to study international experience in cost management and business process control and its transfer into the national context; 4. to define the future vectors of transformation of cost management systems and business process control in the context of Industry 4.0.

Summary of the main material. Cost management systems are constantly evolving under the influence of economic conditions and technological innovations, which requires a continuous review of traditional approaches. For a more comprehensive understanding of these changes, it is advisable to identify the key evolutionary stages and approaches in cost management, which are shown in Fig. 1.

The comparison of the stages of development of approaches to cost management (Fig. 1) makes it possible to see not only the sequence of changes but also the gradual shift of emphasis from strict regulation to flexible adaptability. At the stage of «Classical accounting and costing systems» (1900-1940), the main focus was on the development of directive costing and formalized accounting, which served as the basis for cost control. At that time, costs were considered exclusively as an element of financial reporting; therefore, the system had clearly defined boundaries and minimal adaptability. In fact, already then the scientific works of the classics Wildman J. R. [1], Harrison G. C. [2] shaped the approach to the systematization of costs and laid the foundation for variance analysis. According to the observations of Cooper R., Kaplan R. S. [4] and Waweru N. M. [16], most costing techniques were developed before 1925. The transition to the stage of «Normative and planned accounting through budgeting and standard costing» (1940–1970) was marked by the expansion of the scope through normative and planned accounting, which was based on the principles of budgeting and standard costing. This made it possible to transform costs into an object of systematic management, creating mechanisms of centralized planning and variance control, which subsequently gave enterprises the opportunity to forecast and control production processes, whereas the previous stage only recorded their final results.

As noted by Paton W. A., Littleton A. C. [3], standard costing was the key tool of cost management, which by the 1950–1960 was widely applied in practice [16]. The further development of the stage «Activity-oriented costing and attribution of indirect costs» (1970-1980) was focused on the active use of the attributive approach (based on cost factors), which was embodied in the methodology of activity-based costing (ABC). This approach

KEY EVOLUTIONARY STAGES AND APPROACHES IN COST MANAGEMENT			
Stage		**Approach**	**Features**
STAGE 1 1900-1940	**Classical accounting and calculation systems**	full (direct) costing and formalized accounting as a cost verification tool	emphasis on accuracy of regulatory reporting and compliance with regulations
STAGE 2 1940-1970	**Regulatory and planned accounting through budgeting and standard costing**	planning through standards and deviation control as the basis for cost management	centralized standardization of indicators and the advantage of plan-control in conditions of relative stability of production processes
STAGE 3 1970-1990	**Activity-based costing and indirect cost attribution**	attribution of indirect costs through activities for more accurate costing of products and services	better visibility of resource-intensive operations and adjustment of pricing policy based on activity-based cost structure
STAGE 4 1980-2000	**Organizational and operational optimization**	continuous improvement and elimination of losses in value streams	focus on minimizing unproductive costs, reducing inventories and shortening production cycles
STAGE 5 1990-2010	**Integration of business information systems and total automation**	end-to-end integration of business processes and data centralization for unified accounting and control of resources	unification of accounting procedures, consolidated reporting and increased efficiency of decision-making
STAGE 6 2010-2025	**Analytical and digital transformation in the context of Industry 4.0**	real-time analytics-driven cost management using cyber-physical integration	predictive and prescriptive planning, operational resource control and adaptive adjustment of calculations based on streaming data
STAGE 7 2025-TODAY	**Evolutionary adaptive and ecosystem-based cost management**	flexible, platform-based and ecosystem-based cost management with a focus on the integration of inter-organizational chains	dynamic budgeting, cross-corporate transparency, and proactive recommendations for cooperative risk management

Figure 1. Key evolutionary stages and approaches in cost management

Source: developed by the author based on the following sources [1; 2; 3; 4; 5; 6; 7; 8; 9; 10; 11; 12; 13; 14; 15]

focused on cost drivers and the attribution of indirect resources to specific activities, creating a fundamentally different perspective in which costs were viewed not as a result of activities but as the reasons for their occurrence. The first conceptual developments of ABC belong to Cooper R., Kaplan R. S. [4], while modern reviews (Sánchez-Rebull M. V., Niñerola A., Hernández-Lara A. B. [5]) confirm that interest in this approach remains high. This opened the space for more efficient resource allocation and reduction of irrational costs, as well as increased costing accuracy under the growing complexity of products and services [15]. The stage of «Organizational-operational optimization» (1980–2000) shifted the priority of cost management toward organizational optimization. Unlike the previous stage, where the main task was identifying factors, here the focus was on restructuring business processes. The introduction of Lean and Kaizen approaches contributed to the elimination of waste, reduction of inventories, and overall production time, which increased enterprise flexibility and forced a reconsideration of efficiency criteria. This was made possible thanks to the works of Ohno T. [6], Imai M. [7], Womack J. P., Jones D. T., Roos D. [8], which laid the foundations for «lean production». The transition to the stage of «Integration of enterprise information systems and total automation» (1990–2010) was distinguished by a new level of complexity through the integration of information systems in the form of ERP platforms, fundamentally changing the approach to cost management. While the previous stages dealt with improving individual processes, now end-to-end coordination of all activities was carried out through the unification of accounting mechanisms and tools, which increased operational transparency but created risks of excessive centralization. As Davenport T. H. [9] noted in his work, ERP systems became a new level of integration, where finance, logistics, and cost management obtained a single database.

From 2010 to 2025, the stage of «Analytical-digital transformation in the context of Industry 4.0» strengthened this trend through digital transformation. The use of Industry 4.0 tools and technologies (IoT, Big Data, AI, and digital twins) combined with predictive and prescriptive analytics made it possible to move from reactive responses to proactive management, where each decision is based on scenario modeling and real-time verification of data streams. In their works, Schwab K. [10], Dai J., Vasarhelyi M. [11] emphasized that these technologies became the foundation of a new industrial revolution, and according to Dai J., Vasarhelyi M. [11], they continue to fundamentally transform business models and the field of management accounting. The modern stage of «Evolutionary adaptive and ecosystem cost management», which began its evolutionary development in 2025, marks the culmination of this evolution. Unlike the rigid and predictable approaches of the first half of the twentieth century, today cost management is built on the principles of adaptability and ecosystem interaction. Whereas earlier the key goal was reporting accuracy or compliance control, now the priority is increasingly dynamic budgeting, integration of risk-oriented methods, and the use of intelligent system's recommendations. Thus, ecosystem cost management models, based on platform solutions, blockchain technologies, and agent-oriented architectures, seek to ensure transcorporate transparency and trust among participants in economic processes. Important reference points for this stage were the works of Nakamoto S. [12], Tapscott D., Tapscott A. [13], Parker G., Van Alstyne M., Choudary S. [14], as well as recent studies by Asadi S.K.M. [15], which demonstrate the role of blockchain in creating a new level of accounting transparency.

In conclusion, it can be determined that the key evolutionary stages considered reflect not only the development of tools but also the deep transformation of the very logic of management, where enterprises gradually moved from static cost recording to strategic foresight, platform-based coordination, and collective resource management.

The next step should be to determine how exactly Industry 4.0 has influenced cost management systems and business process control, see Fig. 2.

Based on the data in Fig. 2, it can be noted that the impact of Industry 4.0 technologies on cost management and business process control is revealed through the integration of tools that shape a new approach to analytics, forecasting, and planning.

The Internet of Things enables continuous monitoring of equipment and resources in real time, which increases the accuracy of budgeting and optimizes the production process [17; 18]. Compared to this technology, big data analytics provides a comprehensive analysis of historical and current information, allowing for timely detection of deviations and adaptation of standards, as well as more accurate planning of resource use [19]. While the Internet of Things creates the conditions for detailed recording of system states, big data analytics strengthens the predictive potential of cost management by providing a basis for modeling various scenarios [19]. Artificial intelligence and machine learning, unlike traditional analytical mechanisms, allow for the identification of trends and the generation of recommendations in real time, ensuring high adaptability of business models to changes in demand and market conditions [20; 21]. Combined with robotic automation of routine operations, such solutions reduce the human factor, increase the efficiency of accounting, and shorten the time needed for financial decision-making [20]. As a result, a flexible cost management system is formed, one that not only records data but also actively influences process optimization.

Cyber-physical systems demonstrate another level of integration, as the synchronization of physical and digital processes allows for testing production scenarios without risk to real equipment, which helps minimize accidents while also reducing infrastructure maintenance costs [22]. Unlike this approach, cloud computing provides centralized access to data and resources, significantly increasing the scalability and transparency of management [23]. While cyber-physical systems are more focused on technical integration, cloud technologies emphasize flexible management of information flows and simplification of financial calculations [23]. Digital twins create a fundamentally new logic for modeling business processes, as they reproduce real operations in a virtual environment, allowing for the assessment of potential risks and financial consequences before implementing changes. This ensures forecasting accuracy and reduces the costs of experimental solutions [22]. In contrast, blockchain and smart contracts create conditions for transparency and trust in supply chains, since each transaction is recorded in an open ledger, which eliminates the possibility of manipulation with financial

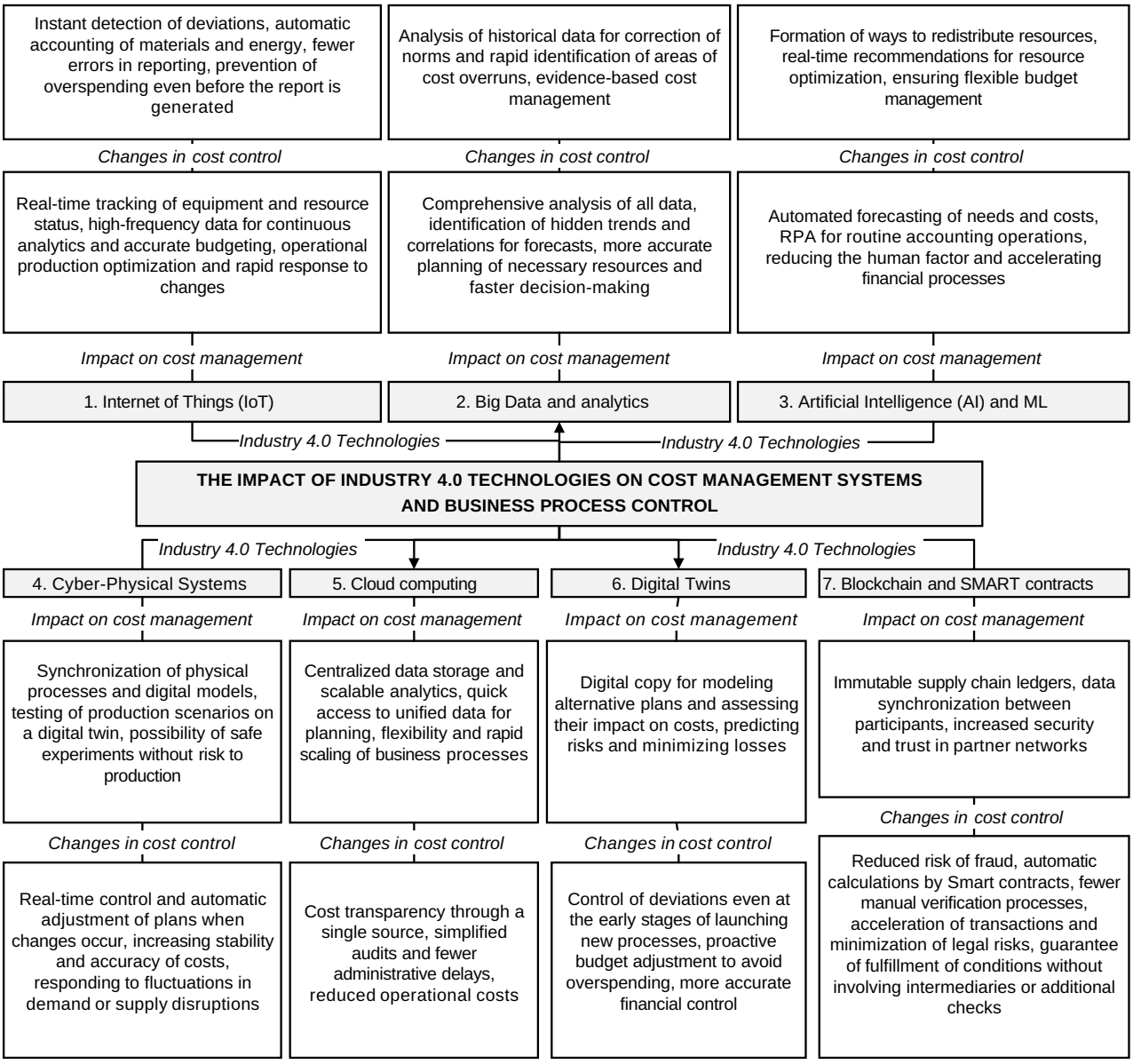

Figure 2. The impact of Industry 4.0 technologies on cost management systems and business process control

Source: developed by the author based on the following sources [17; 18; 19; 20; 21; 22; 23; 24]

operations [24]. While digital twins emphasize the preliminary modeling of costs, blockchain technology focuses on directly ensuring their reliability [24].

In summary, the implementation of Industry 4.0 technologies demonstrates complementary approaches: some tools reduce costs through optimization of technical processes and forecasting, while others ensure transparency and trust in economic transactions. Their differences do not contradict each other but instead form an integrated ecosystem where digitalization combines with automation and algorithmic management, creating a foundation for sustainable business development.

Let us now consider international experience in cost management and business process control, see Fig. 3.

Analysis of international experience in cost management and business process control in Fig. 3 makes it possible to trace different approaches of the world's leading companies to achieving efficiency and increasing competitiveness. Toyota's experience demonstrates that reducing cost and inventory can be accompanied by an increase in quality and productivity, which becomes possible through the systematic implementation of lean manufacturing, based on JIT, Kanban, and Kaizen methods aimed at reducing losses

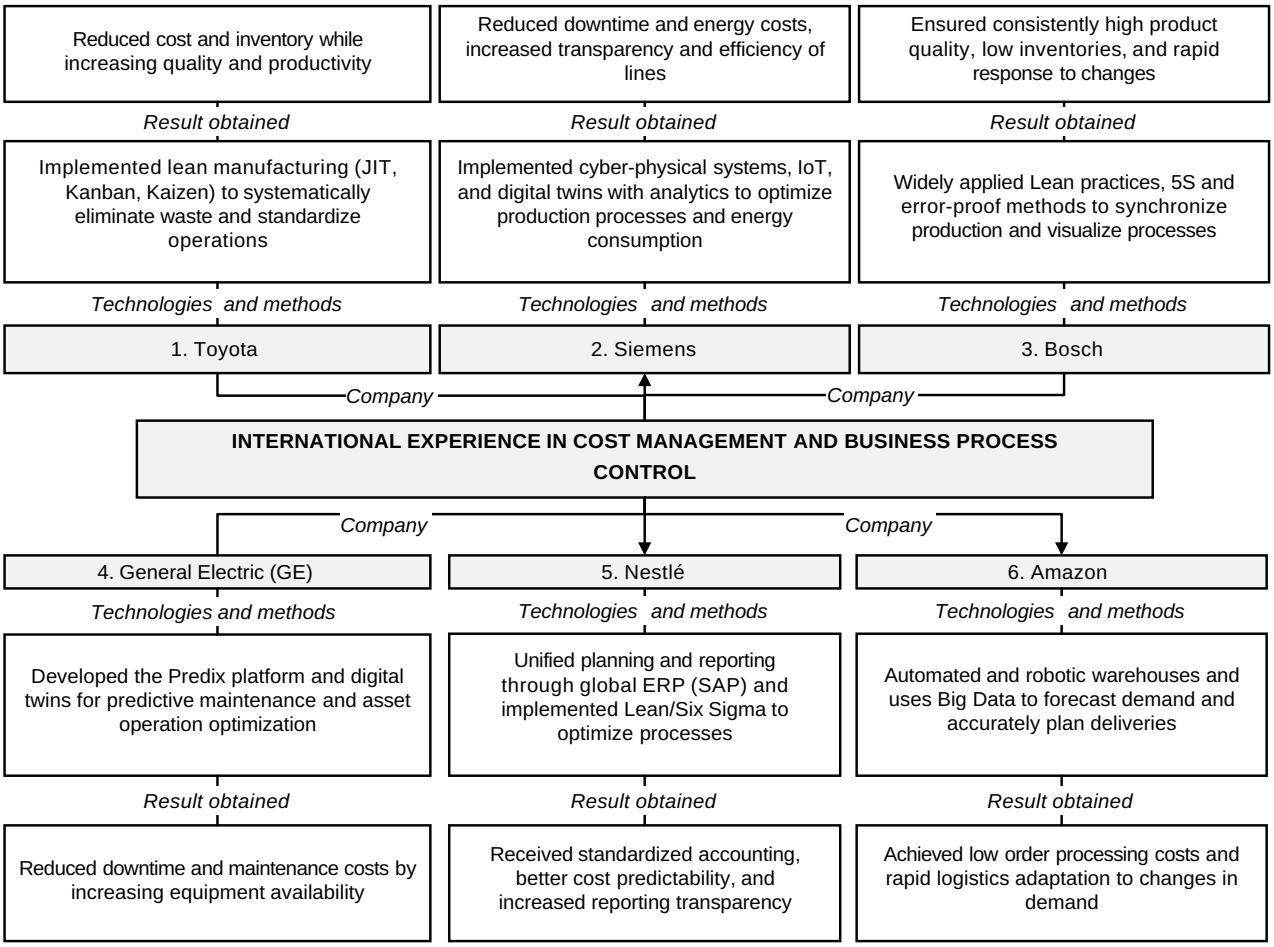

Figure 3. International experience in cost management and business process control

Source: developed by the author based on the following sources [25; 26; 27; 28; 29; 30]

and standardizing operations [25]. In contrast, Siemens focuses on the use of cyber-physical systems and digital twins to minimize downtime, energy costs, and optimize production processes through the flexible integration of Internet of Things technologies and intelligent data analytics [26]. In the case of Bosch, the emphasis is on the wide application of lean practices, combining 5S methods and error-proofing measures to ensure high product quality and reduce the production response time to changes in demand, which distinguishes their approach from Siemens' technological orientation [27]. The experience of General Electric highlights another example of cost management, as the company focused on the development of the Predix digital platform, which made it possible to significantly increase the efficiency of maintenance and reduce equipment downtime [28]. Nestlé's experience points to the synergistic effect of a unified ERP combined with process improvement methods to increase transparency and forecasting accuracy [29]. Amazon highlights that robotics and big data analytics allow real-time reorganization of logistics, but such a strategy requires high data maturity and infrastructure [30].

Comparing the international experience of these companies, the following conclusions can be drawn: 1. the effectiveness of a strategy is determined by the alignment between the nature of the business and the direction of investment, therefore organizational measures are more effective under conditions of predominantly stable processes, while digital solutions are justified where variability and scale dominate; 2. organizational practices provide early and relatively predictable results, while technological investments require a longer horizon but ensure sustainable operational flexibility (in the context of the temporal dynamics of benefits); 3. the necessity of standardized data, clear IT architecture, and personnel competencies for integrating heterogeneous solutions (in the context of the conditions for reproducing practices).

Among practical recommendations for implementing international experience, the following should be highlighted: 1. it is recommended to start with strengthening process discipline and minimizing losses through the introduction of lean practices and error-proofing measures, since this creates the necessary prerequisites for digital investments; 2. in parallel, the foundations of data management should be formed and a basic IT architecture built, after which local pilot projects of the Internet of Things and predictive maintenance for critical assets should be launched. Only under the condition of data quality stability and the presence of operational competencies is it advisable to integrate ERP and analytical platforms to scale effects; 3. at the sectoral level, it is advisable to initiate joint pilot projects and educational centers that catalyze the ecosystem of suppliers and the training of specialists, since the synergy between process discipline and digital maturity determines the long-term return on investment.

The above information makes it possible to form logically connected steps for adapting international practices for Ukrainian enterprises: 1. it is necessary to launch pilot projects on operational optimization based on Lean/Kaizen and JIT with the participation of the state and suppliers (Toyota); 2. simultaneously promote digital transformation of production through the implementation of digital twins and cyber-physical solutions in energy-intensive and machine-building sectors, together with the training of industrial IT specialists (Siemens); 3. standardize and visualize production processes through the implementation of 5S and Poka-Yoke in combination with local IoT solutions and the creation of training and practical centers (Bosch); 4. simultaneously deploy predictive maintenance programs in energy and transport in the format of joint pilots with local IT partners (GE); 5. prioritize the unification of financial and operational accounting through the implementation of ERP/BI combined with Lean/ Six Sigma for transparent cost control (Nestlé); 6. gradually automate logistics with warehouse robotics and the use of ML-based demand forecasting algorithms for distribution and retail (Amazon).

Based on the analysis of the previous stages of cost management systems development (Fig. 1-3), the final outcome of the study will be the formation of future vectors of their transformation in the context of Industry 4.0 (Fig. 4).

According to Fig. 4, the future vectors define both the technical means of optimization and a new methodological paradigm of financial management, within which the integrative nature of digital solutions becomes the key element. While classical models were limited to retrospective recording of costs and periodic control, the future logic of management will be grounded in systemic forecasting, automated verification of operations, and multi-level transparency of processes in real time, transforming cost management into a dynamic and strategically oriented tool. A key prerequisite for this transition will be the implementation of cloud-based financial platforms (Oracle NetSuite, SAP S/4HANA Cloud), capable of ensuring data centralization, integration of operational and strategic processes, and the creation of a unified information space. On this basis, the FinOps concept (Google Cloud FinOps) will evolve, integrating financial accountability with the use of IT resources and creating mechanisms for transparent cost allocation within organizational structures. A logical continuation of this direction will be the development of operational visibility through the Internet of Things and telemetry (Siemens MindSphere sensor systems), which make it possible to continuously monitor financial flows and adapt management decisions to changing environmental conditions. At the same time, the use of artificial intelligence and machine learning (IBM Watson, Azure Machine Learning) will open up opportunities for deep analytical processing of data arrays, the identification of latent patterns, and the construction of preventive scenarios. In parallel, the control system will undergo transformation, where traditional audit in the form of periodic inspections will be replaced by the concept of continuous auditing and process mining (Celonis Process Mining), meaning constant integration of control into operational cycles. This vector will be reinforced by robotic process automation of transactions (UiPath, Blue Prism), minimizing the impact of the human factor and reducing time delays in payment and settlement processing. In turn, the development of digital procurement and smart contracts (Ariba Network, Ethereum-based smart contracts) will provide a fundamentally new architecture of relationships with counterparties, where transparency and trust will be reinforced by algorithmic reliability and reduced transactional risks.

An important addition will be the advancement of management accounting methods based on data and ABC 2.0 (SAP Analytics Cloud ABC),

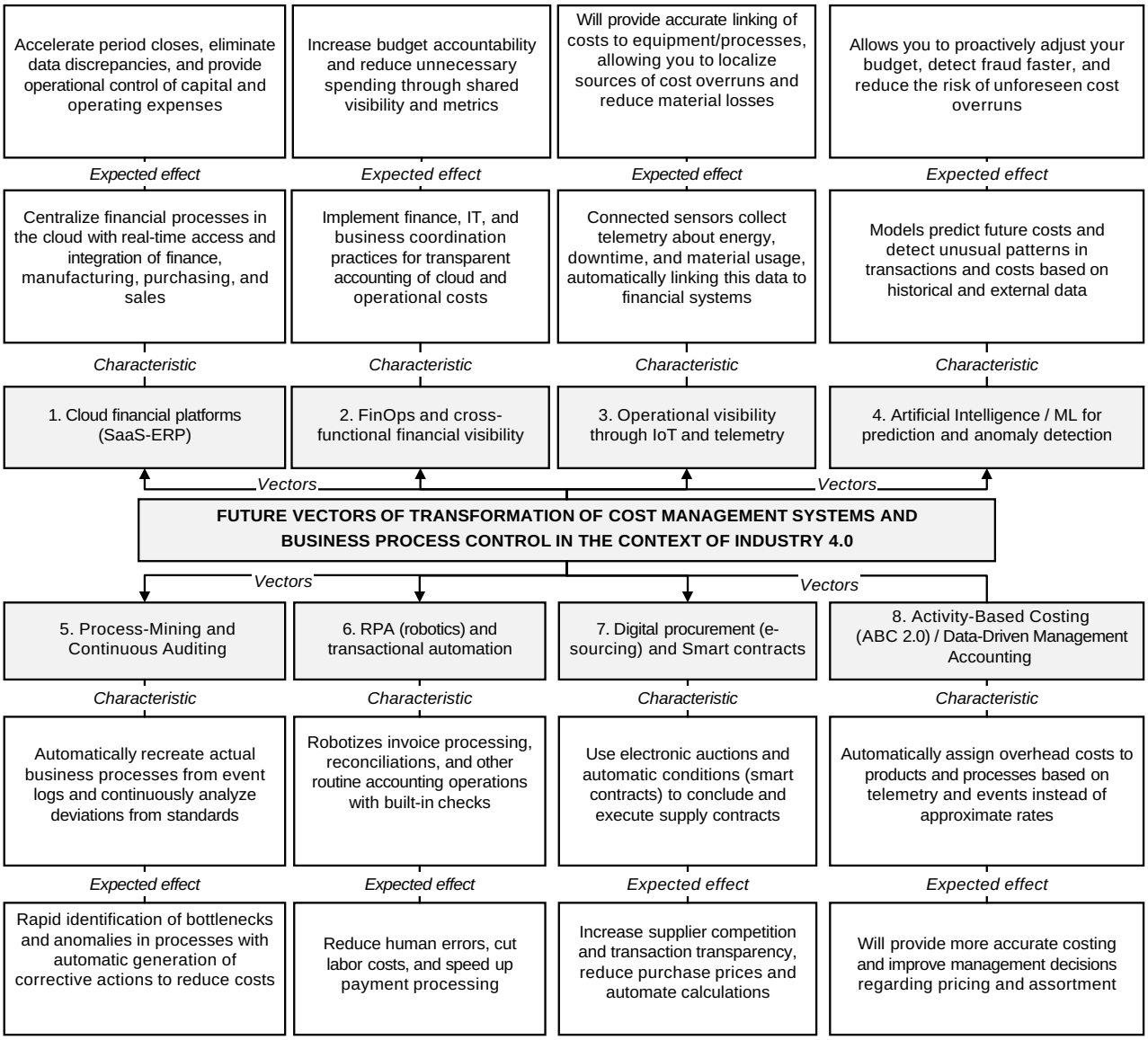

Figure 4. Future vectors of transformation of cost management systems and business process control in the context of Industry 4.0

Source: developed by the author himself

which will make it possible to detail costs and reflect their connection with specific business processes, transforming expenses from mere accounting indicators into a strategic resource for development. As a result, the identified vectors will shape the formation of a comprehensive financial ecosystem of the future, in which managerial decision-making will rely on reliable real-time data, while cost control will perform a verification function and ensure a stable, adaptive, and competitive position of enterprises in the new digital economy.

Conclusions. In the conducted study, the author carried out a comprehensive analysis of the evolution of cost management systems, compared classical approaches with the possibilities of Industry 4.0 technologies, and identified the key factors that hinder the transition from traditional models to ecosystem-based digital solutions. Particular attention was given to summarizing international experience and determining its specific features when transferred into the national context. On this basis, recommended steps for adapting Industry 4.0 technologies to cost management systems and further future vectors of their development were formulated. The defined theoretical significance of the study made it possible to deepen the understanding of the relationship between historical models of cost management and modern digital approaches, as well as to identify directions for their integration.

The practical value of the work lies in the possibility of applying the proposed recommendations as a roadmap for enterprises seeking to move from local experiments to scalable practices in the implementation of cost management system context of the digital economy.

approaches. Further research will focus on testing the studied initiatives and approaches in a specific sector to assess their effectiveness in the conditions of the Ukrainian economy and on developing models of integration into the broader

REFERENCES:

1. Wildman, J. R. (1911) Cost Accounting. New York : The Accountancy Publishing Co. 106 p.

2. Harrison, G. C. (1921) Cost Accounting to Aid Production: A Practical Study of Scientific Cost Accounting. New York : Engineering magazine Company. 234 p.

3. Paton, W. A., Littleton, A. C. (1940) An Introduction to Corporate Accounting Standards. Sarasota : American Accounting Association. 156 p.

4. Cooper, R., Kaplan, R.S. (1988) Measure Costs Right: Make Budgets a Strategic Tool. Boston : Harvard Business Review. 7 p.

5. Sánchez-Rebull, M. V., Niñerola, A., & Hernández-Lara, A. B. (2023). After 30 years, what has happened to Activity-Based Costing? A systematic literature review. SAGE Open, 13(2), 1-20. DOI: https://doi.org/10.1177/21582440231178785

6. Ohno, T. (1978) Toyota Production System: Beyond Large-Scale Production. New York : Productivity Press. 176 p.

7. Imai, M. (1986) Kaizen: The Key to Japan's Competitive Success. New York, Columbus: McGraw-Hill Education. 260 p.

8. Womack, J.P., Jones, D.T. and Roos, D. (1990) The Machine that Changed the World. New York : Simon and Schuster. 352 p.

9. Davenport, T.H. (1998) Putting the Enterprise into the Enterprise System. Boston : Harvard Business Review. 12 p.

10. Schwab, K. (2016) The Fourth Industrial Revolution. London : Portfolio. 192 p.

11. Dai, J., & Vasarhelyi, M. (2023). Management accounting 4.0: The future of management accounting. *Journal of Emerging Technologies in Accounting,* 20(1), 1–13. DOI: https://doi.org/10.2308/JETA-2023-009

12. Nakamoto S. (2008) Bitcoin: A Peer-to-Peer Electronic Cash System. 9 p.

13. Tapscott D., Tapscott A. (2016) Blockchain Revolution: How the Technology Behind Bitcoin Is Changing Money, Business, and the World. New York: Penguin. 384 p.

14. Parker G., Van Alstyne M. and Choudary S. (2016) Platform Revolution: How Networked Markets Are Transforming the Economy. New York : Norton & Company. 352 p.

15. Asadi, S. K. M. (2025). Digital transformation and blockchain technology: A new horizon for cost and managerial accounting. *European Journal of Accounting, Auditing and Finance Research*, 13(8), 31–39. DOI: https://doi.org/10.37745/ejaafr.2013/vol13n8-3139

16. Waweru, N. M. (2010). The origin and evolution of management accounting: A review of the theoretical framework. *Problems and Perspectives in Management,* 8(3), 165–182.

17. Soori, M., & Ahmadi, M. (2023). Internet of things for smart factories in Industry 4.0: A review. Internet of Things and Cyber-Physical Systems. DOI: https://doi.org/10.1016/j.iotcps.2023.04.006

18. Sanakal, A. P. (2025). Internet of Things (IoT) in cost accounting for manufacturing industries. *International Research Journal of Modernization in Engineering Technology and Science*, 7(2). DOI: https://doi.org/10.56726/IRJMETS67476

19. Darwish, N. Y. A., et al. (2025). Big data revolution: Enhancing financial planning and budgeting strategies. *International Journal of Multidisciplinary Applied Business and Education Research*, 6(3), 1044–1055. DOI: https://doi.org/10.11594/ijmaber.06.03.06

20. Sanakal, A. P. (2024). Artificial intelligence and machine learning in product cost planning for manufacturing industries*. International Research Journal of Modernization in Engineering Technology and Science*, 6(10). DOI: https://doi.org/10.56726/IRJMETS62688

21. Shamim, M. M. I., et al. (2023). Advancement of artificial intelligence in cost estimation for project management success: A systematic review. *Modelling*, 6(2), 35. DOI: https://doi.org/10.3390/modelling6020035

22. Fantozzi, I. C., et al. (2025). Digital twins: Strategic guide to utilize digital twins to improve operational efficiency in Industry 4.0. *Future Internet,* 17(1), 41. DOI: https://doi.org/10.3390/fi17010041

23. Panisi, F. (2017). Blockchain and «smart contracts»: FinTech innovations to reduce the costs of trust. *SSRN Electronic Journal*. DOI: https://doi.org/10.2139/ssrn.3066543

24. Roumeliotis, C., et al. (2024). Blockchain and digital twins in smart Industry 4.0: The use case of supply chain. *Designs,* 8(6), 105. DOI: https://doi.org/10.3390/designs8060105

25. Kulkarni, S. A., Nagare, R. R., Nagare, D. N., & Aware, P. N. (2021). Toyota Production System – Maximizing production efficiency by waste elimination. *International Advanced Research Journal in Science, Engineering and Technology*, 8(4). DOI: https://doi.org/10.17148/IARJSET.2021.8448

26. Annanth, V. K., Abinash, M., & Bhaskara Rao, L. (2021). Intelligent manufacturing in the context of industry 4.0: A case study of Siemens industry. *Journal of Physics: Conference Series*, 1969(1), 012019. DOI: https://doi.org/10.1088/1742-6596/1969/1/012019

27. Salgado, P., & Varela, L. (2010). Kanban sharing and optimization in Bosch Production System. *Proceedings of KMIS 2010*, 81–91. DOI: https://doi.org/10.5220/0003102600810091

28. Naiya, S. (2025). AI-powered predictive maintenance in IoT-enabled smart factories. *Research Annals of Industrial and Systems Engineering*, 2(1), 27–35. DOI: https://doi.org/10.22105/SA.2021.281500.1061

29. Büchel, B. i Zintel, C. (2024) «Nestlé Continuous Excellence: Lessons for driving performance improvement». European Financial Review. Available at: https://www.europeanfinancialreview.com/nestle-continuous-excellence-lessons-for-driving-performance-improvement

30. Alalade, E. O. (2025). Digital transformation and supply chain efficiency: A case of Amazon Inc. *International Journal of Research and Innovation in Social Science*, 3(1), 3931–3944. DOI: https://doi.org/10.47772/IJRISS.2024.8120326