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The Impact of Industry 4.0 on the Development of Long-term Technological Development Strategies for Enterprises

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ABSTRACT

The article examines the impact of Industry 4.0 on the formation of long-term technological development strategies of enterprises within the framework of modern management. The purpose of the study is to determine how digital manufacturing technologies transform the logic of strategic planning at enterprises and how these changes can be integrated into practical mechanisms of technological development management. The methodological basis of the research includes methods of theoretical generalization, systematization, economic-statistical and comparative analysis, as well as case analysis of international practices of digital transformation in industrial enterprises. The study found that Industry 4.0 fundamentally changes the content of a company's long-term technological strategy: the strategic focus shifts from the modernization of individual equipment to the development of digital maturity, data integration, management of cross-functional processes, and enhancement of organizational capabilities. It has been proven that the effectiveness of digital transformation depends on the enterprise's ability to combine digital solutions with its business model, human resource policy, change management system, and investment development logic. The study revealed that the digitalization of enterprises in the European Union remains uneven: in 2025, only 20% of enterprises used artificial intelligence technologies, while ERP systems remained significantly more widespread, confirming the existence of fragmented digital transformation. It is substantiated that the level of digital maturity determines the enterprise's ability to transition toward more advanced AI solutions, IoT technologies, and related digital systems. The article also demonstrates that a long-term technological development strategy should be based on the principle of gradual enhancement of digital capabilities: from establishing a digital foundation and data integration to scaling intelligent manufacturing solutions. Based on the analysis of international cases of Schneider Electric, Henkel, Agilent Technologies, and Valeo, it was determined that the greatest economic effect of Industry 4.0 is achieved when digital technologies are simultaneously integrated into manufacturing processes, energy management, supply chains, quality control systems, and workforce development. It was additionally established that the sustainable effect of digital transformation directly depends on the level of cybersecurity, the systematic nature of employee training, and the management's ability to scale successful digital solutions across different business processes. The proposed provisions can be used by enterprises to assess digital maturity, determine the sequence of digital technology implementation, and form a portfolio of digital projects.

KEYWORDS

modernization, long-term strategy, digital transformation, Internet of Things, artificial intelligence. innovations.

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ВПЛИВ ІНДУСТРІЇ 4.0 НА ФОРМУВАННЯ ДОВГОСТРОКОВИХ СТРАТЕГІЙ ТЕХНОЛОГІЧНОГО РОЗВИТКУ ПІДПРИЄМСТВ

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СТАТТЯ

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АНОТАЦІЯ

У статті досліджено вплив Індустрії 4.0 на формування довгострокових стратегій технологічного розвитку підприємств у системі сучасного менеджменту. Метою дослідження є з'ясування того, яким чином цифрові виробничі технології трансформують логіку стратегічного планування підприємств та як ці зміни можуть бути інтегровані у практичні механізми управління технологічним розвитком. Методологічною основою дослідження стали методи теоретичного узагальнення, систематизації, економіко-статистичного і порівняльного аналізу, а також кейс-аналіз міжнародних практик цифрової трансформації промислових підприємств. У результаті дослідження встановлено, що Індустрія 4.0 змінює зміст довгострокової технологічної стратегії підприємства: центр стратегічної уваги зміщується з модернізації окремого обладнання на формування цифрової зрілості, інтеграцію даних, управління міжфункціональними процесами і розвиток організаційних спроможностей. Доведено, що ефективність цифрової трансформації залежить від здатності підприємства поєднувати цифрові рішення з бізнес-моделлю, кадровою політикою, системою управління змінами та інвестиційною логікою розвитку. Виявлено, що цифровізація підприємств у ЄС має нерівномірний характер: у 2025 р. технології штучного інтелекту використовували лише 20 % підприємств, тоді як ERP-системи залишаються значно поширенішими, що підтверджує існування фрагментарної цифрової трансформації. Обґрунтовано, що саме рівень цифрової зрілості визначає здатність підприємства переходити до більш складних AI-рішень, IoT тощо. У статті також доведено, що довгострокова стратегія технологічного розвитку повинна будуватися за принципом поетапного нарощування цифрових спроможностей: від створення цифрового фундаменту й інтеграції даних до масштабування інтелектуальних виробничих рішень. На основі аналізу міжнародних кейсів Schneider Electric, Henkel, Agilent Technologies та Valeo встановлено, що найбільший економічний ефект Індустрії 4.0 досягається тоді, коли цифрові технології інтегруються одночасно у виробничі процеси, енергоменеджмент, ланцюги поставки, систему контролю якості та розвиток персоналу. Окремо встановлено, що стійкий ефект цифрової трансформації безпосередньо залежить від рівня кібербезпеки, системності навчання персоналу та здатності менеджменту масштабувати успішні цифрові рішення між різними бізнес-процесами. Запропоновані положення можуть бути використані підприємствами для оцінювання цифрової зрілості цифрових проєктів.

КЛЮЧОВІ СЛОВА

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1. Introduction

Industry 4.0 has ceased to be a specialized topic for engineering services and has turned into a strategic management issue. This can already be seen in the scale of the actual penetration of technologies into production systems: in 2023, the global fleet of industrial robots reached 4,281,585 units, and the annual volume of new installations was 541,302 [1]. That is, we are talking about a structural change in the production model on a global scale. At the same time, the digital transition is uneven and therefore becomes the subject of a strategic choice. In 2023, 55% of enterprises in the European Union used at least one of the three groups of advanced digital solutions - artificial intelligence, advanced cloud services, or data analytics, while the goal for 2030 is 75% [2]. At the same time, in 2024, 73% of small and medium-sized enterprises reached the baseline level of digital intensity, which is still more than 17 percentage points below the target [2].

Under these conditions, the long-term strategy of technological development of the enterprise can no longer be reduced to the modernization of equipment, the list of IT projects, or individual automation solutions. It now encompasses the way the enterprise collects and uses data, makes decisions in real time, integrates production with logistics, finance and service, forms digital competencies of personnel and at the same time keeps costs, cyber risks and investment horizons manageable.

For management, this means a change of focus. In the process of creating a strategy, it is necessary to simultaneously answer several questions: which technologies create long-term value, and which only temporarily improve a single indicator; how to avoid fragmented digitalization, when an enterprise accumulates “islands of automation” without a system effect; how to combine technological development with a business model, product logic, HR policy, and financial capabilities. In this plane, the managerial dimension of Industry 4.0 begins.

2. Literature Review

The analysis of modern scientific research shows that the problems of Industry 4.0 are gradually shifting from a purely technological interpretation to a strategic and managerial one. If early works focused mainly on production automation, robotization or digital integration of equipment, modern research is increasingly considering Industry 4.0 as a factor in the transformation of the management system, strategic planning mechanisms and the formation of long-term models of enterprise development. So, L. Klarner et al. investigated which areas of management are changing the most under the influence of Industry 4.0. The authors concluded that digital transformation has the most significant impact on process management, personnel management and change management, since digital production systems require new coordination mechanisms [3].

In turn, other scientists, J. Antony and others. analyzed the advantages, barriers and critical factors of the success of the implementation of Industry 4.0 in different economies of the world [4]. The authors showed that the effectiveness of digital transformation significantly depends on organizational culture, the level of staff training, the availability of resources, and the ability of management to coordinate cross-functional changes.

A notable contribution to the development of research was made by L. S. Angreani, A. Vijaya and H. Wicaksono, who proposed to consider digital transformation through models of technological maturity and reference architectures of Industry 4.0 [5]. A similar position is held by D. V. Ferreira, A. P. H. de Gusmão and J. A. de Almeida, who have developed a multi-criteria model for assessing the maturity of enterprises in the context of Industry 4.0 [6]. Research by C.-H. Wu et al. [7] complement the scientific discussion with empirical results on the impact of digital transformation on manufacturing enterprises. The authors proved that the level of digital transformation is directly related to the scale of the enterprise and the innovation of the product.

The practical aspect of Industry 4.0 is significantly strengthened in the work of R. Hrbić [8], dedicated to assessing the early impact of digital technologies on micro, small and medium-sized enterprises in Croatia. The study showed that even the initial stages of digitalization can have a positive impact on return on assets, profitability, and interaction with suppliers. At the same time, the author focuses mainly on the financial results of early digitalization, while the issues of long-term sustainability of the technological strategy remain outside the main focus of the analysis.

Special attention should be paid to the study by A. H. Lassen and M. S. S. Larsen [9], which considers Industry 4.0 through the prism of the innovative capacity of enterprises. Based on the cases of SMEs, the authors proved that effective digital transformation rarely occurs due to a one-time technological breakthrough.

An important addition to the modern scientific discussion is the study of W. Torbacki [10], which proposes an integrated MCDA model of technology prioritization in the process of transition from Industry 4.0 to Industry 5.0. The author combined the DEMATEL and PROMETHEE II methods to evaluate 22 technologies from the perspective of economic, organizational and technological perspectives. We have also previously studied certain aspects of technological modernization of enterprises in the context of scientific and technological progress, digitalization and structural transformations of the business environment [11].

Unlike most previous works, our article considers Industry 4.0 not only as a set of digital technologies, but as a factor in the transformation of the strategic management of the enterprise. The emphasis is on how digitalization changes the content of long-term technological development, how enterprises should form digital maturity, integrate technologies into the business model, build mechanisms for scaling solutions and combine technological investments with the operational, personnel and financial logic of enterprise development.

3. Problem Statement

The purpose of the article is to find out how Industry 4.0 changes the logic of building long-term strategies for the technological development of enterprises in management, as well as how these changes can be translated into practical management decisions. Within the framework of the first task, it is revealed how exactly the content of strategic planning changes under the influence of digital production technologies. Within the framework of the second task, attention is focused on practical mechanisms for the implementation of such a strategy, investment logic, organizational conditions for scaling and real cases of enterprises that have already shown a measurable result.

4. Methods and Materials

The methodological basis of the study was a set of general scientific and special methods, the use of which made it possible to investigate the impact of Industry 4.0 on the formation of long-term strategies for the technological development of enterprises in the management system.

At the initial stage, the method of theoretical generalization and scientific systematization was applied, which made it possible to work out modern approaches to the interpretation of Industry 4.0, digital transformation, digital maturity of enterprises and strategic technological development.

To identify current trends in the digital transformation of enterprises, economic and statistical analysis was used. Based on it, the dynamics of the use of artificial intelligence, ERP systems, BI solutions, cloud services and data analytics by enterprises of the European Union in 2023–2025 is analyzed, as well as the indicators of robotization, digital business intensity and the level of digital technology adoption in international practice are studied. The information base was statistical materials from Eurostat, OECD, International Federation of Robotics, European Commission, European Investment Bank and World Economic Forum.

The method of comparative analysis is used to compare the levels of digital transformation of enterprises, differences in approaches to the implementation of Industry 4.0, as well as to assess the features of the implementation of digital strategies in enterprises of different sizes and levels of technological maturity.

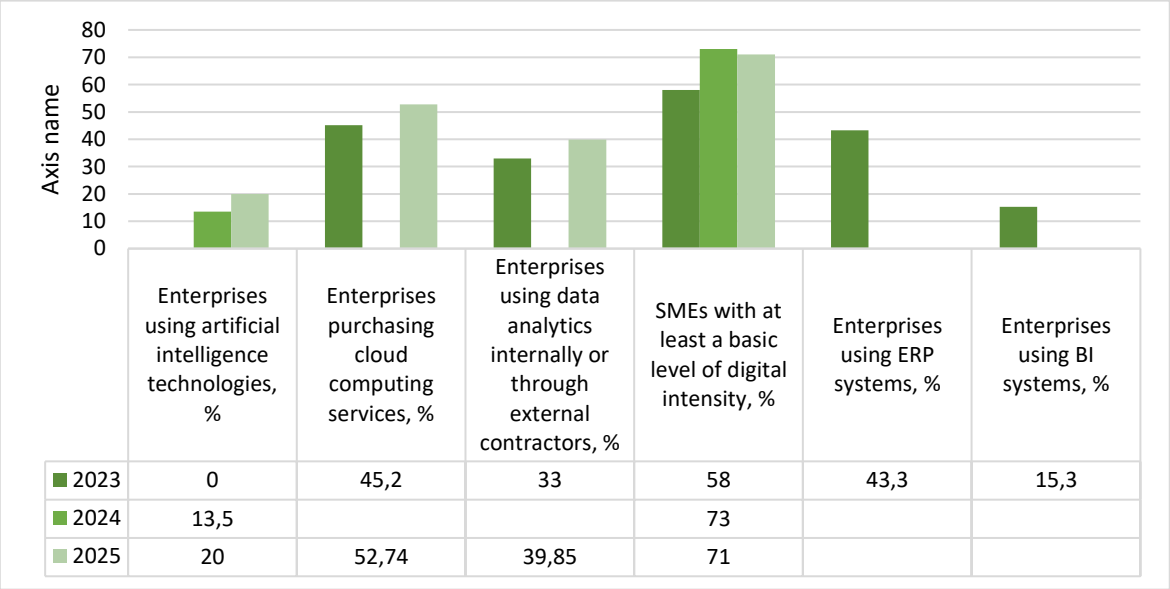
As part of the study, a case study was also used, with the help of which the practical results of the implementation of Industry 4.0 strategies were studied at the industrial enterprises of Schneider Electric (Lexington), Henkel (Düsseldorf), Agilent Technologies (Penang) and Valeo (Shenzhen).

To form generalized conclusions on the strategic logic of technological development of enterprises in the conditions of Industry 4.0, the method of logical generalization and interpretation of results was used.

5. Results and Discussion

In management, identifying how Industry 4.0 changes the very structure of the long-term strategy for the technological development of an enterprise is fundamentally important, because digital transformation affects not only the technical subsystem. According to the results of a systematic review conducted by scientists in 2023, process management, change management, and human resource management fall most under the influence of Industry 4.0 [3]. This is also consistent with empirical comparative research by other authors J. Antony et al. [4], where it is recorded that the benefits of Industry 4.0 in terms of organizational efficiency and flexibility differ between economies, and the resistance of personnel to change has a higher weight in developing countries; In addition, the significance of change-management and project management also differs between continents. Thus, the technological development strategy in the era of Industry 4.0 is cross-functional in nature: it should design not only technical updates, but also a new format of organizational coordination.

The digital statistics of enterprises show well why the classical logic of "getting new equipment and thereby modernizing" no longer works. In 2023, 43.3% of European Union enterprises used ERP systems, 25.8% used CRM, only 15.3% used BI solutions, and almost half of enterprises, 49.9%, used at least one of the three classes of software solutions - ERP, CRM or BI (Figure 1).



	Enterprises using artificial intelligence technologies, %	Enterprises purchasing cloud computing services, %	Enterprises using data analytics internally or through external contractors, %	SMEs with at least a basic level of digital intensity, %	Enterprises using ERP systems, %	Enterprises using BI systems, %
2023	0	45,2	33	58	43,3	15,3
2024	13,5			73		
2025	20	52,74	39,85	71		

Figure 1. Digital enterprise statistics

Source: Built based on [2].

In 2024, only 13.5% of EU businesses used at least one artificial intelligence technology, and in 2025 this figure rose to 20.0%. The share of enterprises that purchased cloud services was 45.2% in 2023 and 52.74% in 2025, the share of enterprises that used data analytics in-house or through an external provider was 33% in 2023 and 39.85% in 2025. Someone has an ERP but lacks a tool outline for AI; Someone has sensors and automation, but no integrated management environment turns data into solutions.

For the manager, this information means that the long-term strategy of technological development should begin not just with technology, but with the real digital foundation of the enterprise. If 15.3% of enterprises have BI, and 43.3% have ERP, then the massive desire to immediately switch to AI without solving data issues, process integration, and a single accounting system gives a superficial effect. It is no coincidence that the OECD in the Digital Economy Outlook 2024 shows that large firms are on average three times more likely than small firms to adopt IoT, four times more likely to adopt cloud solutions, five times more likely to use big data analytics, six times more likely to use AI, and they use ERP almost 13 times more often than small companies [12]. Hence, the strategic conclusion: for small and medium-sized enterprises, the correct development trajectory cannot copy the path of large corporation's one-to-one. It must be phased; the enterprise invests in the top layer of technologies without a supporting structure.

That is why technological maturity is becoming the central concept in modern literature. In the article L. S. Angreani, A. Vijaya and N. Wicaksono [5] emphasized that in order to strengthen the strategy for the transition to Industry 4.0, it is necessary to align maturity factors with reference architectures of digital transformation. And in the study of D. V. Ferreira et al. [6] It is emphasized that the assessment of the current technological state of the enterprise is the starting point for determining the improvement strategy, and the maturity model allows you to identify specific actions for moving to a higher level. Because of this, the long-term strategy of technological development should be built as a map of the transition from one level of digital maturity to another, where each stage is tested through economic outcome, process integration and organizational readiness.

This conclusion is confirmed by empirical works on the heterogeneity of digital transformation. In a study by C.-H. Wu [7], dedicated to Taiwan manufacturing companies, cluster analysis showed five consecutive levels of digital transformation, and a survey of the top 1000 enterprises with 139 responses found that larger companies and enterprises with higher product innovation are more likely to achieve a higher level of digital transformation; At the same time, profitability and type of production did not demonstrate a statistically significant relationship with the level of digitalization. For strategic management, this is a very important signal: the technological strategy must be fastened with the innovation strategy of the enterprise. If a firm works with a more complex, variable or individualized product, then its need for data, algorithms and flexible production systems grows faster than that of an enterprise with stable mass production.

Another change concerns the decision-making horizon. The European Investment Bank report [13] highlights that the wider adoption of digital and green technologies is key to competitiveness and sustainability, and the use of big data and AI is positively associated with productivity, job creation and green transformation. The same report separately indicates that sectors that invest more in new products, processes or services tend to be more digital. Therefore, a long-term strategy cannot be judged only by a short payback horizon.

Benchmarking is also of particular importance. According to the International Federation of Robotics, in 2023, the density of robotization in the EU was 219 robots per 10 thousand people. employees, while in the Republic of Korea - 1,012 [14]. This means that the long-term strategy must take into account the technological distance to the industry frontier. If an enterprise plans to work in a highly competitive segment with short product update cycles, then the issues of automation, sensors, digital twins, and analytics become structural.

At the same time, the current dynamics show that the inertial scenario is not enough. According to the European Commission [15], under the current trends, by 2030 only 64% of enterprises will use the cloud, 50% - big data, and 17% - AI, which indicates the risk of not achieving an ambitious digital goal in the business sector. For enterprises, this is of direct managerial importance: whoever builds a strategy on the principle of a delayed digital transition actually decides on the future backlog.

Therefore, it should be concluded that under the influence of Industry 4.0, the long-term strategy of technological development of the enterprise is transformed from a technical re-equipment plan into a system of strategic design of digital maturity. It is based on data architecture, process integration, change management, digital competencies, and the ability to combine technological investments with the product, operational, and financial logic of the enterprise. It is this strategy that gives a chance to avoid fragmentation and turn digitalization into a source of long-term competitive advantage.

The second task of the current study is to translate the strategic logic of Industry 4.0 into a specific managerial mechanism of action, i.e. how to implement a long-term technological strategy so that it does not stop at the level of presentations, individual pilots and disparate procurement. According to the World Economic Forum [16], more than 70% of companies that invest in advanced analytics, artificial intelligence or 3D printing do not go beyond the pilot stage; at the same time, the Global Lighthouse Network has already accumulated more than 700 proven use cases and 153 digital transformation beacons. This means that the main problem today is not a shortage of technology, but a shortage of management decisions that can translate technology into a scalable economic effect.

This leads to the first practical principle: a long-term strategy should be designed immediately for scaling. In 2023, the World Economic Forum [17] recorded that 82% of new lighthouse enterprises consider scale to be the main criterion for designing digital solutions. Moreover, 85% of enterprises from this network lost less than 10% of revenue during the peak of the COVID-19 pandemic, while among other manufacturers, only 14% could say about this level of resilience.

The practical power of this approach is confirmed by the latest results of lighthouse enterprises. In the new cohort of 2025, the average increase in labor productivity reached 53%, and conversion costs decreased by an average of 26%; at the value chain level, these same approaches resulted in a 50% reduction in time to market for new products, a reduction in Scope 1 and 2 emissions by 30–50%, material waste by an average of 30%, and energy and water consumption by about 25% [16]. For management, this is important for two reasons. Firstly, digital transformation has the greatest effect not where it is reduced to the automation of a single operation, but where it is related to the product cycle, supply chain, energy management and personnel policy. Secondly, the economy of Industry 4.0 increasingly has a multi-effect: the same digital circuit simultaneously affects defects, lead time, resource costs, and the quality of the solution.

For a practical comparison, it is advisable to look at the cases of Schneider Electric in Lexington, Henkel in Düsseldorf, Agilent Technologies in Penang and Valeo in Shenzhen (Table 1).

Table 1. Practical results of the implementation of Industry 4.0 technologies at industrial enterprises in international practice

Comparison platform	Solution Core	Recorded effect
Lexington	IoT connectivity, smart energy meters (power meters), predictive analytics	energy consumption −26%; net CO_2 emissions −30%; water consumption −20%
Düsseldorf	Digital twin and benchmarking of 30 factories	energy intensity −38%; water consumption −28%; waste volume −20%
Penang	artificial intelligence in the supply chain, 3D printing, zero-code workflows	productivity +40%; production costs −32%; delivery lead time −48%; the proportion of personnel who have undergone upskilling is 88%; staff turnover - 3.5% against 9.4% of the industry average
Shenzhen	artificial intelligence, diagnostics and troubleshooting with genAI, "lights-off" workshops	defectiveness of finished products −45.9%; lead time −34,5%; productivity +60.2%; specific energy consumption −27.1%

Source: Summarized based on analysis [18; 19].

The above cases are valuable because they show the correct managerial logic. At Lexington, digital strategy begins with increasing the granularity of energy data, after which the data is transformed into a tool for managing costs and resource efficiency. At Düsseldorf, the local factory becomes a node for network benchmarking, i.e., the data is used not only for control, but also for cross-plant training and standardization of solutions. In Penang, digital transformation is only generating economic impact because it simultaneously embraces the supply chain, people's skills, and engagement culture; The Upskilling parameter here is part of the financial result. At Shenzhen, the value of genAI is embedded in a closed cycle of quality control, lead time, and power consumption. So, a successful case of Industry 4.0 is always a technology plus a management circuit that makes it reproducible.

After that, the second principle is visible: the strategy should have a clear sequence of capacity building. In a special document, the OECD identifies four key prerequisites for successful implementation: communication, data (algorithms, calculations), skills and finance [20]. Translated into corporate management, this means that a long-term strategy should go from a digital foundation to high-level intelligent solutions. First - data, integration, managed process architecture. Next are priority use cases tied to margin, lead time, defectiveness, or resource costs. Then, scaling and transferring solutions from one process to another. And only then, full-fledged algorithmizing and automation at the level of the enterprise network. Where this is violated, the strategy turns into a collection of costly digital initiatives without a systemic result.

The third principle is related to the fact that the technology strategy in Industry 4.0 necessarily includes cybersecurity and personnel development. In 2024, 92.76% of enterprises in the EU used at least one ICT security measure, but 21.54% of enterprises in 2023 had already suffered the consequences of ICT incidents [21]. Only 35.50% of enterprises had documented cybersecurity measures, practices or procedures, and only 21.82% of such documents were identified or revised within the last 12 months [20]. At the same time, in 2024, only 22% of businesses in the EU conducted staff training to develop or improve digital skills [21]. This is a management signal - an enterprise can invest in sensors, robots, analytics and the cloud, but if it does not create a cybermanagement discipline

and does not invest in the competence of people, the technological strategy becomes vulnerable. It seems to exist, but it does not scale securely and does not withstand a long development cycle.

From this follows the general practical outline of the long-term strategy of technological development of the enterprise.

First, the company must record its real level of digital maturity and determine where digitalization affects the business economy the most: in production, planning, maintenance, quality, energy, or service. Then, not a list of technologies is formed, but a portfolio of management effects: what losses need to be removed, where flexibility is needed, where the bottleneck is defectiveness, and where there is a lack of data transparency. Further, technologies are selected for these effects, and not vice versa. After that, the scaling mechanism is determined: who owns the data, who is responsible for integration, and how the solution is transferred between sites, factories, or functions. And only on this basis is the investment cycle built - with controlled logic, regular revision of priorities and strict reference to KPIs in terms of productivity, execution time, defects, energy and staff training.

6. Conclusions

Thus, about the first task, it is advisable to draw the following conclusion: Industry 4.0 radically changes the content of the long-term strategy of technological development of the enterprise. It shifts the focus from hardware upgrades to managing digital maturity, data architecture, process integration, and organizational capacity development. In the strategic dimension, this means that enterprises become part of the business model, the logic of value creation and the mechanism for forming a sustainable competitive advantage. Therefore, an effective long-term strategy in the conditions of Industry 4.0 should be mature-oriented, cross-functional and closely related to the product and operational strategy of the enterprise.

As for the second task, the conclusion is more applied. The real result is not the presence of digital technologies themselves, but the managerial ability to turn them into a scalable circuit of solutions. Practice shows that a strategy works when it combines a step-by-step build-up of digital capabilities, a clear connection with financial and operational metrics, systematic staff training, cyber resilience, and a mechanism for transferring a successful solution from one process to another. For an enterprise, this means the need for the discipline of portfolio management of digital initiatives, rather than chasing individual technological innovations.

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