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Digitalization of Management Processes and Enhancement of Innovative Mechanisms in Textile Enterprises

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Abstract: This article examines the methodological foundations and practical mechanisms for digitalizing management systems and implementing innovative approaches in textile enterprises. The views of international, CIS, and Uzbek scholars are critically analyzed, and the systems-process, dynamic capabilities, digital maturity, lean-digital integration, and institutional-cluster approaches are considered in relation to different levels of the management system. Based on the analysis, a six-stage closed-loop mechanism aimed at improving production efficiency, a digital maturity index, and a digitalization efficiency coefficient are proposed.

Keywords: textile industry, management system, digital transformation, Industry 4.0, innovative approach, digital maturity, ERP, MES, OEE, production efficiency

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1. Introduction

Digital transformation has become one of the key drivers of improvements in the management systems of industrial enterprises. This is particularly important in the textile industry, which is characterized by complex production chains, high resource intensity, and rapidly changing market demand. The use of digital technologies can substantially strengthen enterprise competitiveness and operational efficiency by integrating production, supply, logistics, sales, and financial management processes, enabling more rational use of resources, and supporting faster managerial decision-making.[1][2][3]

International studies indicate that the adoption of Industry 4.0 technologies in the global textile industry remains at an early stage, with existing projects primarily focused on improving productivity and reducing costs through process automation (Dal Forno et al., 2023). However, the question of how technology should be integrated with management mechanisms remains open. This underscores the need to examine digitalization not merely as a technological upgrade, but as a management mechanism closely linked to strategic planning, resource allocation, control, and innovation activities.[4][5]

From this perspective, integrating digital technologies with innovative management approaches is particularly important for textile enterprises. Such integration can strengthen coordination among different areas of enterprise activity, improve resource-use efficiency, optimize costs, and enhance management quality. Therefore, identifying effective directions for digitalizing management processes and

improving innovative mechanisms in textile enterprises represents an important area of both scientific and practical research.

Over the past decade, the digitalization of management systems has become a subject of intense academic debate. [6] These discussions largely revolve around the question of whether digitalization is primarily a technological issue or, rather, a matter of managerial and organizational change. Using bibliometric methods to examine global research trends in the textile and apparel industry, B. Deepthi and V. Bansal (2024) report a rapid increase in publications in this field, while noting that the concept of Industry 4.0 continues to be interpreted in different ways. In their study of the German textile industry, M. Fromhold-Eisebith et al. (2021) emphasize that the effects of digital manufacturing technologies depend strongly on historically established organizational structures and regional conditions; consequently, optimistic projections are not always confirmed in practice.[7][8]

Based on a comprehensive review, G. Vial (2019) defines digital transformation as a process aimed at improving an organization by triggering significant changes in its characteristics through combinations of information, computing, communication, and connectivity technologies. In Vial's model, technology does not generate outcomes by itself; it initially creates disruptions in the market, to which the organization responds strategically, thereby changing its value-creation pathways and giving rise to structural changes and organizational barriers. In our view, one of the model's major strengths is its recognition of organizational barriers as an integral component of transformation.[9][10]

P. Verhoef et al. (2021) distinguish three stages of digital change: digitization (converting analog information into digital form), digitalization (improving existing processes through digital tools), and digital transformation (changing the business model). The authors emphasize that successful transformation requires digital resources, a flexible organizational structure, a digital growth strategy, and a system for measuring objectives and outcomes. This distinction is highly useful from a practical perspective. In our view, many domestic textile enterprises are currently positioned between the first and second stages, and it would therefore be inappropriate to recommend an immediate transformation of their business models.[11]

Research conducted in Brazil has enabled Industry 4.0 technologies to be classified into two layers (Frank et al., 2019). The first comprises front-end technologies directly related to operations (smart manufacturing, smart products, smart supply chains, and smart working), while the second consists of base technologies that support them (the Internet of Things, cloud computing, big data, and analytics). The authors conclude that enterprises tend to adopt technologies in a certain sequence rather than randomly, with smart manufacturing at the center of this process. Because the study was conducted in the context of an emerging economy, its findings are particularly relevant to Uzbekistan. We likewise support the view that digitalization should begin at the production-shop-floor level.[12][13]

P. Bertola and J. Teunissen (2018) introduced the concept of "Fashion 4.0," arguing that digital transformation is reshaping all links of the fashion and textile value chain, including design, manufacturing, distribution, and retail, while the consumer is becoming an active participant in this chain. In their view, these changes require new competencies and new business models. The study is valuable because it directly addresses the industry and adopts a value-chain perspective. However, this approach is primarily characteristic of brand- and design-centered companies. In Uzbekistan, where yarn continues to account for a substantial share of exports, digital tools for managing production and supply chains remain a priority.[14][15]

2. Materials and Methods

A. Majumdar, H. Garg, and R. Jain (2021) involved 40 experts from the Indian textile and apparel industry and used interpretive structural modeling (ISM) to systematize barriers to Industry 4.0 adoption. The main barriers identified by the authors include a shortage of skilled personnel, insufficient commitment from top management, limited government support, and weak research and development activities. As a solution, they propose a “triple helix” model based on cooperation among government, industry, and academia.

The reviewed studies address the technological, strategic, and institutional dimensions of digitalization largely as separate areas. A unified approach that integrates these dimensions into a single mechanism within the management system of a textile enterprise has yet to be fully developed. Research by scholars from CIS countries and Uzbekistan has examined production-capacity management and financial security in textile enterprises in considerable depth; however, the systematic integration of these issues with digital management tools is only beginning to emerge. This indicates the need for further theoretical and empirical research within the scope of the present topic.

This article is based on theoretical and applied approaches to the digitalization of management processes in textile enterprises, the development of innovative management mechanisms, and the assessment of their impact on enterprise performance. The study employs comparative analysis, a systems approach, generalization, induction, and deduction to identify priority directions for integrating digital technologies into the management system.[16]

3. Results and Discussion

Digitalizing management processes in textile enterprises cannot be reduced to the introduction of individual technologies; it requires the alignment of the management model, information exchange, and decision-making mechanisms. Therefore, systematizing methodological approaches to digital transformation and identifying the interrelationships among them are of particular importance.[17]

Systematizing these approaches makes it possible to identify the main directions of digitalization and determine how they interact within the management system. The methodological approaches to digitalizing management systems in textile enterprises and the relationships among them are presented in Table 1.

Table 1. Methodological Approaches to Digitalizing the Management Systems of Textile Enterprises

No.	Methodological approach and key representatives	Level within the management system	Content
1	Systems-process approach (Kagermann et al., 2013; Manglani et al., 2019)	Architecture level	Integration of management and production processes within a unified digital environment through the vertical and horizontal integration of ERP-MES-IIoT systems
2	Dynamic capabilities approach (Teece, 2007; Warner & Wäger, 2019)	Strategic level	Timely identification and exploitation of digital opportunities and reconfiguration of organizational processes in response to changing conditions
3	Digital maturity	Diagnostic level	Assessment of the enterprise's

No.	Methodological approach and key representatives	Level within the management system	Content
	approach (Schumacher et al., 2016; Dal Forno et al., 2023)		initial level of digitalization and determination of subsequent stages of development
4	Lean-digital integration (Buer et al., 2018; Tortorella & Fettermann, 2018)	Operational level	Reduction of waste, standardization of business and production processes, and their further improvement through digital technologies
5	Institutional-cluster approach (Majumdar et al., 2021; Fromhold-Eisebith et al., 2021)	External environment level	Cooperation among government, industry, and educational institutions and the development of digital platforms at the cluster level

The methodological approaches presented in Table 1 cover different levels of digitalization management in textile enterprises. Their content and practical significance can be interpreted as follows.[18]

Under the systems-process approach, an enterprise is viewed as a set of interconnected subsystems, while digitalization serves to integrate information flows among them. Within the “Industrie 4.0” framework, H. Kagermann et al. (2013) distinguish vertical integration, horizontal integration across the value chain, and end-to-end engineering throughout the product life cycle. This approach is particularly relevant to the textile industry, where spinning, weaving or knitting, dyeing and finishing, and garment manufacturing are closely interconnected. Another group of researchers has examined the potential of IoT technologies for process monitoring and equipment maintenance (Manglani et al., 2019). Accordingly, the digital management architecture should be based on the integrated operation of ERP, MES, and IIoT systems. In particular, the MES layer functions as the key link for transmitting real-time shop-floor data to higher management levels.[19]

The dynamic capabilities approach defines dynamic capabilities as the ability to sense opportunities and threats, seize them, and reconfigure organizational resources (Teece, 2007). K. Warner and M. Wäger (2019) apply this concept to digital transformation by distinguishing digital sensing, digital seizing, and digital transforming capabilities and interpreting digital change as an ongoing process of strategic renewal. In textile enterprises, this approach requires rapid adaptation to changes in market demand, order volumes, delivery times, and product traceability requirements. Digitalization should therefore be organized not as a stand-alone IT project, but as a continuous management function.

A. Schumacher et al. (2016) propose a model for assessing Industry 4.0 readiness using 62 indicators across nine dimensions: strategy, leadership, customers, products, operations, culture, people, governance, and technology. A. Dal Forno et al. (2023) specifically note that the adoption of Industry 4.0 technologies in the global textile industry remains at an early stage. We therefore argue that an enterprise's current condition should be diagnosed before digital investments are undertaken. Considering

the specific characteristics of the textile industry, the general maturity model should also incorporate data integration across technological stages and the ability to trace product provenance. The digital maturity index may be calculated as follows:

$$DMI = \frac{\sum w_j L_j}{5}, \quad \sum W_j = 1 \quad (1)$$

where

L_j - the enterprise's maturity level for dimension j (from 1 to 5);

w_j - the weighting coefficient determined through expert assessment.

If the index value is below 0.4, the enterprise is classified as being at the initial level; a value of 0.4–0.6 indicates a developing level; 0.6–0.8, an integrated level; and above 0.8, a mature level. The proposed threshold values are preliminary and their precise quantitative boundaries should be established on the basis of empirical analysis.[20]

The lean-digital integration approach is based on combining lean management principles with modern digital technologies in production processes. S.-V. Buer, J. Strandhagen, and F. Chan (2018) note that Industry 4.0 and lean manufacturing are complementary. G. Tortorella and D. Fettermann (2018) empirically demonstrate that their joint application improves enterprise performance. R. Nayak and R. Padhye (2018) systematize opportunities for automating cutting, sewing, material handling, and quality control in garment manufacturing. According to this approach, rather than immediately digitalizing an inefficient process, it is preferable first to streamline and standardize it and then further improve it through digital technologies. When assessing the alignment between lean principles and digital management, the Overall Equipment Effectiveness (OEE) indicator is particularly important (Nakajima, 1988).

$$OEE = A \times P \times Q \quad (2)$$

where

A - equipment availability (actual operating time relative to planned production time);

P - performance rate (actual output relative to standard output);

Q - quality rate (good output as a proportion of total output).

When records are maintained manually, OEE is usually estimated at the end of a shift or month. When data are captured directly from equipment, however, OEE becomes a management tool capable of identifying the cause of each stoppage.

According to the institutional-cluster approach, the effectiveness of digitalization is determined not only by an enterprise's internal resources and capabilities, but also by the institutional and regional environment in which it operates. A. Majumdar et al. (2021) regard cooperation among government, industry, and academia as an important mechanism for overcoming barriers arising in the digital transformation process. This view is consistent with the findings of M. Fromhold-Eisebith et al. (2021), who emphasize that the outcomes of technological transformation depend on regional characteristics and the historically developed economic environment. L. Dalenogare et al. (2018) further demonstrate that the benefits obtained from Industry 4.0 technologies vary according to the type of technology applied and the conditions under which it is implemented. In the case of Uzbekistan's textile industry, the regional disparities identified by E. Zarova and B. Tursunov (2021) likewise suggest that applying a single universal model of digitalization does not necessarily produce identical outcomes. From this perspective, cluster mechanisms can enable shared access—particularly for small and medium-sized enterprises—to digital infrastructure such as common ERP systems, product-traceability platforms, and data centers, thereby reducing the cost of digital transformation and increasing its effectiveness.

It should be emphasized that these five approaches are not alternatives to one another; rather, they are complementary. The systems-process approach addresses

digital architecture, dynamic capabilities address strategic adaptation, digital maturity provides diagnostics, lean-digital integration focuses on operational efficiency, and the institutional-cluster approach covers the external cooperation environment. Their integrated application provides a methodological basis for developing a comprehensive digital management system in a textile enterprise.

Applying these methodological approaches to practical management processes requires the development of a consistent mechanism for digitalizing management systems in textile enterprises. Based on the methodological analysis, we propose a six-stage mechanism for management-system digitalization. The mechanism is built on a closed-loop principle, whereby the outcomes of each stage provide baseline information for diagnosis in the subsequent cycle. In this sense, digitalization is viewed not as a one-time technological project, but as a process of continuous improvement of the management system.

At the first stage, the enterprise's level of digital maturity is assessed, key processes are mapped, and baseline values are established for OEE, production-capacity utilization, resource consumption, and quality indicators. The integral assessment methodology developed by K. Krivyakin, B. Tursunov, and Z. Hakimov (2018) may be used to determine the initial state of production-capacity utilization. The diagnostic stage identifies technological, organizational, and competency gaps between the enterprise's current and target states.

At the next stage, a digital transformation strategy, budget, responsible units, and target KPIs are established in accordance with the diagnostic findings. International experience indicates that insufficient active involvement of top management is a significant barrier to digitalization (Majumdar et al., 2021). Therefore, the project should be implemented under the supervision of enterprise management and should involve not only IT specialists, but also technologists and representatives of production, planning, and other relevant departments.

Before digital systems are introduced, product and material codes, technological routes, operating standards, and defect classifications should be standardized. Digitalizing a disorganized process does not eliminate existing problems; rather, it transfers them into the new system. From this perspective, lean tools help simplify processes and create a stable operating environment for digitalization (Buer et al., 2018).

Following standardization, ERP, MES, and IIoT systems should be integrated progressively, initially tested in a pilot production shop, and subsequently scaled to other areas. This approach reduces implementation risks and unnecessary costs while enabling cybersecurity, data backup, and intersystem integration to be established consistently. Once a unified data environment has been created, innovative solutions such as AI-based defect detection, predictive maintenance, demand forecasting, and digital product traceability can be introduced. At this stage, developing employees' digital competencies is particularly important.

At the subsequent stage, KPIs are monitored regularly, and decisions are made on whether to scale, improve, or discontinue digital solutions based on the results. Across different stages of production, digital tools can support inventory management, equipment-performance monitoring, the reduction of unplanned downtime, improvements in quality and resource efficiency, and supply-chain coordination. At the same time, major risks include poor interoperability among systems, the selection of technologies without reference to actual needs, shortages of qualified personnel, and the implementation of foreign solutions without adaptation to local conditions. Digitalization should therefore be carried out with due consideration of the enterprise's technological level, human-resource capabilities, and existing infrastructure.

4. Conclusion

The findings demonstrate that the digitalization of management systems in textile enterprises cannot be limited to the introduction of technologies alone. Its effectiveness is closely associated with improvements in management processes, the allocation of responsibilities, decision-making mechanisms, and systems for evaluating outcomes.

The systems-process, dynamic capabilities, digital maturity, lean-digital integration, and institutional-cluster approaches were synthesized as complementary methodological foundations. On this basis, a six-stage mechanism was proposed, encompassing diagnostics, strategic management, standardization, digital infrastructure, innovation and human resources, monitoring, and adaptation. Diagnostics and process standardization were identified as essential prerequisites for digital transformation.

In the context of Uzbekistan, digitalization should be implemented gradually, taking into account enterprises' technological and financial capacities as well as their human-resource potential. For small and medium-sized enterprises, particular importance should be attached to shared digital infrastructure at the cluster level, the implementation of pilot projects, and the development of employees' digital competencies.

Overall, digitalization should be organized as a continuous transformation process that integrates the enterprise's management model, production processes, and human capital. Evaluating the practical effectiveness of the proposed mechanism using empirical data and identifying the relationship between the level of digitalization and production efficiency are of substantial scientific and practical importance.

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