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Models for Adapting Business Strategies in Manufacturing Enterprises Amid Digital Technology Integration

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Abstract: This article explores current approaches to the digital transformation of business strategies in manufacturing enterprises, identifying the core prerequisites and influencing factors for successful adaptation in the context of Industry 4.0. The study provides a comprehensive review of discrete maturity models, platform-based and hybrid approaches, incorporating BIM frameworks and interregional partnerships. Six key catalysts of digital transformation are identified: the predominance of information exchange, the acceleration of communication processes, the restructuring of organizational models, the rise of enabling technologies (IoT, Big Data, AI), evolving competency requirements, and the emergence of digital ecosystems. A unified matrix of digital tools is presented, including IoT, Big Data, AI, robotics, ERP/MES/PLM systems, and 3D printing. The article also outlines organizational and managerial mechanisms for implementation, covering agile-based structures, digital functional domains, and project financing models. The insights presented will be of interest to researchers in strategic management and digital transformation, particularly those focused on the theoretical justification and empirical validation of adaptive business models within Industry 4.0 manufacturing environments. Additionally, the approaches discussed may prove valuable to industrial enterprise executives, digital integration consultants, and government experts involved in shaping regulatory frameworks that promote digitization in the manufacturing sector.

Keywords: digital business transformation, digital maturity, Industry 4.0, business strategy, manufacturing enterprises, IoT, big data, ERP, agile, ecosystem.

Introduction: The relevance of this topic lies in the fact that, in the era of the Fourth Industrial Revolution, digital change has evolved beyond isolated IT solutions and now requires a full-scale rethinking of strategic management in manufacturing enterprises. Accelerated information exchange, increasing demands for agile decision-making, and intensified global competition have significantly elevated the need to integrate digital technologies at the level of business models and management processes [1, 2].

Academic studies on the adaptation of business strategies in manufacturing organizations under digital integration fall into several major thematic clusters, each reflecting distinct methodological and subject-oriented approaches.

First, within the theoretical foundations of digital transformation, key emphasis is placed on the concept of dynamic capabilities and the alignment of digital strategy with the organization's overall direction. Canhoto A. I. et al. [3] emphasize the importance for small and medium-sized enterprises (SMEs) to develop flexible digital capabilities that can rapidly respond to evolving market and technological demands. Ghosh S. et al. [6] analyze the mechanisms by which enterprises cultivate "digital dynamic capabilities" that drive transformation both at the strategic and operational levels. Shen L., Zhang X., and Liu H. [4], drawing on the textile sector, show that the impact of digital technologies on transformation outcomes depends directly on "digital innovation orientation," which moderates the link between digital capabilities and performance results. Machado C. G. et al. [5] explore organizational readiness and demonstrate that the maturity of digital initiatives is heavily influenced by cultural and institutional conditions within manufacturing companies, placing limits on the speed and depth of transformation.

Second, considerable attention is paid to business model innovation and its evolution under digital pressure. Zheng L. J. et al. [1], focusing on SMEs, propose a step-by-step model for integrating digital tools, with key elements including environmental risk assessment, data collection setup, digital supply chain formation, and continuous refinement of the business model. Favoretto C. et al. [2] note that the shift from traditional to digital business models in manufacturing passes through a stage of rethinking the value proposition, which imposes new demands on process architecture and customer relationship systems.

Finally, a third group of studies focuses on the strategic aspects of digital transformation in international and logistics contexts. Meyer K. E. et al. [7] analyze "international business in the digital age," where digital platforms and national institutional environments create a paradox: global strategies must account for local regulatory and cultural distinctions, complicating the creation of a unified digital business model. Shevchenko D. A. et al. [8] illustrate how integrating intelligent logistics systems accelerates industrial restructuring by acting as a bridge between digital ecosystems and physical manufacturing processes.

Kagermann H. [9] examines a cyber-physical systems integration model that highlights the interplay between digital services and traditional manufacturing processes. He argues that moving to a hybrid infrastructure demands a rethink not only of operational workflows but also of management practices, in order to secure a sustainable competitive edge through the synergy of data and hardware.

Ajayi M. O. and Laseinde O. T. [10] adapt Porter's value-chain framework to pinpoint both opportunities and shortcomings in digital-technology adoption. They show how each of the five primary activities—and all four support activities—can incorporate digital solutions, ranging from automated inventory-management systems to analytics platforms for demand forecasting.

Finally, several online sources survey digital-transformation trends and tools at the intersection of manufacturing and sustainability. The "Top Digital Transformation Trends Shaping Sustainable Manufacturing in 2024" report [11] on sustainablemanufacturingexpo focuses on "green" digital initiatives, particularly digital twins and energy-management platforms. A Bosch Software Technologies post [12] on the company's official website explores manufacturers' environmental responsibility through the Industry 4.0 lens, emphasizing cloud services and IoT infrastructure as

keys to transparency and carbon-footprint reduction.

Despite the complementarity of these approaches, the literature reveals a number of contradictions. Some authors place dynamic capabilities at the core of transformation, while others rely on maturity metrics—leading to differing interpretations of what drives successful change. Furthermore, models describing the evolution of business models often overlook institutional and cultural barriers, which are extensively documented in other works. Several studies focus heavily on technological and strategic elements but provide insufficient coverage of human factors, such as change management and employee resistance, as well as issues of cybersecurity in large-scale digitization. There is also a lack of longitudinal empirical research into the long-term effectiveness of digital initiatives and their impact on business model resilience. Moreover, interactions between traditional industrial processes and new digital platforms and ecosystems at the supply chain level remain underexplored.

In this context, promising directions for future research include the integration of dynamic capabilities and maturity frameworks, along with a more holistic consideration of institutional, human, and cyber-physical factors in adapting business strategies during digital transformation.

The aim of this article is to analyze existing models for adapting business strategies in manufacturing enterprises during digital technology integration, taking into account maturity dimensions such as technological infrastructure, process transformation, organizational structure, and financial and human resources.

The scientific contribution lies in the systematic synthesis of discrete maturity models, platform-based and hybrid approaches—including BIM integration and interregional partnerships—alongside the development of a unified matrix of digital tools and the description of organizational and managerial mechanisms for their implementation in Industry 4.0 manufacturing contexts.

The working hypothesis is that applying a comparative methodology to existing research on strategic adaptation under digital integration will reliably identify their strengths and limitations, synthesize best practices, and thus support the development of a unified framework for transforming management strategies in the context of Industry 4.0.

In this study, the author conducted a qualitative synthesis of six principal adaptation models based on criteria such as maturity dimensions (technological infrastructure, process transformation) and the degree of platform integration (BIM frameworks, digital ecosystems). The analytical procedure employed a rigorous comparative content analysis and thematic aggregation of model components, systematically mapping core technological instruments and organizational mechanisms to construct an integrated framework for strategic adaptation in Industry 4.0 manufacturing contexts.

The study's methodology is based on a comparative analysis of existing research in the field.

A corpus of twelve sources—comprising peer-reviewed studies and publicly available case reports of modern-tool implementations in manufacturing firms—served as the study's sample. From these works, three principal adaptation-strategy models were extracted: discrete maturity frameworks, platform-centric approaches and hybrid schemes.

The models were compared according to:

1. Maturity levels (number and descriptive scope)

2. Core dimensions—technology infrastructure, process transformation, organizational structure and financial–human-resource assets

3. Application context (specific industries and geographic regions)

4. Degree of BIM and platform-solution integration

Analysis followed a systematic comparative-classification method. In the first phase, models were grouped by type and primary dimensions. Next, their constituent elements—IoT, Big Data, AI, robotics, ERP/MES/PLM systems and other digital enablers—were catalogued alongside organizational mechanisms such as agile governance structures, ROI/TCO evaluation frameworks, workforce-development programs and grant-funding or change-management

processes.

To synthesize findings, content-analysis techniques and narrative summaries were employed, allowing the identification of both common patterns and substantive divergences across the adaptation-strategy landscape.

1. Preconditions and Drivers of Digital Transformation in Business Strategy

Digital transformation in manufacturing began with the implementation of standalone IT solutions and the automation of narrow operational tasks. However, with the rise of the Fourth Industrial Revolution (Industry 4.0), the very nature of business models has shifted. Industry 4.0 is understood as the integration of cyber-physical systems, the Internet of Things (IoT), and artificial intelligence into production environments—enhancing the flexibility and adaptability of enterprises [1, 7].

The table 1 below outlines the key factors that stimulate companies to revise their strategies under the influence of digital transformation.

Table 1: Factors stimulating enterprises to revise strategies under the influence of digital transformation [1, 7, 9]

Factor	Description
Dominance of information exchange	Intellectual capital and data as core strategic resources
Speed and volume of communication	Real-time transfer of large data volumes via digital networks
Organizational structure transformation	Shift toward agile, networked structures and integrated platform solutions
Emergence of new technologies	Big Data, AI, blockchain, virtualization, digital twins
Changing competency requirements	Demand for digital literacy, analytical thinking, and engineering skills
Formation of digital social ecosystems	Partner networks and platforms linking all actors in the value chain

As shown in Table 1, the primary factors driving companies to overhaul their strategies in the wake of digital transformation are, first, the ascendancy of information exchange—where intellectual capital and data have become the organization's chief strategic assets, and communications over digital networks occur in real time—and second, the shift in organizational structures toward agile, networked teams and integrated platform-based solutions.

In parallel with these digital transformation "catalysts," enterprises face a number of constraints, including:

- Slow adaptation of internal processes. Many companies struggle to rethink entrenched business models and encounter resistance to change at both management and operational levels [2].

- Financial limitations and investment risks. Implementing IT platforms and upgrading equipment requires significant capital; underfunding can hinder digital transformation, especially for SMEs [6].

- Technological and infrastructure risks. The unreliability or incompatibility of emerging technologies and challenges in ensuring cybersecurity pose substantial threats to operational continuity.

- Human resource constraints. A shortage of qualified specialists and the difficulty of workforce reskilling delay the deployment of integrated digital solutions [5].

- Regulatory and institutional barriers. Issues such as standardization, legal frameworks, and platform interoperability may limit access to international markets [7].

Thus, successful digital transformation depends on achieving a balance between technological advancement and comprehensive risk management—an essential condition for revisiting and adapting business strategies in manufacturing enterprises.

2. Review and Classification of Strategy Adaptation Models

Three principal classes of models are commonly distinguished in the context of digital strategy adaptation: discrete maturity models, platform (ecosystem-based) approaches, and hybrid or industry-specific frameworks.

Discrete maturity models describe the stages of digital maturity an organization passes through and are primarily used to assess readiness and identify strategic development directions.

Platform models, the second category, emphasize the creation or participation in digital platforms as a core driver of strategic transformation.

Finally, hybrid models combine maturity-based and platform-based approaches while incorporating sector-specific characteristics and requirements.

The table 2 below provides a classification of business strategy adaptation models applicable to manufacturing enterprises.

Table 2: Classification of Business Strategy Adaptation Models for Use in Manufacturing Enterprises [3, 7, 8]

Model	Maturity Levels	Key Dimensions	Application Domain
Digital Maturity	3 (low, medium, high)	Organizational readiness, competencies, infrastructure, data	Manufacturing enterprises
Adoption Maturity Model	3 groups / 8 indicators	Strategy, integration, infrastructure, analytics, adoption	Industrial firms (Italy, Canada)
Industry 4.0 Readiness Model	5	Culture, technology, processes, strategy, governance	Manufacturing sector

Model	Maturity Levels	Key Dimensions	Application Domain
Four-Stage BIM-Integrated Model	4	ICT, communications, IoT, data, business model (incl. BIM)	Construction industry
Digital Ecosystem	–	Omnichannel architecture, modularity, partnerships, data governance	General business
Digital Transformation Playbook	–	Customer centricity, agile frameworks, innovative product/service design	General business

As Table 2 shows, all business-strategy adaptation models aim to incrementally build digital capabilities across key dimensions—from organizational readiness and infrastructure to processes, governance and analytics—while targeting specific sectors (machinery, construction and general business). Some frameworks define a precise numerical maturity scale (three to five levels or eight indicators), whereas others present conceptual guidelines without fixed stages, highlighting the flexibility of digital-transformation approaches.

While discrete models help structure the stages of digital progression, they are often generalized and require industry-specific calibration. Platform-based approaches focus on ecosystems and partnerships, which are essential for global competitiveness but less effective for managing operational processes on the shop floor. Hybrid and industry-specific models—such as those that integrate BIM—offer a synthesis of both perspectives and account for the practical realities of industrial sectors.

For manufacturing enterprises, an optimal approach involves combining diagnostic maturity models with platform elements and tailoring them to the specific industry context. This integrated methodology forms the foundation for the author's model presented in the following section.

3. Tools and Practical Mechanisms for Implementing Digital Technologies in Manufacturing Enterprises

3.1 Technological instruments

This section presents an original modular framework for adapting business strategies in the context of manufacturing transformation. The model is based on a synthesis of contemporary research findings [1, 3; 4–6] and integrates a comprehensive set of technological, organizational, financial, and human-capital instruments.

Effective digital transformation in manufacturing enterprises requires not only a robust technological foundation but also well-structured organizational mechanisms and sustainable financial and talent support. The digital toolkit consists of a range of complementary technologies, each addressing specific tasks related to production and management:

- Internet of Things (IoT) and Cyber-Physical Systems (CPS): These technologies enable real-time data collection and transmission via smart sensors and devices, supporting predictive maintenance and dynamic resource management. For example, General Electric deployed IoT sensors and AI-driven analytics across its manufacturing plants, reducing unplanned downtime by 20 % and boosting overall equipment effectiveness by 5 % [11].

- Big Data Analytics and Data Lake Platforms: Provide the ability to store and process large volumes of structured and unstructured data, helping

uncover hidden patterns and optimize business processes.

- Cloud Computing (IaaS/PaaS/SaaS): Offers scalable computing resources, reduces capital expenditures, and enables instant access to services from any location [3].

- Artificial Intelligence and Machine Learning: Support intelligent automation of quality control, failure prediction, and managerial decision-making. Bosch provides a notable example: by deploying an Industry 4.0 framework that integrates AI, IoT and analytics platforms, the company achieved a 10 % uplift in process efficiency and a 10 % increase in throughput, while saving up to €0.5 million per year on a single production line. At the same time, eleven factories—covering some 5,000 machines—were interconnected into a unified network, enabling seamless connectivity and real-time data exchange [12].

- Robotics and Smart Automation: Incorporates industrial and collaborative robots to increase productivity and workplace safety [6].

- Digital Management Platforms (ERP, MES, SCM, CRM, PLM): Integrate key business processes—from production planning to customer interaction and full product lifecycle management.

- Additive Manufacturing (3D Printing): Enables direct production of complex components from digital models, reducing time and cost of prototyping [1, 4].

3.2 Organizational mechanisms

Organizational mechanisms in the context of digital transformation at manufacturing enterprises form an integrated system of formal and informal structures, processes and cultural practices that synchronize strategic objectives with agile operational execution. These mechanisms encompass the establishment of Centres of Excellence and digital laboratories for piloting innovations, the formalization of roles such as Chief Digital Officer and Change Agents to steer transformation, the creation of end-to-end Scrum and Kanban teams that foster cross-functional collaboration, and the launch of corporate accelerators and hackathons to stimulate bottom-up innovation. Process-oriented tools include a digital PMO employing hybrid Water-Scrum-Fall methodologies, a continuous-learning environment delivered through LMS platforms and gamified training, and adaptive KPIs within an Extended Balanced Scorecard (Balanced Scorecard 4.0) that track not only financial outcomes but also digital maturity and innovation activity. Together, these elements comprise a change-management architecture that continuously recalibrates internal resources, accelerates decision-making and secures sustainable competitive advantage in the Industry 4.0 era.

Figure 1 outlines the organizational and managerial mechanisms for strategic adaptation in manufacturing enterprises.

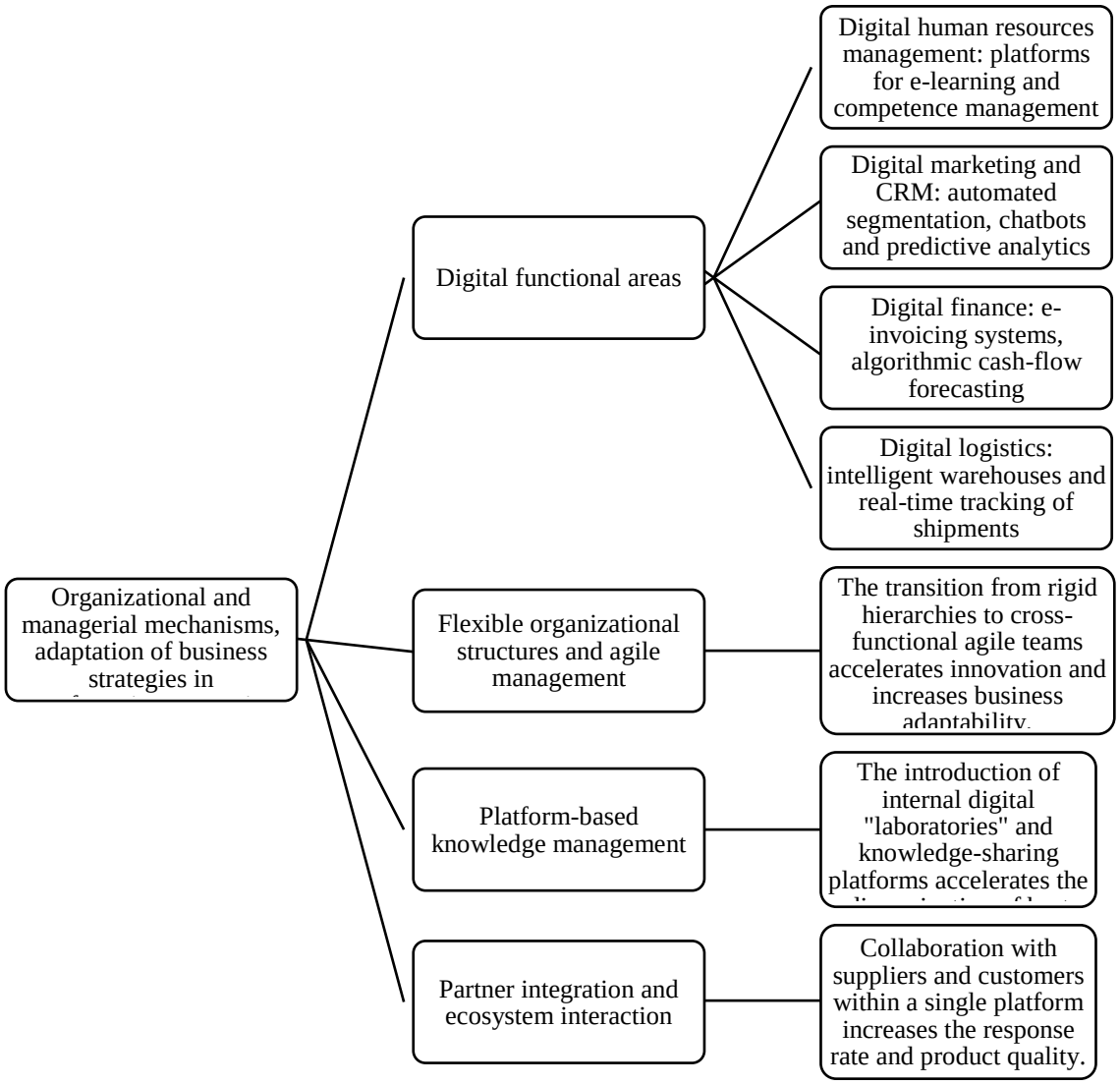

Figure 1. Organizational and managerial mechanisms for adapting business strategies in manufacturing enterprises [1, 3, 4, 6]

The success of digital transformation also depends heavily on ensuring stable financial support and developing relevant competencies. Key elements include:

- Investment Evaluation and ROI: Calculating total cost of ownership (TCO) and net present value (NPV) for each digital initiative at the business case stage is essential for substantiating expenses.

- Grant and Incentive Mechanisms: Public programs and dedicated funds (e.g., the "Digital Economy" fund) can partially cover CAPEX and encourage the adoption of domestic technological solutions.

- Development of Digital Skills: Continuous training systems, retraining programs, and partnerships with universities help ensure a qualified workforce capable of managing and advancing digital tools.

- Change Management: Encompasses internal communication, training, KPIs, and motivational frameworks designed to reduce resistance and accelerate the adoption of new technologies [5, 10].

The strategic adaptation model includes five interrelated blocks: 1) Assessment Module – Focuses on digital maturity and strategic diagnostics, identifying bottlenecks and prioritizing the implementation of IoT/CPS, Big Data/Data Lakes, and cloud services. 2)

Technology Module – Covers the integration of AI/ML, robotics, and additive technologies to enable intelligent quality control, predictive maintenance, and agile prototyping. 3) Platform Module – Implements digital platforms (ERP, MES, SCM, CRM, PLM) to form cohesive product lifecycle management chains. 4) Organizational and Managerial Module – Includes change management frameworks, communication and motivation systems, and educational partnerships aimed at developing digital competencies [5]. 5) Resource Module – Ensures financial and investment support through ROI, TCO, and NPV calculations, alignment of grant and incentive mechanisms, and KPI monitoring for implementation.

Inter-module connections and feedback loops allow for real-time adjustment of strategic priorities, ensuring resilient and adaptive digital transformation within the enterprise.

In sum, the combination of advanced technologies, flexible organizational mechanisms, and carefully structured resource support forms a solid foundation for the effective digital transformation of business strategies in the manufacturing sector.

CONCLUSION

In today's environment of global competition and rapid technological advancement, digital transformation has become an essential component of strategic development for manufacturing enterprises. The review conducted confirms that while traditional strategy models offer clear frameworks for assessing digital maturity, they often require industry-specific adaptation. In contrast, platform- and ecosystem-based approaches enable companies to integrate partners and customers into a shared digital environment. Hybrid models that incorporate BIM integration and interregional partnerships demonstrate higher practical relevance for the manufacturing sector.

The analysis of digital transformation drivers identified six key catalysts: the dominance of information flows over physical ones, accelerated communication, the shift toward flexible organizational structures, the active implementation of IoT, Big Data, and AI, evolving competency profiles, and the emergence of digital ecosystems. The study shows that successful deployment of digital tools (IoT platforms, Big Data analytics, cloud services, robotics, ERP/MES/PLM systems) requires not only technical infrastructure but also new managerial mechanisms, including agile teams, digital functional zones, knowledge-sharing platforms, and balanced project financing models.

Building on these findings, the study proposes an integrated methodology for adapting business strategies—combining a discrete assessment of maturity across four dimensions (technology, processes, structure, resources) with a roadmap for implementing digital tools and organizational practices. This framework enables manufacturers to structure their transformation processes in stages, mitigate risks, and maximize the synergistic impact of digitalization.

The practical value of the research lies in the applicability of the proposed model for strategic planning and phased implementation of digital innovation by manufacturing managers. It also provides a foundation for justifying investment decisions and evaluating the effectiveness of transformation initiatives. Future research should focus on empirically validating the model and expanding it to account for sector-specific characteristics and regulatory contexts.

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