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## STRATEGIC INNOVATION MANAGEMENT: IMPLEMENTATION OF 3D PRINTING AS A COMPETITIVE ADVANTAGE FOR THE ENTERPRISE

In the modern context of digital transformation and Industry 4.0, additive manufacturing (3D printing, AM) has evolved beyond a mere tool for prototyping and is increasingly being employed in serial and even mass production. At the same time, its implementation requires not only technical investments but also systematic strategic innovation management – including changes in business models, supply chains, workforce qualifications, and performance evaluation systems. Recent analytical reviews and market forecasts indicate a steady increase in the role of AM in industry and an expansion of its application areas, particularly in metal manufacturing, aerospace, and medical sectors [2].

3D printing has the potential to significantly reduce product development and market launch time (time-to-market), which is especially critical in a competitive environment characterized by short product life cycles. Additionally, AM enables companies to decrease inventory levels and logistics costs by promoting production localization and on-demand manufacturing. Meanwhile, market reports demonstrate accelerated growth in segments related to end-use part production, a rise in sales of metal AM systems, and growing enterprise interest in investing in additive technologies. These trends make the issue of strategic management in the implementation of 3D printing critically important for enhancing enterprise competitiveness [4].

Strategic innovation management represents a comprehensive set of policies, procedures, and managerial decisions aimed at the systematic integration of technologies that generate long-term competitive advantages. In the context of 3D printing, this encompasses the selection of technological platforms (FDM, SLS, SLA, DMLS, etc.), the formation of product and process portfolios, the integration of AM with CAD/PDM/ERP/MES systems, personnel training and retraining, assessment of certification risks and compliance with standards, as well as economic evaluation using indicators such as total cost of ownership (TCO), return on investment (ROI), and break-even point. The managerial focus should shift from isolated pilot projects to large-scale, strategically managed implementation programs [3]. 3D printing can create competitive advantages through several mechanisms, as illustrated in Figure 1.

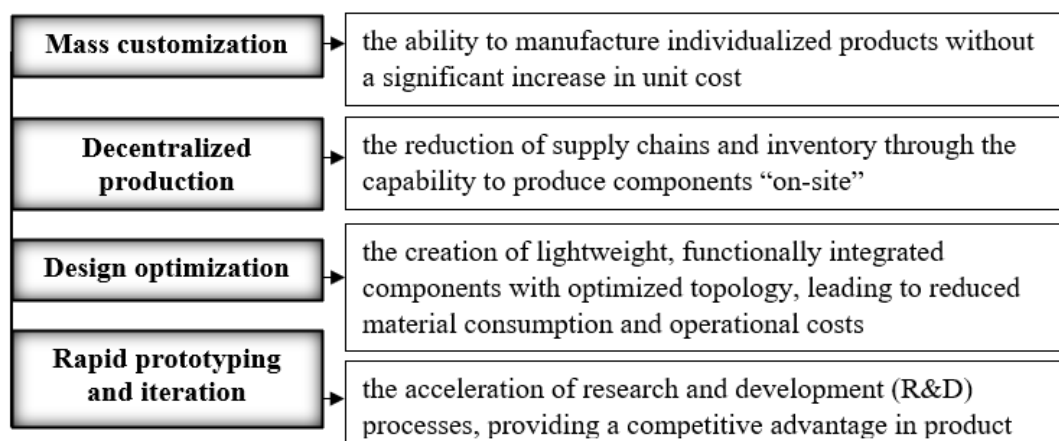


Figure 1 – Mechanisms of 3D Printing as a Tool for Creating Competitive Advantages

Source: compiled by the authors based on [1]

These effects are confirmed by both analytical reports from consulting firms and industry studies [1].

The implementation of additive manufacturing (AM) is not limited to the acquisition of printers. The main challenges include the development of a comprehensive strategy (defining which parts of production should be transitioned to AM), changes within the supply chain, certification of materials and processes (particularly for critical applications in aerospace and medical industries), data integration, and design cybersecurity (protection of CAD files). Additionally, human resource issues – from design engineers to machine operators – play a crucial role. Managers must establish key performance indicators (KPIs) to assess the impact of AM technologies on enterprise performance metrics such as production cycle time, cost price, defect rate, and return on investment (ROI) [3].

Economic assessment should include a total cost of ownership (TCO) analysis, calculation of the investment payback period, and sensitivity analysis based on material prices, machine productivity, and market demand. It is important to compare AM with traditional manufacturing methods for specific niches (e.g., small-batch production or components with complex geometries). Furthermore, multi-criteria decision-making approaches (such as the Analytic Hierarchy Process – AHP) are advisable for selecting technologies and forming project portfolios [4]. An example of a strategic approach and the main stages of implementation is presented in Figure 2.

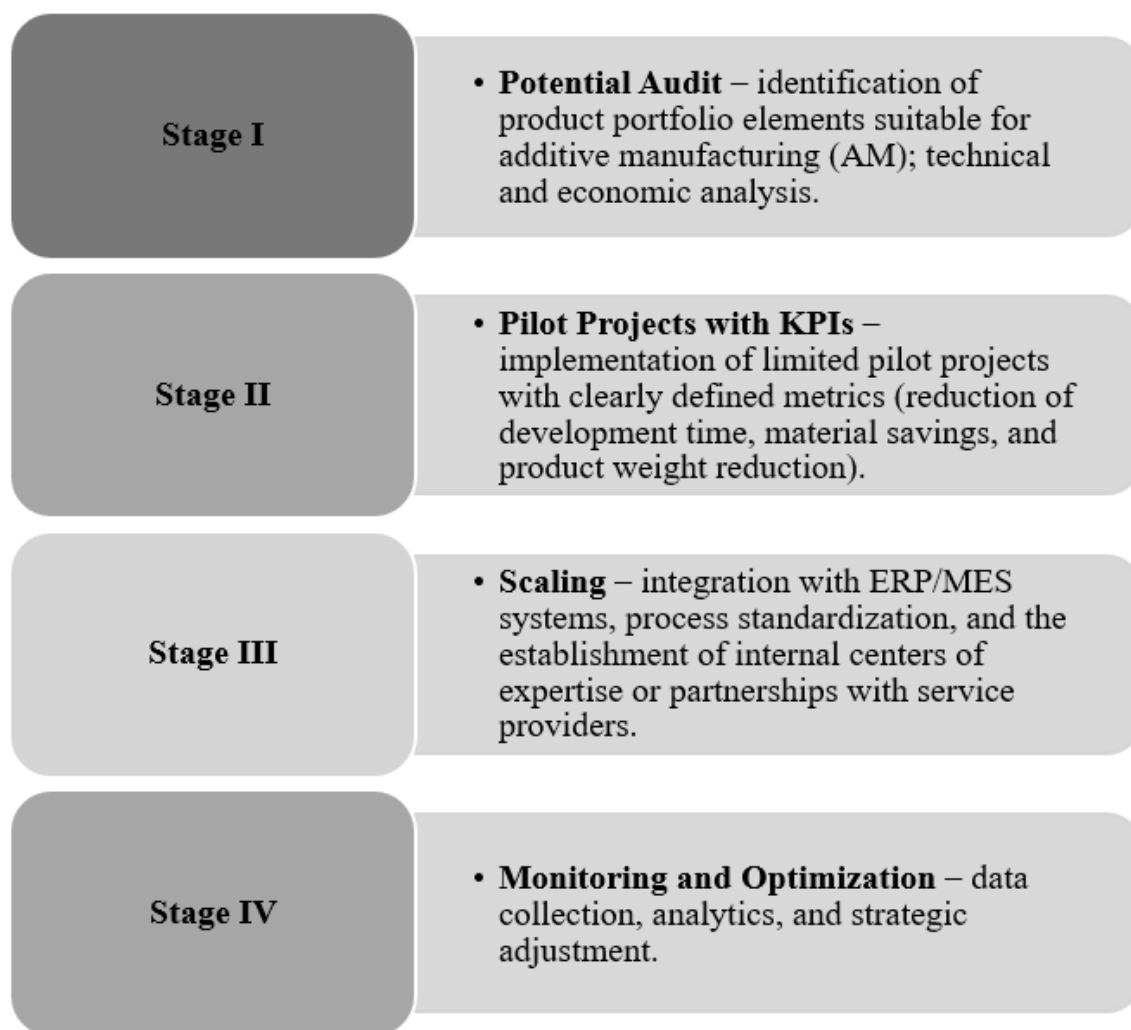


Figure 2 – Key Stages of 3D Printing Implementation

Source: compiled by the authors based on [3]

The risks associated with implementing additive manufacturing (AM) technologies in enterprise operations are multifaceted, encompassing both financial-economic and organizational-technological aspects. Primarily, a significant barrier is the high initial investment required for the acquisition of advanced equipment, the establishment of appropriate infrastructure, and the training of qualified personnel. Additional complexity arises from regulatory constraints related to the certification of complex components, particularly in highly regulated industries such as aerospace, medical, and defense, where compliance with international quality standards is a prerequisite for market access. Among the technical risks, issues with process repeatability, stability, and quality control of finished products should be highlighted, as these factors can negatively affect reliability and compliance with consumer requirements. An important aspect of the risk landscape is also intellectual property protection: digital models and 3D printing files may be subject to unauthorized copying or modification, creating potential threats to product safety and the company's competitive position.

At the same time, successful implementation of AM strategies is possible with a number of key success factors. One critical factor is strategic support from top management, which ensures the prioritization of innovation within the corporate strategy and the allocation of necessary resources. The presence of clearly defined business cases demonstrating the economic feasibility of investments through ROI metrics, reduced production cycle times, or decreased logistics costs is also essential. Implementation effectiveness increases when additive manufacturing is integrated into the enterprise's digital ecosystem – including ERP, PLM, and MES systems – allowing full control over the product life cycle. Equally important is the development of partnerships with material suppliers, technology companies, and certification bodies, which facilitates compliance with industry standards and enhances production quality. Finally, the development of internal competencies – including professional skill enhancement, establishment of AM expertise centers, and accumulation of in-house implementation experience – is strategically significant. The combination of these elements not only reduces risks but also contributes to the creation of a long-term competitive advantage in the context of digital production transformation.

In conclusion, 3D printing demonstrates real potential to generate competitive advantages through accelerated innovation, design optimization, and decentralized production. To transform technological capabilities into sustainable advantages, enterprises require strategic innovation management – from vision and business model development to KPI establishment and scaling of successful pilot projects. Economic feasibility depends on the specific application: AM is more advantageous in small-batch production, customization, and the manufacturing of complex components; however, each case requires a thorough TCO/ROI analysis.

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