PROBLEMS AND SOLUTIONS IN INTEGRATING DIGITAL TECHNOLOGIES INTO PROJECT MANAGEMENT IN MECHANICAL ENGINEERING

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DOI: 10.31364/SCIRJ/v13.i01.2025.P01251010
http://dx.doi.org/10.31364/SCIRJ/v13.i01.2025.P01251010

Abstract: This article examines the challenges encountered during the integration of digital technologies into project management within the mechanical engineering industry. The practical application of these technologies is a key direction for modern industry, primarily aimed at increasing efficiency and reducing costs. However, digitalization is inevitably accompanied by a range of difficulties and obstacles, including technological barriers, skill gaps among personnel, and challenges in adapting innovations across enterprises of different scales. The purpose of this study is to systematize approaches to addressing the most common and critical issues, based on the analysis of scientific literature, and online resources, including conceptual strategies, nuances of practical implementation of technological developments, and educational aspects. The study identifies contradictions related to technology maturity assessments and insufficient attention to the social and organizational dimensions of digital transformation. The findings conclude that the success of transformation in the analyzed field is directly dependent on a systematic approach that integrates strategy development, enhancement of educational programs, active use of artificial intelligence tools, and more. The author's contribution lies in organizing fragmented knowledge on the topic, identifying shortcomings in existing research, and proposing recommendations for addressing specific problems. The materials will be valuable for both researchers studying digital transformation in industry and practitioners responsible for integrating innovations into mechanical engineering.

Keywords: automation, integration, mechanical engineering, project management, digitalization, digital twins, digital technologies

Introduction

Modern mechanical engineering is characterized by the high complexity of manufacturing processes, a wide range of technical solutions, and the necessity for rapid adaptation to changing market conditions. Global competition requires enterprises to improve project management efficiency, minimize time and financial costs, and maintain consistent product quality. However, traditional management approaches based on a linear sequence of stages often fail to meet these demands.
One promising approach to address this issue involves the implementation of digital technologies. This includes the use of tools such as:

- planning software;
- data analysis automation;
- the introduction of digital twins;
- machine learning for predictive analytics.

http://dx.doi.org/10.31364/SCIRJ/v13.i01.2025.P01251010

These approaches enhance project management transparency, improve the accuracy of deadline forecasting, and optimize resource utilization.

Despite the obvious advantages of digitalization, integrating technological innovations into the mechanical engineering field presents a range of challenges:

- reorganization of organizational processes;
- the need for employee training;
- infrastructure modernization.

Therefore, a critical area of focus is the analysis of key aspects related to the practical implementation of digital technologies in this field. This includes describing their functional capabilities and assessing their impact on labor organization, particularly in light of the most pressing challenges and their possible solutions.

Materials and Methods

Modern research dedicated to the subject under discussion encompasses a wide range of issues, including the implementation of digital twins, data analysis, the development of online laboratories, and the automation of project processes. Relevant publications can be tentatively grouped into several thematic categories.

For instance, in the work of A. Miklosik and A.B. Krah [6], key directions for digitization initiatives in mechanical engineering are highlighted, with an emphasis on the need for a structured approach to modernization. Similarly, the article by A. Gasparre, L. Beltrametti, and L. Persico [3] describes the current state of Industry 4.0 technologies in the analyzed sector, including the prospects for automation and the integration of the Internet of Things. This work also identifies accompanying barriers to innovation, particularly the challenges of integrating new developments into traditional production processes.

The publication by R. Zhu, L. Wang, and Yu. Feng [10] examines long-term trends in the development of intelligent systems in mechanical engineering, including the application of artificial intelligence to enhance production adaptability. Online materials [1, 5] explore the broader impacts of digitalization on the industry as a whole, outlining the primary benefits, such as increased efficiency and reduced time costs.

The study by A. Ferrari and K. Willcox [2] focuses on the use of digital twins in the analyzed field, drawing comparisons with aerospace engineering. The authors demonstrate how technological innovations facilitate design optimization and reduce production risks. In B. Gerschütz, Y. Consten, S. Goetz, and S. Wartzack's work [4], a detailed analysis of digital development using the Paddme process is provided, showcasing its effectiveness for systematizing project activities. The work by Yu. Xu and colleagues [9] introduce an approach to extracting tolerance information from drawings using deep learning and image processing, helping to automate the analysis of information flows.

Research interest in educational aspects is evident in the publication by P. Treffinger, M. Canz, and J. Glembin [8], which examines how students perceive online laboratories equipped with digital twins. The authors conclude that interactive digital platforms significantly enhance learner engagement. C. Stechert's work [7] characterizes distributed project management based on a case study in an educational environment, demonstrating how innovative tools improve coordination.

A review of the sources reveals certain contradictions in the authors' approaches and opinions. For example, A. Ferrari and K. Willcox [2] focus on "mature" digital twin technologies, while A. Miklosik and A.B. Krah [6] point out the challenges of scaling

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their integration. Additionally, the issues of adapting these developments for small and medium-sized enterprises remain insufficiently addressed.

In preparing this article, the following methods were employed: content analysis, systematization, statistical data processing, and generalization. These approaches made it possible to provide a comprehensive evaluation of the digitalization process in mechanical engineering. Future studies are recommended to concentrate on the challenges of adapting technologies for enterprises of various scales.

Results and Discussion

According to statistical data, the global mechanical engineering market is projected to grow at an average annual rate of 4.7% until 2032. As industries continue to develop new technologies and refine existing systems, the expertise of mechanical engineers will remain invaluable [5].

The digitalization of project management is a multi-level process encompassing a wide range of technological advancements—from basic task automation tools to complex solutions based on artificial intelligence [3, 8].

A central element of this approach is the use of software packages, such as project management systems (PMS), which facilitate the coordination of all participants, provide operation visualization, and track key performance indicators (KPIs).

These systems ensure the integration of information flows from various sources:

- engineering calculations;
- production schedules;
- supply chain data;
- financial reports.

This enables the creation and enrichment of a unified information environment, improving coordination within project teams. Furthermore, digitalization supports the automation of routine operations, including calculations, scheduling, report processing, and risk assessment.

One key advantage of digital technologies is the deployment of Big Data analysis tools, which can detect hidden patterns within the management mechanism. For example, machine learning algorithms can forecast potential delays based on historical data and suggest ways to address them.

Another significant area is the use of digital twins. In mechanical engineering, these models enable the creation of virtual replicas of equipment, production lines, or entire factories. This approach facilitates testing, scenario evaluation, and process optimization without the risks associated with physical experimentation [2].

The process of integrating digital technologies into project management in mechanical engineering involves several stages (Figure 1).

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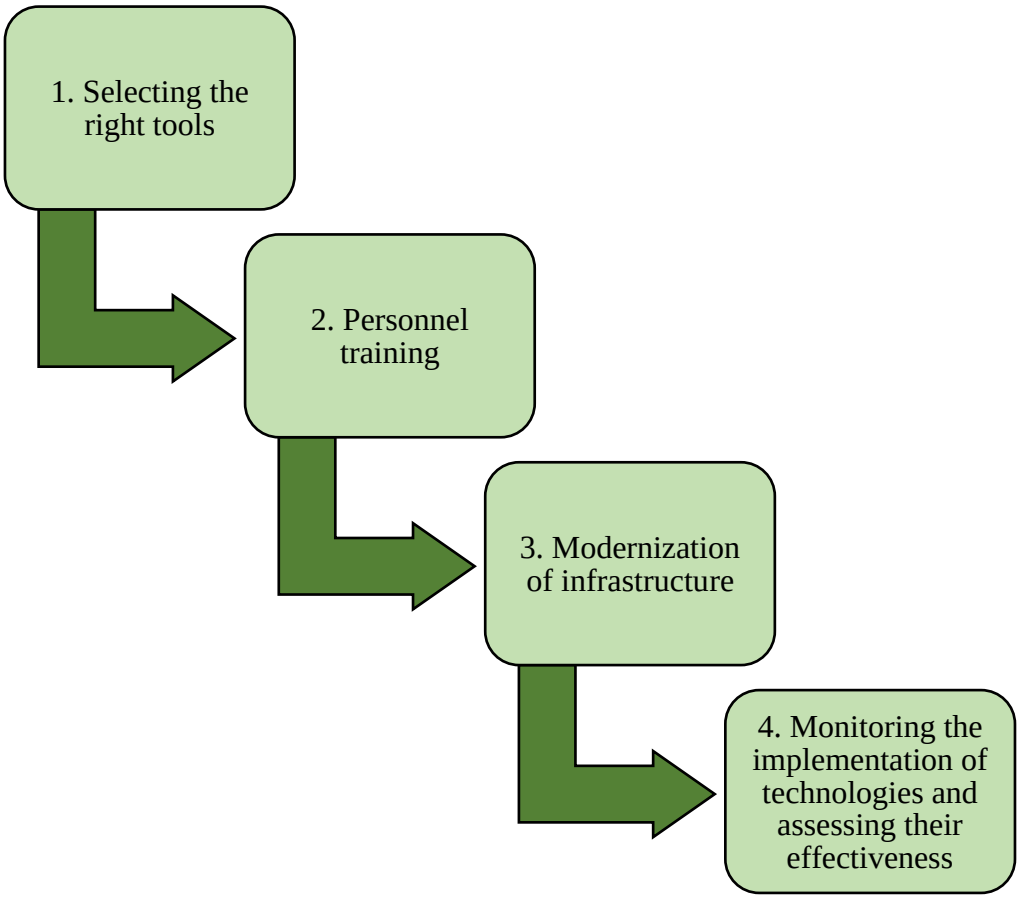

Fig. 1. The stages of digital technology implementation in project management in mechanical engineering (compiled by the author based on [4, 6, 8, 9])

Initially, appropriate tools are selected that align with the project's specifics and the production environment. This involves identifying the functional requirements for the software, analyzing available solutions on the market, and adapting them to the enterprise's needs.

The next stage involves staff training. Integrating new technologies requires employees not only to have technical skills but also a clear understanding of the principles behind these new tools. A critical component is the development of training programs and simulators that allow personnel to practice using technological solutions before their deployment in a real production environment.

Subsequent steps focus on upgrading the infrastructure. Successful digitalization is not feasible without enhancing the company's IT framework, including server capacity, data storage systems, and high-speed networks. Alongside these upgrades, special attention is paid to information security issues, given that project management in mechanical engineering often involves handling confidential technical information.

In the final stage, the implementation of the technologies is monitored and their effectiveness is assessed. Both traditional performance metrics and specialized indicators are used for this purpose, such as:

- the level of process automation;
- reduction in project task completion times;
- improved accuracy in risk forecasting.

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Given the points outlined above, it is necessary to address the specific problems in this area (Figure 2), accompanied by a discussion of possible solutions.

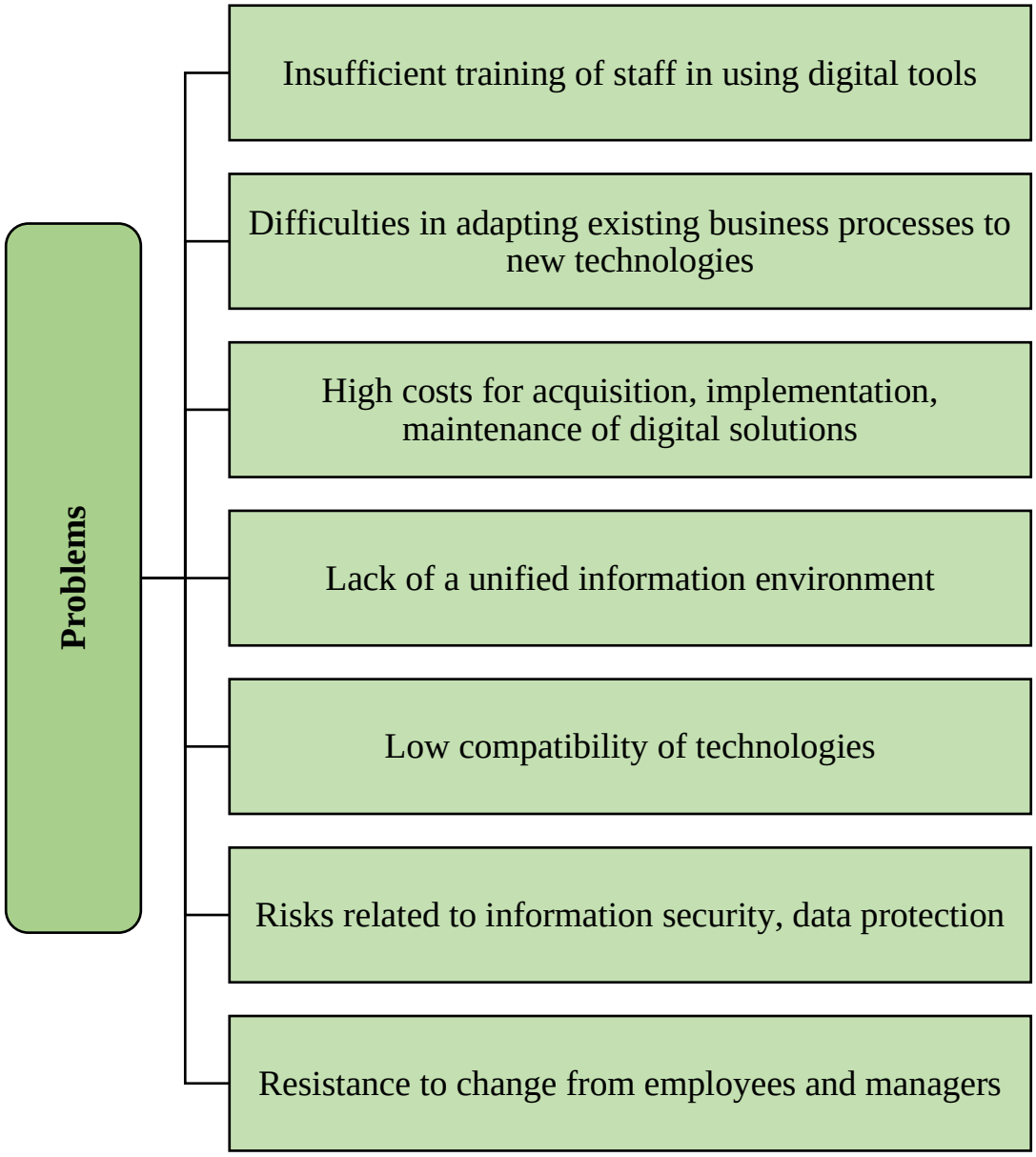

Fig. 2. Systematization of the problems of integrating digital technologies into project management in mechanical engineering (compiled by the author based on [3-5, 7, 9, 10])

Most employees at mechanical engineering enterprises have experience working with traditional management systems, but digitalization requires new knowledge and skills. This pertains to working with software platforms, data analysis, and digital environment interaction. A lack of competencies reduces the effectiveness of implemented technologies.

Addressing this issue requires the development of training programs and staff skill enhancement initiatives. Enterprises are advised to organize training sessions, use simulators, and apply methods based on real project scenarios. It is also important to designate coordinators or specialists who can help teams master the latest technologies.

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Business processes in mechanical engineering are often highly complex and tightly regulated. Integrating digital solutions necessitates their restructuring, which often entails changes to the organizational structure, adjustments to management standards, and the redistribution of employee functions.

To overcome this challenge, conducting a preliminary process audit is recommended to identify which processes can be automated and which require refinement. Engaging experts and employing methodologies such as Agile or Lean can help create flexible workflows that easily adapt to new developments.

The integration of the tools discussed in this article involves significant financial investments, primarily in software acquisition, equipment upgrades, and IT infrastructure development. For many enterprises, particularly smaller ones, such investments may be unaffordable.

To optimize costs, businesses are advised to adopt a phased approach to digitalization, starting with the implementation of the most critical tools. Leveraging cloud technologies (SaaS) can help reduce equipment purchase costs. Government or grant support may also be available, particularly for strategically important sectors.

Many mechanical engineering enterprises rely on disparate management and accounting systems that are not synchronized. This lack of integration complicates data exchange, hinders coordination between departments, and increases the likelihood of errors. Establishing a unified information environment can be achieved by implementing comprehensive software platforms that integrate all project management aspects. A crucial condition for this integration is ensuring the compatibility of new technologies with existing systems through the use of open interface standards (APIs).

Mechanical engineering projects often involve handling sensitive technical information, where breaches can cause significant damage to the enterprise. The use of digital technologies raises the risk of cyberattacks, unauthorized access, and data leaks.

To ensure security in this context, companies should implement modern protective measures, such as:

- encryption;
- control systems;
- regular vulnerability assessments.

Additionally, it is recommended that companies conduct cybersecurity training for employees and establish incident response policies.

Finally, the integration of digital solutions often encounters resistance at both staff and management levels. Common reasons include fears of job losses, mistrust of new tools, and a lack of understanding of their benefits.

Effectively addressing this issue requires strong communication strategies. Leaders must convey the goals of digital innovation, highlight the advantages, and illustrate positive outcomes through concrete examples. Engaging personnel in the process, creating pilot projects, and publicly acknowledging successes can help reduce tension and increase engagement. Below is the proposed sequence of steps (Table 1).

Table 1 – Algorithm of actions to reduce resistance to change (compiled by the author)

http://dx.doi.org/10.31364/SCIRJ/v13.i01.2025.P01251010

Stage	Description	Specific Measures
1. Diagnosis	Identifying the reasons for resistance and the key sources of distrust toward digitalization.	Conducting employee surveys, interviews with management, and analyzing corporate culture.
2. Information	Clearly communicating the goals and benefits of technology implementation to all participants.	Organizing meetings, and presentations, and publishing informational materials.
3. Involvement	Engaging staff in the process of implementing digital innovations.	Forming project groups, involving personnel in testing and selecting tools.
4. Training	Enhancing employees' skills to effectively utilize new tools.	Developing training programs, conducting workshops, and hosting master classes.
5. Piloting	Launching pilot projects to test technologies and demonstrate their advantages.	Implementing small-scale projects with new solutions and analyzing the results.
6. Support	Providing ongoing assistance and oversight during the integration process.	Assigning mentors, and technical experts, and promptly addressing emerging issues.
7. Recognition	Promoting positive experiences.	Organizing public awards and publishing successful case studies.

Applying the proposed algorithm is expected to significantly reduce resistance to change, ensuring a smoother process of integrating digital solutions into project management. The key elements are transparent communication, early-stage employee involvement, a focus on training, and demonstrating the tangible benefits of new approaches. This approach will foster a favorable environment for transformations, strengthen employee trust in management, and ultimately increase the likelihood of successful initiative implementation.

Conclusions

In the current environment, integrating digital technologies into project management within mechanical engineering represents a critical component of the industry's development, ensuring global market competitiveness. The use of these tools contributes to improving operational efficiency and reducing costs, which is especially relevant given the pronounced dynamism of production processes. However, successful digitalization requires a systematic approach, including adapting the tools to meet enterprise needs, training personnel, and modernizing infrastructure.

This integration process is accompanied by numerous challenges. Comprehensive steps involving personnel retraining, resource optimization, rational allocation, and ensuring information security enable organizations to overcome existing barriers and achieve significant productivity and competitiveness growth.

It appears that the future of mechanical engineering is closely tied to the development and widespread application of digital solutions. Their adoption opens up numerous additional opportunities to streamline and accelerate operations, improve product quality, and strengthen the positions of businesses in a highly competitive environment.

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