

ENHANCING TECHNOLOGICAL INNOVATION IN THE MECHANICAL MANUFACTURING INDUSTRY IN VIETNAM

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ABSTRACT

The mechanical manufacturing industry plays a foundational role in the process of industrialization and modernization, while also serving as a driving force for the development of other industries. In the context of digital transformation and the Fourth Industrial Revolution, technological innovation has become an urgent requirement to enhance the competitiveness of Vietnam's mechanical sector. This article analyzes the current state of technological innovation in the mechanical manufacturing industry, identifies the achieved results, limitations, and underlying causes, and thereby proposes several solutions to promote technological innovation in the coming period.

Keyword: mechanical manufacturing; technological innovation; digital transformation; Industry 4.0; Vietnam

1. INTRODUCTION

In the context of deepening globalization and international economic integration, together with the rapid development of the Fourth Industrial Revolution, technological innovation has become a key factor determining the competitiveness and sustainable development of each nation. For Vietnam, the process of industrialization and modernization is entering a new phase with increasingly higher requirements for growth quality, production efficiency, and the ability to participate more deeply in global value chains. In this process, the mechanical manufacturing industry plays a particularly important role, serving as the foundation of national industry by providing machinery, equipment, and technology for most other economic sectors.

However, in practice, Vietnam's mechanical manufacturing industry still faces many limitations compared to countries in the region and around the world. The level of technology remains modest, the degree of automation is still low, and the capability to design and manufacture high-tech products is limited. Most mechanical enterprises are small and medium-sized, lacking investment capital for technological innovation, while their ability to access and master advanced technologies remains constrained. In addition, the linkage between enterprises and research institutes and universities is not yet strong, resulting in limited effectiveness in technology

transfer and the application of research outcomes to production.

Meanwhile, global trends in the mechanical industry are shifting rapidly toward automation, digitalization, and smart manufacturing, with the increasing application of technologies such as artificial intelligence (AI), the Internet of Things (IoT), big data, 3D printing, and industrial robotics. These trends not only transform production methods but also restructure the entire value chain of the mechanical industry, creating both opportunities and challenges for developing countries like Vietnam. Without timely technological innovation, Vietnam's mechanical industry will face difficulties in improving productivity, product quality, and competitiveness in international markets.

Recognizing the importance of technological innovation, in recent years the Vietnamese government has issued various policies and strategies to promote the development of the mechanical sector, emphasizing the enhancement of technological capacity and encouraging research, development, and the transfer of advanced technologies. However, implementation in practice still faces many shortcomings and has not yet met the requirements of development in the new context.

Based on these issues, the study titled "Enhancing Technological Innovation in the Mechanical Manufacturing Industry in Vietnam" is of both

theoretical and practical significance. The article aims to analyze the current state of technological innovation in the mechanical manufacturing industry, clarify the achieved results, limitations, and underlying causes, and propose feasible solutions to promote technological innovation, thereby enhancing competitiveness and ensuring the sustainable development of Vietnam's mechanical industry in the coming period.

2. THEORETICAL FOUNDATIONS OF TECHNOLOGICAL INNOVATION IN THE MECHANICAL MANUFACTURING INDUSTRY

Technological innovation is defined as the process of modifying, improving, or applying new technologies to production activities in order to enhance productivity, product quality, and business performance. In the mechanical manufacturing industry, technological innovation goes beyond investing in modern machinery and equipment; it also includes improvements in production processes, management methods, product design, and the organization of production toward lean and intelligent systems.

According to modern economic growth theories, especially endogenous growth theory, technological innovation is regarded as a key driver of long-term growth through improvements in total factor productivity (TFP). For the mechanical manufacturing industry, which has a high level of technical content and strong spillover effects, technological innovation is particularly important because it not only directly affects the efficiency of the sector but also has significant impacts on other industries such as processing and manufacturing, construction, transportation, and agriculture.

The content of technological innovation in the mechanical manufacturing industry can be considered from several main aspects. First, innovation in equipment and production technologies includes the application of advanced machining technologies such as CNC, industrial robots, 3D printing, and automated production lines. Second, innovation in product design and development involves the use of CAD, CAM, and CAE software to shorten design time, improve accuracy, and optimize products. Third, innovation in management and production organization focuses on applying advanced management models such as Lean Manufacturing, Flexible Manufacturing Systems, and Smart

Factory models. Fourth, innovation in human resources emphasizes training highly skilled engineers and workers capable of operating and mastering modern technologies.

In addition, technological innovation in the mechanical manufacturing industry is influenced by various factors, including the institutional environment, government policies, access to capital, the quality of human resources, and the level of linkage among stakeholders within the innovation system. Among these factors, the role of the State is particularly important in providing strategic direction, creating a supportive environment, and assisting enterprises in their technological innovation efforts.

Furthermore, in the context of digital transformation, technological innovation in the mechanical manufacturing industry is closely associated with the application of digital technologies such as artificial intelligence, the Internet of Things, big data, and cloud computing. These technologies contribute to enhancing automation, optimizing production processes, and improving forecasting and decision-making capabilities within enterprises.

Overall, technological innovation in the mechanical manufacturing industry is a comprehensive process that encompasses multiple dimensions, including technology, management, and human resources. It is a critical factor determining the competitiveness and sustainable development of the industry in the context of global integration and the Fourth Industrial Revolution. Based on this theoretical foundation, analyzing the current situation and proposing solutions to strengthen technological innovation in Vietnam's mechanical manufacturing industry is both necessary and meaningful.

3. CURRENT SITUATION OF TECHNOLOGICAL INNOVATION IN VIETNAM'S MECHANICAL MANUFACTURING INDUSTRY

In recent years, alongside the process of industrialization, modernization, and international economic integration, Vietnam's mechanical manufacturing industry has made notable progress, with increasing attention given to technological innovation. This is considered a key factor in enhancing labor productivity, improving product quality, and strengthening the competitiveness of enterprises in an increasingly

intense global market. However, the current state of technological innovation in the industry shows clear disparities among different groups of enterprises and still reveals many limitations that require comprehensive assessment.

First, regarding the achieved results, it can be observed that a number of mechanical enterprises, especially large firms and foreign-invested enterprises, have actively invested in technological innovation and gradually approached modern manufacturing trends. Many enterprises have widely adopted advanced machining technologies such as CNC machines, automated production systems, industrial robots, as well as design and simulation software such as CAD, CAM, and CAE. The application of these technologies has not only improved product accuracy but also shortened production time and reduced operational costs. Some enterprises have implemented advanced production management solutions such as Enterprise Resource Planning (ERP), Lean Manufacturing, and have gradually moved toward Smart Factory models.

In addition, research and development activities and innovation within the mechanical sector have shown positive improvements. Some enterprises have proactively invested in product design and development, gradually mastering certain core technologies instead of merely focusing on processing and assembly. Collaboration between enterprises and research institutes and universities has initially improved, contributing to the promotion of technology transfer and the application of research outcomes into production practice. Moreover, government support policies such as the national technology innovation program, industrial supporting development programs, and industrial promotion policies have created certain favorable conditions for enterprises to access resources and new technologies.

However, despite these positive results, technological innovation in Vietnam's mechanical manufacturing industry still faces significant limitations. First, the technological level of most enterprises remains at a medium or relatively outdated level compared to other countries in the region. The majority of mechanical enterprises are small and medium-sized, accounting for a large proportion but having limited financial capacity, which makes it difficult to invest in technological innovation. The adoption of high technologies,

automation, and digital transformation remains fragmented and has not been implemented widely or systematically.

Another notable issue is the low localization rate in the mechanical industry, with many high value-added mechanical products still heavily dependent on imports. Domestic enterprises mainly participate in low value-added stages such as processing and assembly, while key stages such as design, manufacturing of core components, and product development have not yet been fully mastered. This not only reduces the competitiveness of enterprises but also limits the ability of Vietnam's mechanical industry to integrate deeply into global value chains.

Furthermore, the research and development capacity of enterprises remains weak and has not met the requirements of technological innovation in the new context. Linkages between enterprises and research institutes and training institutions are still loose and lack effective coordination mechanisms. Many scientific research results have not been commercialized or widely applied in production. At the same time, although the workforce in the mechanical industry is abundant in quantity, it is limited in quality, with a shortage of highly skilled engineers and experts capable of mastering and developing advanced technologies.

From a managerial perspective, many mechanical enterprises have not paid adequate attention to technology management and long-term innovation strategies. Management thinking often remains traditional, with a lack of proactiveness in accessing and applying advanced management models. As a result, technology investments are sometimes inefficient, lack clear direction, and are not closely aligned with overall business development strategies.

The causes of these limitations stem from multiple factors. First, the institutional environment and policies supporting technological innovation are not yet fully developed, lack coherence, and have not created strong incentives for enterprises. Access to preferential funding for technological innovation remains difficult due to complicated procedures. In addition, the innovation ecosystem within the mechanical sector is still underdeveloped, lacking sufficiently capable research and technology transfer centers.

Moreover, awareness among some enterprises regarding the importance of technological

innovation is still limited, and it is not yet considered a vital factor for competitiveness. Risk aversion, lack of information about new technologies, and insufficient investment resources have prevented many enterprises from actively pursuing innovation. At the same time, competition from foreign enterprises with advantages in technology and capital also creates significant pressure on domestic firms.

In summary, the current state of technological innovation in Vietnam's mechanical manufacturing industry reflects the coexistence of positive developments and persistent limitations. Although certain progress has been made in accessing and applying modern technologies, the industry has yet to achieve a technological breakthrough. This situation calls for urgent, comprehensive, and effective solutions to promote technological innovation, thereby enhancing competitiveness and ensuring the sustainable development of the industry in the coming period.

4. SOLUTIONS TO ENHANCE TECHNOLOGICAL INNOVATION IN VIETNAM'S MECHANICAL MANUFACTURING INDUSTRY

To promote technological innovation in Vietnam's mechanical manufacturing industry in the new context, it is necessary to implement a comprehensive and synchronized system of solutions with close coordination among the State, enterprises, and stakeholders within the innovation ecosystem. These solutions should not only focus on technical aspects but also encompass institutional frameworks, resources, governance, and international cooperation.

First, it is essential to further improve the institutional framework and policies supporting technological innovation in a consistent, stable, and feasible manner. The government should develop stronger incentives in terms of taxation, credit, and land use for enterprises investing in advanced technologies, especially those related to automation, smart manufacturing, and digital transformation. At the same time, administrative procedures should be reformed and simplified to facilitate easier access to innovation support funds, particularly for small and medium-sized enterprises. Establishing venture capital funds and innovation funds in the mechanical sector is also an important measure to support breakthrough technological projects.

Second, it is necessary to promote research and development (R&D) activities and technology transfer. The State should increase investment in research institutes, technology centers, and universities specializing in mechanical engineering, while fostering the "triple helix" model involving the State, scientists, and enterprises to enhance research efficiency and practical application. The establishment of innovation centers and specialized technology transfer centers in the mechanical field will help bridge the gap between research and production. In addition, enterprises should be encouraged to allocate funds for science and technology development and proactively invest in R&D and product innovation.

Third, developing high-quality human resources is crucial to meet the requirements of technological innovation. Training programs at vocational institutions and universities need to be fundamentally reformed to align with practical business needs and updated with new technologies such as artificial intelligence, industrial robotics, digital design, and smart manufacturing. At the same time, retraining and upskilling programs should be strengthened to help the existing workforce adapt to rapid technological changes. Expanding international cooperation in training, expert exchange, and knowledge transfer will also contribute to improving the quality of human resources in the sector.

Fourth, accelerating digital transformation in mechanical enterprises is essential. Enterprises should develop digital transformation strategies appropriate to their scale and capabilities, gradually applying technologies such as the Internet of Things (IoT), big data, artificial intelligence (AI), and cloud computing in production management and business operations. The implementation of advanced management systems such as ERP, MES, and SCM will not only optimize production processes but also enhance quality control and data-driven decision-making. At the same time, the development of smart factory models and flexible manufacturing systems should be encouraged to improve productivity and adaptability to market changes.

Fifth, strengthening international cooperation and actively participating in global value chains is necessary. Through collaboration with multinational corporations and foreign

enterprises, Vietnamese mechanical firms can access advanced technologies, learn modern management practices, and enhance production capabilities. It is important to effectively leverage free trade agreements (FTAs) to expand export markets, while selectively attracting foreign direct investment (FDI), prioritizing projects that involve technology transfer and linkages with domestic enterprises. Additionally, enterprises should be supported in building strong brands and improving product quality standards to meet international market requirements.

Sixth, developing supporting industries and the innovation ecosystem within the mechanical sector is a key solution. Strengthening supporting industry enterprises capable of supplying high-quality components, parts, and materials will help increase localization rates and reduce dependence on imports. At the same time, it is necessary to build a robust innovation ecosystem involving enterprises, research institutes, universities, investment funds, and intermediary organizations to promote sustainable technological innovation.

Finally, improving corporate governance and technology management capacity is essential. Mechanical enterprises need to adopt modern management thinking and develop long-term strategies associated with technological innovation and digital transformation. The application of advanced management models, along with enhanced risk management and innovation management, will enable enterprises to use resources more efficiently, improve competitiveness, and better adapt to market fluctuations.

5. CONCLUSION

In the context of the global economy undergoing profound transformation under the impact of the Fourth Industrial Revolution, technological innovation has become an inevitable requirement for the development of Vietnam's mechanical manufacturing industry. The analysis shows that although the sector has achieved certain positive results in applying new technologies, improving productivity, and gradually integrating into global value chains, there remain significant limitations in terms of technological level, innovation capacity, human resource quality, and production autonomy. These limitations call for synchronized and long-term solutions, ranging from improving institutional frameworks and policies, increasing

investment in research and development, promoting digital transformation, to enhancing the quality of human resources and expanding international cooperation. In particular, enterprises must play a central role in the process of technological innovation by proactively improving management capacity and accessing advanced technologies to adapt to increasingly intense competition. It can be affirmed that strengthening technological innovation is not only a driving force for enhancing the competitiveness of the mechanical manufacturing industry but also an important contributor to the country's industrialization and modernization process. If effectively implemented, the proposed solutions will create a solid foundation for Vietnam's mechanical industry to develop in a modern, sustainable manner and to integrate more deeply into the global economy in the coming period.

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