Research on the Implementation Method and Path of Lean Digitization in Enterprises

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Abstract: Lean digitization is the deep integration of lean management and digital technology, empowering each other to help manufacturing enterprises optimize resource allocation, improve production efficiency, enhance operational efficiency, and improve customer experience. Lean digitization has two basic characteristics: firstly, using digital technology and intelligent technology to break through the cognitive limitations of complex management in machine motion and enterprise activities, enabling more detailed "continuous improvement" of complex processes and flow management in the digital space; The second is to use lean thinking to guide digital transformation construction, achieving the goal of continuous improvement in manufacturing processes, operational processes, and organizational management with limited features and data volume. This article proposes a new method that combines digital tools with lean theory, sorts out the paths and important elements of lean digital technology at different stages, and describes ways for enterprises to enhance their lean digital capabilities from different dimensions, helping them achieve comprehensive lean improvement in the context of digitization.

Keywords: Lean Management; Digital Tools; Flow Standardization Continued Improvement

1. Introduction

Since the 1950s, lean management has been the main means of guiding production in the manufacturing industry, laying a solid foundation for the excellent operation of enterprises. With the increasing complexity of manufacturing processes and manufacturing techniques, traditional lean management is insufficient to meet the growing operational demands [1]. More and more advanced manufacturing enterprises are deeply integrating traditional lean and advanced digital technologies to break through existing management bottlenecks, achieve changes in production management models, and further improve the efficiency of traditional lean management. Many enterprises are facing the problem of insufficient production capacity, mainly due to the lack of transparency in information at the production line and factory levels. To address this issue, various manufacturers are researching ways to overcome the limitations of lean management at the data level through the empowerment of digital technology.

Lean management is widely used by manufacturing enterprises to eliminate waste and improve efficiency, playing a crucial role in enhancing business management level. Currently, the manufacturing enterprise still faces several operational challenges, including unclear R&D goals, uncoordinated planning, and a lack of process regulation, which lead to resource waste, delays, and increased risks. Production is hindered by order changes, inefficient management, and unstandardized processes, affecting delivery timelines. Additionally, low automation and complex workflows result in frequent anomalies and waste. Inadequate supply chain management, poor supplier coordination, and lack of transparency further delay production and lead to inventory and quality issues, ultimately impacting on-time delivery. Meanwhile, Lean management has many classic methods and tools that can be used to reduce costs and increase efficiency in different stages and scenarios, which would significantly mitigate the conflict in supply chain and vulnerability of production process. However, most of these

traditional tools require manual statistics and management, which cannot meet the efficiency requirements of the industry. The continuous emergence of digital technology has made up for these shortcomings. Enterprises use automation equipment, automatic filling, form generation and other technologies to perform a large amount of repetitive work, which not only reduces labour costs, but also makes work processing more efficient and accurate. For example, companies use machine vision for quality inspection of complex products or hazardous scenarios, improving inspection accuracy while eliminating safety hazards. In addition, enterprises utilize technologies such as data collection, big data analysis, and BI to visualize their materials, processes, and personnel, reducing human interference and reliance on experience, and achieving more accurate management and decision-making. The application of technologies such as artificial intelligence and digital twins makes it possible for enterprises to predict order planning, production planning, equipment maintenance, and other aspects, further improving the profitability of cost reduction and efficiency improvement.

2. Lean Digitization Implementation Method

The current construction of digital and intelligent factories places more emphasis on the standardization and integration of interfaces and data, the deployment and integration of automation equipment, data collection and analysis, and the application of cutting-edge technologies. However, it often neglects the relevance to the business and management goals of enterprises, resulting in a low application rate of digital factories [2]. Lean thinking can guide the construction of digital intelligent factories through process standardization, lean layout, and cost-effectiveness. Although there is no standardized construction paradigm of lean digital factory at present, lean digitization can be used as a reference system for the construction of new factories to guide enterprises to improve the lean content in factory planning and construction plans, strengthen the correlation between digital software and hardware and management system, as well as business objectives, so that the planning of new factories can be close to business, have unified process standards and data standards, and have both openness, flexibility, progressiveness and economy.

In recent years, more and more companies have recognized the importance of lean management in improving their management level and digital transformation. Lean and digitization mutually empower and promote each other, which can help enterprises effectively reduce operational complexity and lay a solid foundation for intelligent development. Lean thinking runs through the entire life cycle of lean digitization implementation, establishing a customer-oriented value stream and standards for management, products, industry, operations, etc., building a standardized and flexible production system, achieving an upward cycle of continuous improvement, and forming the basic environment for enterprise lean digitization implementation. The implementation of lean digitization is a systematic project that requires the realization of enterprise strategic goals as the core, covering research and development, supply chain, production, sales, and service links. Through digital technology, product digitization, operational digitization, performance digitization, and employee digitization are achieved, realizing the full process lean management of digitization [3].

Exploring the implementation of lean digitization, which involves continuously optimizing processes, eliminating waste, and utilizing minimal resources to create maximum value, can help enterprises gradually achieve comprehensive digitization and intelligence on the basis of improving management systems, effectively enhancing their competitiveness. The implementation of lean digitization in enterprises is a systematic project that cannot be achieved overnight. It requires top-level planning, step-by-step implementation, and gradual progress [4]. The successful experience of lean digitization worldwide tells us that the implementation of lean digitization requires several important phases, including implementation on business scenario units, production processes, cross-business integration and collaboration, global operation within enterprise, and industrial and supply chains, shown as Figure 1.

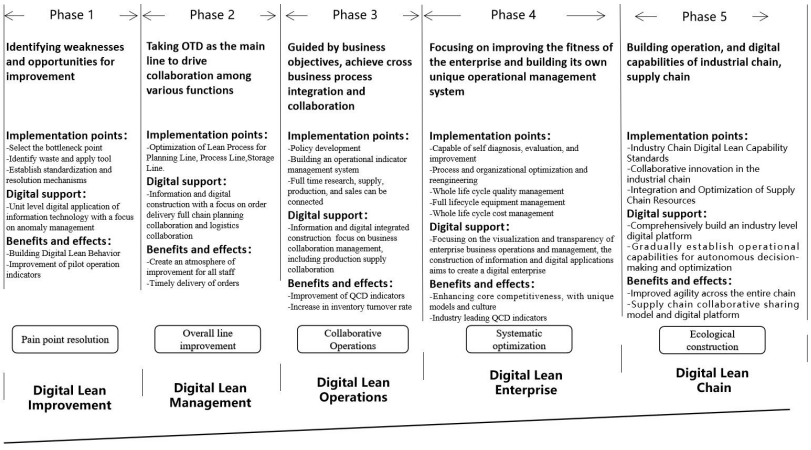

Figure 1. Lean Digital Implementation Roadmap

Phase 1: The actual construction of digital lean improvement based on business scenario units requires the establishment of on-site management standards in pilot projects, and the solidification of standards and processes through low-cost, small-scale, and quickly deployed digital applications to rapidly promote lean digital improvement. Afterwards, based on the digital lean management of production and management processes, the implementation of lean digitization expanded from pilot projects to business lines [5].

Phase 2: At this stage, it is necessary to use the management standards of the scenario as the basis to drive the management process and support of the business line, use on-site management to drive functional departments, and use on-site demand and order delivery as the center to drive the best collaborative improvement of business processes on site. For example, lean transformation should be carried out on business process modules such as order planning, process management, warehousing and logistics, and seven major tasks on site (safety, quality, production, cost, equipment, personnel, environment), and these transformations should be digitized and solidified to form a lean digital management system for the business line. If the enterprise is already using digital systems such as MES and ERP, it needs to add corresponding functions based on lean improvement on the basis of the original system to ensure the consistency between the digital system and the management system.

Phase 3: The third stage is digital lean operation based on business integration collaboration. At this stage, it is necessary to establish an optimization system for business integration, which achieves collaborative connections between various business processes through common elements and standards; It is also necessary to integrate business processes into financial management and achieve collaborative management of business indicators and business management process element data linkage. Standard processes, unified data formats, and interconnected system interfaces are the foundation of collaboration, while digital systems that integrate various business lines are the carriers of collaboration. All production and management actions can be operated on the system and presented with progress and results through dashboards.

Phase 4: The fourth stage is a digital lean enterprise based on a comprehensive operational system. At this stage, it is necessary to build the enterprise's own operational management system, establish a continuous improvement model around strategic business objectives, and create a lean based, data-driven lean digital enterprise. The enterprise builds its own lean operational framework, aligning business strategies with data-driven decision-making. The goal is to establish a continuous improvement model centered on strategic business objectives, ensuring that all digital and lean management efforts contribute to long-term operational excellence. Enterprises must continuously enhance their core business indicators and operational efficiency through the enterprise-level lean digital platform. The integration of standardized management processes, real-time data analytics, and predictive decision-making tools enables the enterprise to reach industry-leading levels of performance.

Phase 5: The final stage is the digital lean construction based on the industrial chain and

supply chain. This stage is the application and capability enhancement of lean digitization in the industrial chain and supply chain, enabling enterprises to respond to various market changes while maintaining stable development, establishing the security, stability, and flexibility of the supply chain, and achieving cooperation and win-win outcomes with industry related enterprises; It is even possible to promote the products and related management standards of enterprises through industrial platforms, driving the common development of industries, and enabling enterprises to achieve stable and sustainable development in the industry and industrial chain.

The implementation of lean digitization is a structured, iterative process that progresses from business scenario unit improvement to enterprise-wide integration and, ultimately, to industrial collaboration. Global experiences in lean digitization highlight the importance of adopting a phased approach, beginning with localized pilot projects and expanding systematically across business functions. By integrating lean management principles with digital technologies, enterprises can enhance production efficiency, optimize business processes, and create intelligent, data-driven operational systems. The successful transformation into a lean digital enterprise not only improves internal efficiency but also positions the organization as a leader in industrial digitalization, fostering sustainable development and long-term industry competitiveness [6].

3. Analysis of Different Phases

Unit improvement is the starting point for lean digital development in enterprises. At this stage, enterprises need to clarify their strategic goals, identify key and bottleneck points through lean methods, and use them as pilot projects for implementing lean digitization, in order to achieve the goal of applying digitization for rapid improvement [7]. At this stage, firstly, enterprises need to use lean thinking to analyse and determine management elements, with the goal of achieving process flexibility and minimizing waste, and establish on-site lean management standards and processes. Next, the enterprise will use lean methods to carry out lean transformation of production line layout, standard operations, equipment management, quality management, safety management, etc. based on workstation units, and use automation equipment, robots, sensor data collection, 5G technology, digital management and other means to create pilot units that integrate lean and digitization, shown as Figure 2.

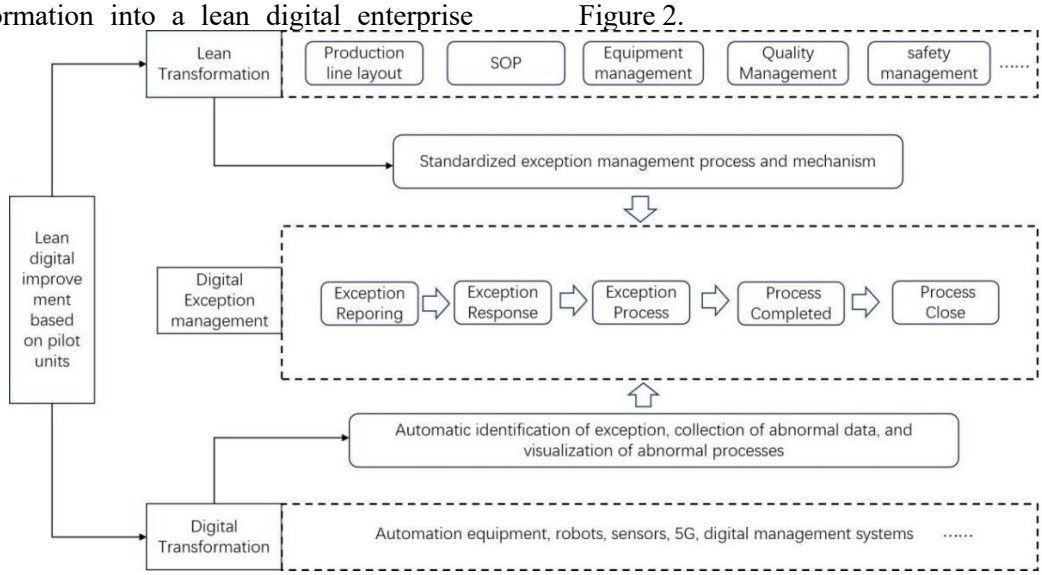

Figure 2. Digital Lean Improvement of Business Scenario Units

The core task of enterprises at this stage is to reduce production interruptions caused by frequent anomalies and avoid unnecessary waste. The identification of anomalies, information collection, and anomaly handling are the key to digital planning and application in this stage, and standardization and anomaly information collection are the foundation of digital anomaly management. Enterprises need to establish an anomaly management process and mechanism for identifying and resolving problems; It is also necessary to identify one's

own level of digitization and add anomaly management functions on the basis of the original digitization, to achieve real-time detection, alarm, transmission and resolution of anomaly problems, and to monitor the anomaly handling process in real time. Digital tools will be used for data analysis and visualization of the entire process of anomaly management, in order to better identify and solve problems, and manage the progress of anomaly handling.

The second stage of promotion is the expansion of lean digitization in business processes after gaining experience and management standards through pilot implementation. Enterprises focus on value creation and timely delivery of orders, streamline on-site value processes, carry out process re-engineering and standardization, clarify supporting departments and business processes for management standards, and ensure process simplification and on-site feasibility. At this stage, it is necessary to construct and manage a lean digital production line based on lean thinking. Lean digital production lines have two characteristics: firstly, gradually using automated machines to replace inefficient and unstable manual operations in the process; The second is to achieve real-time visualization management and continuous improvement of production planning, quality, equipment, production materials and other dimensions through the system, shown as Figure 3.

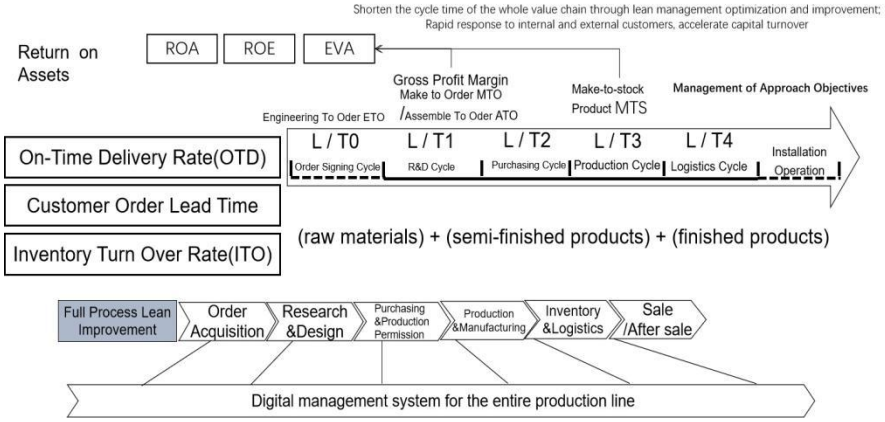

Figure 3. Digital Lean Management Process for Production and Management

The lean digitization construction in this stage requires enterprises to carry out lean transformation in business processes such as warehouse logistics collaboration, process optimization, and flexible production planning. Lean helps eliminate waste in production lines and management processes, continuously refine management elements and standards, and achieve seamless collaboration among various business scenarios through lean management of data and information generated by processes; By introducing digital functions such as task control, deviation handling, anomaly analysis, and problem handling, lean digital management of various business lines is achieved with the goal of improving on-time delivery of OTD, enhancing the level of enterprise OTD capabilities. When a company has clear management elements, standardized management methods, and visible management data in its management process from site to function, management responsibilities, goals, and gaps will be clearly visible, thereby supporting the shortening of order cycles, timely delivery of orders, and rapid turnover and revenue of funds. For example, enterprises can use lean methods as a guide to integrate and analyze data on dimensions such as research and development progress, procurement status, inventory management, production status, quality, equipment resource assurance capabilities, customer delivery services, and operations through digital systems, thereby achieving lean, efficient, and transparent management of the entire business process [8].

Next, enterprises comprehensively carry out the integration of multiple business lines, and achieve lean digital management of production processes and business processes such as research and development design, processes, production, supply chain, marketing management, quality, equipment, manpower, warehousing, and logistics by creating operational management models and platforms

[9-11]. Enterprises need to simplify, intensively improve, and establish standards for processes, especially lean management interfaces, management elements and data, management standards, etc; It is necessary to clarify the correlation logic between various business lines, form standardized system documents for processes, construct a digital lean operation system for multi business integration and collaboration, and integrate the system on the basis of standardization in dimensions such as processes, data, organizational structure, and functions, ultimately forming a cross business and efficient collaborative management system.

Enterprise operation is the process of breaking down strategy into goals and achieving them through management process efficiency and business synergy efficiency [10]. The promotion of lean business processes in enterprises should be based on achieving operational goals, reducing waste, creating maximum value with minimal resource investment, and delivering customer orders on time; Monitor and evaluate key operational indicators such as production efficiency, inventory levels, and product quality to ensure they align with the company's operational goals, shown as Figure 4.

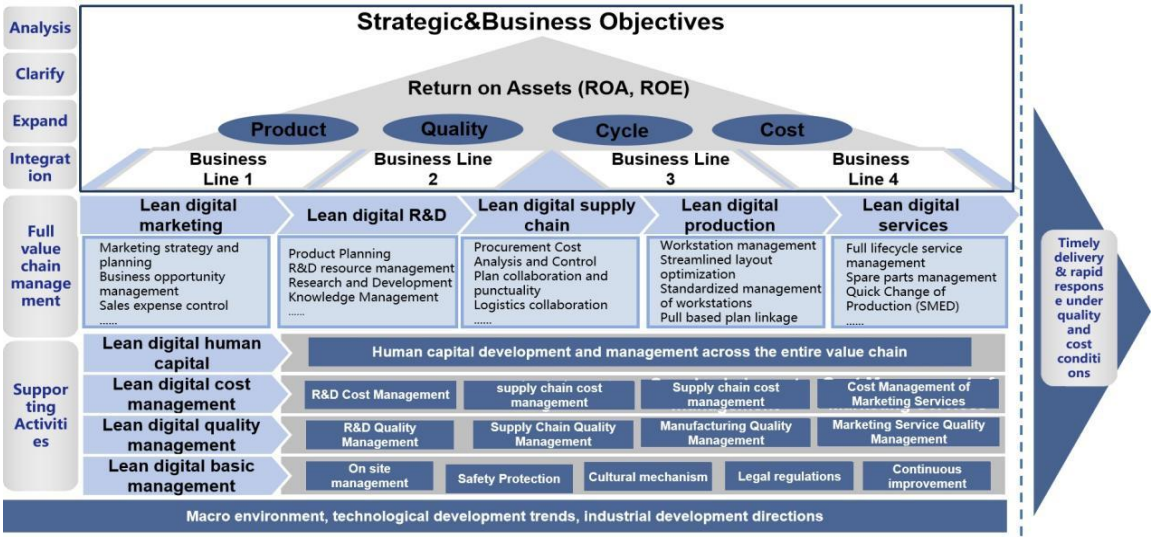

Figure 4. A Digital Lean Operation Framework for Integration and Collaboration across Lines of Business

The next stage is to continuously improve the operational management mode, enhance organizational and employee capabilities, and build a lean digital enterprise through the coordination of the above points, lines, and surfaces. This process requires the integration and improvement of existing standards around the enterprise's business objectives and operational management processes, forming a standard system for enterprise production and business management, creating a visualized and transparent lean digital enterprise platform, using data-driven management decisions and improvements, and thereby driving management improvement; Combining standards for independent diagnostic evaluation, continuously improving customer satisfaction and market competitiveness.

The lean digital operation management system includes: workstation system, rhythmic flow production line; Simulation lines, such as simulated distribution lines and simulated production lines, can predict and handle various issues that affect the normal operation and plan execution of the production line through data analysis, achieving stable, efficient, and high-quality production [12, 13]; The functional business management line, namely the design management line, process management line, procurement logistics management line, production planning management line, cost management line, and quality management line, is a business management process and management standard aimed at meeting the management needs of the workstation based rhythm production line; The functional business management platform, which includes market, human resources, security environment, equipment assets, after-sales, and information platforms, supports the operation and management of the entire business system

process.

The final stage is to drive partners and related supporting enterprises to form a lean cooperation model based on a chain empowerment network. Lean digital enterprises use their own system as the core carrier to create a replicable, scalable, and linkable system platform, and rely on the platform to achieve efficient linkage and collaboration with relevant supporting suppliers, enhance the resilience and security of the supply chain and industrial chain, and promote industrial integration. The successful lean digitization construction of the industrial chain should be carried out from four aspects: analysis, integration, innovation, and monitoring [14, 15]. Firstly, it is necessary to conduct a comprehensive analysis of the structure, functions, processes, key nodes, and pain points of the industrial chain, identify the goals, needs, and difficulties of digital construction, and develop reasonable plans and solutions. Secondly, industrial chain integration should be achieved through digital platforms and networks to effectively connect and collaborate upstream and downstream of the industrial chain, break down information silos, optimize resource allocation, and improve supply chain efficiency and response speed. At the same time, there is innovation in the industrial chain, through data mining and intelligent analysis, to discover the potential value and opportunities of the industrial chain, promote innovation in products, services, models, and technologies, and increase value and differentiation advantages. Finally, there is industry chain monitoring, which uses digital instruments and sensors to monitor and control the operational status, quality indicators, and risk factors of the industry chain in real time, achieving early warning, prevention, and optimization, and ensuring the stability and sustainability of the industry chain. (See Figure 5 for details)

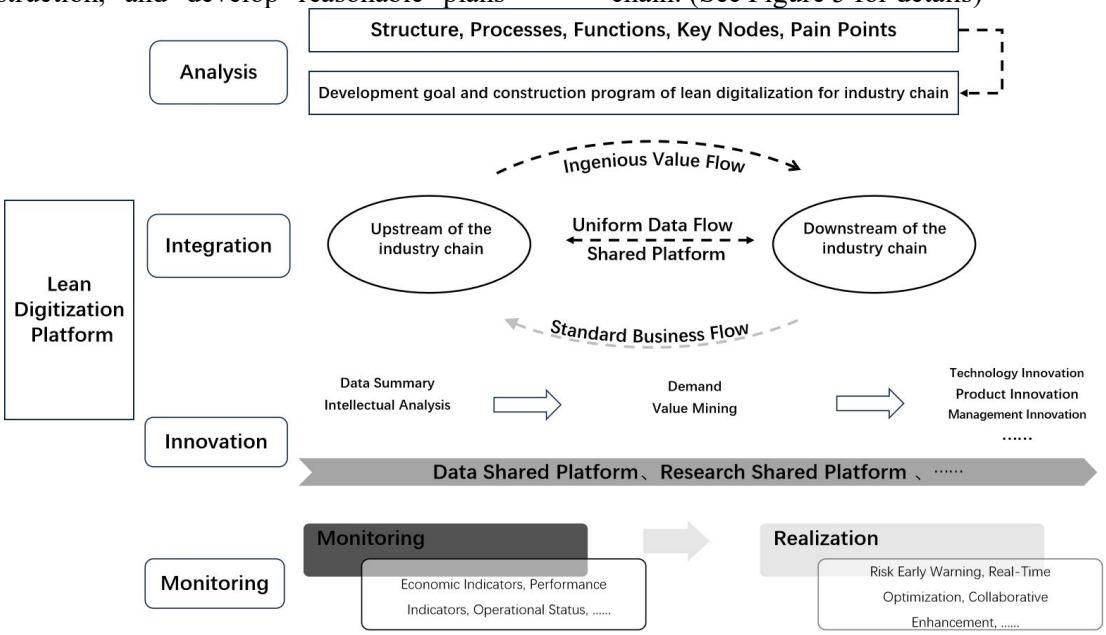

Figure 5. Lean Digitization Implementation Architecture for Industrial and Supply Chain

The phased implementation of lean digitization enables enterprises to transition from localized unit improvements to fully integrated digital lean ecosystems that span business processes, operational management, and supply chain collaboration. By systematically addressing bottlenecks, standardizing processes, and leveraging digital technologies, enterprises can enhance efficiency, reduce waste, and improve overall business agility. The structured approach ensures that improvements at each stage build upon previous successes, leading to a seamless integration of digital lean methodologies across all business functions. Ultimately, the successful implementation of lean digitization not only strengthens an enterprise's internal capabilities but also enhances industry-wide competitiveness by fostering collaboration, innovation, and resilience within the supply chain and industrial ecosystem. This comprehensive transformation positions enterprises to adapt to market dynamics, optimize resource utilization, and achieve

sustainable growth in an increasingly digitalized and competitive environment [16].

4. Conclusion

Digitization provides critical support for the continuous innovation of lean management, helping it cope with challenges such as production fluctuations, rapid updates, and mass customization. By utilizing the methodology and model presented in this article, enterprises can gradually achieve the deployment and implementation of lean digitization through scenario improvement, process upgrading, integrated collaboration, global system construction, and supply chain lean. Through digital intelligent technology, enterprises can achieve timely and automated resolution of production process anomalies, reducing production fluctuations and waste; Using digital twins, artificial intelligence, and other methods to improve the efficiency of lean research and development, achieve more efficient new product output, and optimize existing products; Utilizing digital technology to make lean production plans more aligned with market demand, enabling standardized production lines to be quickly and flexibly adjusted; By using technologies such as data analysis and big models, without changing the existing equipment of the enterprise, the process and data of the enterprise are sorted and analyzed, and the optimal values of key production indicator variables are given. The full integration of lean and digitization will greatly increase the upper limit of traditional lean tools and trigger a change in lean management mode.

By utilizing the methodology and model presented in this article, enterprises can gradually achieve the deployment and implementation of lean digitization through scenario improvement, process upgrading, integrated collaboration, global system construction, and supply chain lean. The full integration of lean and digitization will greatly increase the upper limit of traditional lean tools and trigger a change in lean management mode.

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