

The Application and Challenges of Agile Project Management in the Digital Transformation of Traditional Manufacturing

Siqi Xie^{1*}

¹ Guangxi Normal University, Guilin, China

Email Address

858003246@qq.com (Siqi Xie)

*Correspondence: 858003246@qq.com

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Abstract:

As the global manufacturing industry enters the Industry 4.0 era characterized by “multi-variety, small-batch, mass customization,” traditional manufacturing enterprises face multiple challenges including fragmented market demand, accelerated technological iteration, and increased supply chain uncertainty. This paper focuses on the application practices and implementation obstacles of agile project management methods in the digital transformation process of traditional manufacturing. Through a combination of theoretical analysis and case studies, it systematically explores the integration path of agile principles with manufacturing characteristics. The research finds that leading enterprises such as ABB and Nucotech have successfully applied agile methods to hardware development and complex manufacturing scenarios by constructing an organizational model of “core middle platform + agile front-end,” implementing iterative R&D processes, and establishing value-oriented evaluation systems, significantly enhancing market responsiveness and innovation capability. However, traditional manufacturing faces structural obstacles when introducing agile methods, including inherent cultural conflicts, rigid organizational structures, fragmented technical systems, and difficulties in benefit evaluation. This paper further proposes a systematic implementation path from four dimensions: cultural cultivation, organizational restructuring, process optimization, and technological empowerment, providing a reference framework with both theoretical guidance and practical value for the digital transformation of traditional manufacturing enterprises.

Keywords:

Agile Project Management, Traditional Manufacturing, Digital Transformation, Organizational Change, Intelligent Manufacturing

1. Introduction

Against the backdrop of a profound restructuring of the global manufacturing competition landscape, digital transformation has shifted from an option for

enterprises to a necessity for survival and development. Chinese manufacturing is at a critical stage of transitioning from “mass production” to “flexible intelligent manufacturing,” with market demand exhibiting unprecedented fragmentation and personalization. Taking Hikvision's Tonglu Intelligent Factory as an example, its production data intuitively reflect the intensity of this challenge: there are over 30,000 hardware product models, an average daily order volume of approximately 10,000, an average batch size of only about 40 units, and a customization rate of up to 75%. This production model of “multi-variety, small-batch, mass customization” has fundamentally shaken the management logic of traditional manufacturing, which was based on economies of scale and stable planning, placing new demands on market responsiveness, production flexibility, and innovation capability.

Concurrently, agile project management, originating from software development, offers new ideas for the manufacturing industry to address the above challenges with its core values of “embracing change,” “rapid iteration,” and “customer collaboration.” Agile project management is essentially a management theory and method for dealing with complexity, uncertainty, and high risk, representing the development and evolution of traditional project management (Ke Wenxiu et al., 2009)[1]. However, many small and medium-sized enterprises still over-rely on traditional linear management models and have failed to systematically apply agile methods, rendering them inadequate in responding to rapidly changing demands (Zhang Pengfei, 2025)[2]. The long-established hierarchical organizational structures, linear process designs, and standardized production models in traditional manufacturing starkly contrast with the flat collaboration, iterative advancement, and flexible adaptation emphasized by agile methods. This fundamental conceptual difference makes the application of agile methods in manufacturing both highly promising and uniquely challenging.

This paper aims to deeply explore the actual application models, achievements, obstacles, and solutions of agile project management in the digital transformation of traditional manufacturing. By combining theoretical analysis with case studies, this research attempts to answer the following core questions: First, how can the core principles of agile project management be integrated with the operational characteristics of traditional manufacturing? Second, in which areas and in what ways have leading manufacturing enterprises successfully applied agile methods? Third, what are the main obstacles faced by manufacturing enterprises when introducing agile methods? Fourth, how can an implementation path for agile transformation suitable for the characteristics of manufacturing enterprises be constructed? Answering these questions will not only help enrich the application of project management theory in manufacturing scenarios but also provide valuable references for the digital transformation practices of numerous manufacturing enterprises.

2. Paradigm Comparison Between Agile Project Management and Traditional Manufacturing Management

2.1. Core principles and frameworks of agile project management

Agile project management originated in the software development field as a reflection and breakthrough of the traditional waterfall development model. Its core ideas are embodied in the Agile Manifesto published in 2001, emphasizing “individuals and interactions over processes and tools,” “working software over comprehensive documentation,” “customer collaboration over contract negotiation,”

and “responding to change over following a plan.” However, agility is not a set of rigid rules but a principle-based guide that needs to be adapted to the organizational context (Wang Shiyi, 2024)[3]. In large-scale promotion, frameworks like SAFe attempt to solve multi-team collaboration and strategic alignment issues, but their successful implementation still heavily depends on the adaptability of organizational culture and team understanding (Lu Wenjia, 2018)[4]. These values reflect agile methods’ adaptability to uncertain environments and pursuit of continuous value delivery. The agile project management process reveals that material changes are a unity of certainty and randomness, expands the philosophical connotations of time and space, and adopts a systematic management approach (Ke Wenxiu et al., 2009)[1], providing a philosophical foundation for its adaptation to changing environments.

In terms of specific practical frameworks, Scrum is one of the most widely applied agile methods. It constructs a highly transparent, inspectable, and adaptable project management system by setting fixed iteration cycles (typically 2-4 weeks), clarifying role divisions (Product Owner, ScrumMaster, Development Team), and utilizing visualization tools (Product Backlog, Sprint Backlog, Burndown Chart). As agile methods expand to larger organizations, frameworks such as LeSS (Large-Scale Scrum) and SAFe (Scaled Agile Framework) have emerged to address issues of multi-team collaboration, strategic alignment, and large-scale implementation. It is noteworthy that these frameworks are not rigid rule sets but rather principle-based guidelines that need adaptation to specific organizational contexts.

2.2. Paradigm characteristics of traditional manufacturing management

The management system of traditional manufacturing is built upon classical theories such as industrial engineering, lean production, and Six Sigma, forming the following distinct characteristics:

Plan-Driven Processes: Based on Material Requirements Planning (MRP) and Enterprise Resource Planning (ERP) systems, manufacturing has formed a vertical decomposition system from long-term production plans to shop floor instructions. This model emphasizes forecast accuracy and plan stability, ensuring process controllability and consistency through Standard Operating Procedures (SOP). In some highly complex systems engineering fields, such as aerospace model development, refined management methods like the N-P-5-3-1 plan (full lifecycle plan → project plan → 5-year market plan → 3-year rolling plan → annual plan) have even been developed, ensuring traceability and controllability of tens of thousands of technical indicators over long cycles through Work Breakdown Structure (WBS) (Wang Xun et al., 2025)[5].

Functional Organizational Structure: Traditional manufacturing enterprises typically adopt a functional organization based on specialized division of labor, with clear boundaries between departments such as R&D, process engineering, production, quality, and procurement. This structure facilitates the accumulation of professional knowledge and the improvement of scale efficiency, but it can also lead to "silo" phenomena, increasing communication costs and response delays for cross-functional collaboration.

Pursuit of Standardization and Stability: The core competitiveness of manufacturing has long been based on economies of scale, achieving cost advantages through product standardization, process stabilization, and equipment specialization. This

model is cautious about changes, as any adjustment in the production process may trigger quality risks, efficiency losses, and cost increases.

2.3. Conflict and potential for integration between agile and traditional paradigms

Introducing the agile paradigm into traditional manufacturing essentially represents a collision and integration of two different management philosophies. This collision unfolds across multiple dimensions: temporally, agile's short-cycle iterations contrast with manufacturing's long-cycle planning; in terms of quality philosophy, agile's "working software" needs coordination with manufacturing's "zero defect pursuit"; regarding attitude towards change, agile's "embracing change" creates tension with manufacturing's "change control." Fundamentally, traditional project management is plan-driven, while agile project management is value-driven (Li Liang, 2019)[6]; the former focuses on following predefined plans and scope, whereas the latter emphasizes flexibly responding to changes during project execution to continuously deliver maximum value.

However, there is also a deep foundation for integration between the two. Firstly, the "continuous improvement" (Kaizen) concept in lean production highly aligns with agile's iterative thinking, both emphasizing small steps, rapid feedback, and gradual optimization. Secondly, the market uncertainty faced by manufacturing is fundamentally similar to the demand uncertainty faced by software development, both requiring organizations to possess rapid response capabilities. Furthermore, modern intelligent manufacturing systems, through technologies like the Internet of Things (IoT), digital twins, and artificial intelligence, significantly reduce the cost of virtual verification and rapid trial and error, creating technical conditions for the application of agile methods in the physical world. The two are not irreconcilable. Research shows that in the development of complex products integrating hardware and software, a "hybrid agile" model can maintain manufacturing's strict requirements for quality and processes while incorporating agile's iterative responsiveness (Zhou Yapu, 2024)[7]. Additionally, digital transformation provides the technological possibilities for agile implementation in manufacturing, such as rapid trial and error and virtual verification supported by digital twins and IoT (Zhang Minghai et al., 2024)[8].

3. Application Practices of Agile Project Management in Manufacturing Digital Transformation

3.1. Agile transformation of R&D systems

Product R&D is the earliest and most mature area for applying agile methods in manufacturing. Leading enterprises have successfully integrated agile principles into the hardware product development process through organizational restructuring, process reengineering, and evaluation system reconstruction.

In terms of organizational restructuring, Nucotech adopted a dual collaborative architecture of "core technology department + product design department." The product design department acts as the agile front-end, directly facing the market and customers, responsible for demand insight and product definition; the core technology department serves as the capability middle platform, focusing on key technological breakthroughs and modular component development. This "small front-end, large middle platform" model maintains the depth and continuity of technological R&D while ensuring flexibility and timeliness in market response. Similarly, in its agile

transformation for the Smart Power business unit, ABB reorganized over 1,100 employees into more than 100 cross-functional agile teams, breaking down traditional functional barriers and forming organizational units oriented towards customer value streams.

Regarding process reengineering, Nuctech combined practices from the Scrum framework, such as sprint cycles, user stories, and daily stand-up meetings, with the characteristics of hardware R&D. Product managers continuously gathered frontline user feedback by deeply engaging in application scenarios like mines and airports, translating it into specific “user stories,” such as “mine operators need equipment to maintain stable imaging quality in high-dust environments.” These requirements were prioritized based on business value and entered the product backlog to guide subsequent iterative development. R&D teams typically carried out iterations in cycles of 4-8 weeks, each iteration focusing on verifiable technological breakthroughs or functional implementations, such as optimizing ray source parameters or improving detector sensitivity. Through reviews and retrospectives at the end of each iteration, teams could quickly adjust the focus of the next stage of development.

Evaluation system reconstruction reflects agile’s value orientation. Nuctech established a comprehensive evaluation system covering three dimensions: delivery speed, technological accumulation, and customer value. The technological accumulation dimension specifically focused on indicators such as core parameter iteration rate, number of technology patents, and technology reuse rate, encouraging R&D teams to accumulate reusable technological assets while solving specific problems, achieving a virtuous cycle of “solving one problem, precipitating one method, forming one set of standards.” This evaluation approach breaks through traditional R&D management’s limitation of “focusing on output, neglecting outcome,” highly aligning with the Agile Manifesto’s principle of “working software over comprehensive documentation.”

3.2. Agile practices in production operations

As the degree of market personalization deepens, agile thinking is extending from the R&D domain to the production operations end. Manufacturing enterprises enhance their production systems’ ability to cope with changes by applying flexible production systems, intelligent scheduling algorithms, and visual management.

Flexible production system construction serves as the physical foundation supporting agile operations. Hikvision’s Tonglu Intelligent Factory deployed over 1,500 mobile robots to form an intelligent logistics network, managing tens of thousands of SKUs in real-time, achieving fully automated and intelligent logistics scheduling from raw materials to finished products. On the fully automated unmanned production line for smart cameras, by integrating equipment such as robotic arms, auto-focusing systems, and industrial cameras, it overcame process challenges like automatic insertion of flexible wire harnesses and grasping of unordered materials, achieving unmanned operation across all processes, with overall line efficiency increased by 243% compared to traditional lines.

Intelligent scheduling and sequencing systems act as the “decision-making brain” for agile operations. Facing the extremely complex scenario of approximately 10,000 orders per day and an average line changeover frequency as high as 18 times, Hikvision developed a decision-making system consisting of a “planning agent” and a “scheduling agent.” The “intelligent order consolidation” model within automatically

merges orders with high similarity in process and materials, reducing the average changeover time in the electronics assembly factory by 50% and cutting order switching time to about 9 minutes. This intelligent scheduling, based on constraint theory and machine learning algorithms, enables the manufacturing system to handle massive, discrete, heterogeneous order flows while maintaining a certain level of efficiency.

Visual management introduces agile's "transparency" principle to the production floor. Magellan Aerospace in Canada used large interactive displays (75-inch touch screens) in its composite manufacturing center to visually present production plans based on Gantt charts. Teams held stand-up meetings twice a week, reviewing progress and adjusting plans around these visualization tools. This practice led to a 25% improvement in product output and quality over 18 months. Visual management not only enhances information transparency but also promotes team collaboration and rapid decision-making, serving as a direct manifestation of agile principles at the shop floor level.

3.3. Cultivating agility in organization and culture

The essence of agile transformation is organizational cultural change. Manufacturing enterprises that successfully implement agility generally pay attention to building a "soft environment," providing organizational support for agile practices by cultivating new cultures, adjusting incentive mechanisms, and empowering frontline teams.

The shaping of a culture of experimentation and feedback was a prominent outcome of ABB's agile transformation. By systematically introducing frameworks like Scrum, Scrumban, Nexus, and LeSS, combined with the OKR (Objectives and Key Results) goal management system, ABB built a new organizational model centered on the customer, characterized by high autonomy and rapid iteration. This model encourages teams to innovate boldly within manageable risks and achieve collective growth through continuous, open dialogue. The deep integration of agile methods in hardware development significantly shortened the product lifecycle from concept to market through rapid prototyping and iterative testing.

The new model of human-machine collaboration reflects agility's "individuals and interactions" principle. Hikvision's intelligent factory does not unilaterally pursue "unmanned" operations but seeks the optimal division of labor between humans and machines in complex environments. Standardized, highly repetitive tasks, or those requiring extreme precision, are handled by automated equipment and AI systems; while tasks requiring flexible judgment and handling of non-standard situations leverage human experience and adaptability. This pragmatic view of collaboration makes agile solutions more universally applicable and economically viable.

In terms of digital tool enablement, project management software like DingTalk Cloud Dispatch supports agile practices through "granular goal management." An automotive parts company, by breaking down its annual R&D goals into 23 phased tasks, each with clear acceptance criteria and timelines, increased project progress visibility by 40%. The system supports dynamic adjustment mechanisms; when external environmental changes cause goal deviations, managers can quickly adjust task priorities and resource allocation. This combination of top-down penetrating management and bottom-up agile response forms a new management paradigm.

Table 1. *Application models and effectiveness of agile project management in different manufacturing domains.*

Application Area	Core Practices	Representative Enterprises/Cases	Main Achievements
R&D System	Dual collaborative organizational structure, iterative development, value-oriented evaluation	Nuctech, ABB	R&D cycle shortened by 30-50%, increased technology reuse rate, accelerated market response
Production Operations	Flexible automation, intelligent scheduling, visual management	Hikvision, Magellan Aerospace	Changeover time reduced by 50%, production efficiency increased by 243%, quality improved by 25%
Organizational Culture	Cultivating experimentation culture, human-machine collaboration, digital empowerment	ABB, DingTalk Cloud users	Enhanced innovation capability, increased employee engagement, project transparency increased by 40%

4. Main Challenges and Obstacles in Agile Transformation

4.1. Deep-seated conflicts at the cultural and ideological level

There is a fundamental conflict between the stability-oriented culture traditionally formed in manufacturing and the change-embracing culture emphasized by agile methods. Manufacturing quality management systems, safety specifications, and process discipline are largely based on “preventing deviations” and “solidifying best practices.” Employees are accustomed to executing standards rather than proactively innovating, and management often views agility merely as a tool to “shorten project timelines,” neglecting its cultural connotations (Cao Huan, 2022)[9]. This cognitive bias leads to superficial transformations that fail to impact the organization’s deep-seated behavioral patterns.

Agile project management is particularly suitable for exploring new fields like new products and services; its core lies in creating highly adaptable teams capable of responding swiftly to external environmental changes (Qu Hong, 2007)[10], which significantly differs from the role positioning in traditional manufacturing.

Many senior managers in manufacturing enterprises have cognitive biases regarding agile methods, simplistically viewing them as tools to “shorten project timelines” while overlooking the underlying cultural change requirements. During implementation, management often seeks to gain the benefits of agility while maintaining existing power structures and control mechanisms. This “form without substance” implementation approach leads to agile practices becoming superficial, failing to generate substantive results. Although Shaanxi Diesel Engine Company achieved significant results through PDCA cycles during its lean digital transformation, its transformation primarily reflected continuous improvement concepts, still distancing it from a comprehensive agile cultural shift.

4.2. Structural obstacles at the organizational and process level

The hierarchical organizational structure of traditional manufacturing is a primary structural obstacle to agile transformation. Traditional processes, such as engineering change management, have long cycles, making it difficult to adapt to the iterative

rhythm of agility (Ding Wei, 2024)[11]. Clear reporting relationships, rigid departmental boundaries, and standardized functional responsibilities, while beneficial for control and coordination in mass production, severely constrain the formation and operation of cross-functional teams. When implementing agile R&D, Nucotech had to establish special business units as operational entities, integrating market liaison, demand analysis, product definition, and design capabilities to break down “silo” limitations. Such organizational restructuring requires significant courage for change and management wisdom.

Manufacturing enterprises’ process systems are mostly designed around stable production and risk control, with changes requiring complex review, approval, and notification procedures. For instance, an Engineering Change Notice (ECN) in a traditional manufacturing enterprise often takes weeks or even months to complete the entire process, whereas agile development may require daily or even more frequent adjustments. This mismatch in process rhythm makes it difficult for agile teams to respond quickly to market feedback.

The lag in performance evaluation systems also poses a significant obstacle. Performance evaluation still focuses on individual and departmental output rather than team value delivery, weakening collaborative motivation (Lin Chuanbo, 2023)[12]. Traditional manufacturing performance appraisals are often based on individual contributions and departmental goals, while agile methods emphasize team outcomes and customer value. This difference in evaluation orientation leads employees to face a dilemma between “doing what benefits the team” and “doing what benefits personal performance,” undermining the collaborative motivation within agile teams.

4.3. Integration challenges at the technical and system level

The information system architecture of traditional manufacturing generally suffers from “siloization.” Systems such as ERP, MES, PLM, and WMS are often built independently and implemented in phases, lacking unified data standards and interface specifications, hindering end-to-end decision-making (Wang Baogong, 2023)[13]. This fragmented system architecture makes it difficult for agile teams to obtain end-to-end real-time data to support rapid decision-making. Kingdee Cloud’s analysis points out that traditional ERP systems show signs of strain when dealing with complex manufacturing businesses like “multi-variety, small-batch, engineer-to-order,” exposing their shortcomings based on post-event recording and rigid processes.

The uneven digitization level of existing equipment becomes another barrier. Older equipment with low digitization levels makes data acquisition difficult, constraining agile responsiveness on the production floor (Xiong Ruoyu, 2023)[14]. Many manufacturing enterprises, especially SMEs, have limited automation and informatization of production equipment, heavily relying on manual operations and experience-based judgment. The challenge of “mixing new and old equipment” faced by Shaanxi Diesel Engine Company during its transformation is a common issue. This situation makes data collection, status monitoring, and real-time feedback on the production floor difficult to achieve, limiting the application depth of agile methods in the manufacturing execution layer.

Data quality and consistency issues are equally significant. Manufacturing data is often scattered across different departments and systems, with numerous duplicate records, inconsistent standards, and lagging updates. Without high-quality real-time data support, data-driven rapid decision-making and continuous improvement become

impossible, hindering the realization of agile transformation's "data-driven" advantage.

4.4. Uncertainty in benefit evaluation and return on investment (ROI)

The difficulty in quantifying the value of agile transformation has become a significant reason for many manufacturing enterprises to hesitate. Unlike automation equipment investments, where capacity improvements and labor savings can be directly calculated, the benefits of agile transformation are often reflected in "softer" indicators such as increased flexibility, faster responsiveness, and enhanced innovation, which are difficult to quantify precisely and realize in the short term. Although agile project management has advantages in dealing with uncertainty, the scientific and comprehensive evaluation of its effectiveness is itself a complex and challenging issue (Chi Zhijie, 2025)[15].

The cost structure and pricing models of manufacturing also complicate the evaluation of agile transformation benefits. The competitive advantage of traditional manufacturing heavily relies on economies of scale, spreading fixed costs through mass production. In contrast, the small-batch, multi-variety production model supported by agile methods may lead to higher unit costs in the short term. Enterprises need to find a new equilibrium between cost increases and improved market responsiveness, but mature evaluation models for determining this balance point are lacking. Some research has focused on cost and time management in agile project management, noting that due to various incomplete factors, this method has not yet been proven to effectively improve the success rate and work efficiency of all projects (Li Ruoyi, 2017)[16], further confirming the complexity and contextual dependence of benefit evaluation.

Table 2. Main challenges of agile transformation in traditional manufacturing.

Challenge Dimension	Specific Manifestations	Root Cause Analysis	Impact Level
Culture & Ideology	Resistance to change, cognitive bias, role conflict	Cultural conflict between stability orientation and change embracement	High (Fundamental Obstacle)
Organization & Process	Departmental silos, rigid processes, lagging evaluation systems	Inertia of hierarchical organizations and linear processes	High (Structural Obstacle)
Technology & System	Information silos, outdated equipment, poor data quality	Complexity of historical investment accumulation and system integration	Medium-High (Implementation Obstacle)
Benefit Evaluation	Difficulty quantifying value, short-term cost increase, difficulty determining balance point	Mismatch between manufacturing cost structure and agile benefits	Medium (Decision-Making Obstacle)

5. Implementation Path Suggestions

5.1. Cultural cultivation and mindset change

Successful agile transformation begins with cultivating the cultural soil. Manufacturing enterprises need to position agile transformation as a profound organizational cultural change, not merely an adjustment in project management

methods. The firm commitment and active participation of leadership are crucial. Enterprises should accumulate experience and gradually promote agile practices through pilot projects (Tang Ning, 2023)[17].

Establishing a progressive cultural change path can reduce organizational disruption. Starting with pilot projects, selecting products or business units facing high market pressure and requiring high innovation as “agile testbeds” is advisable. ABB’s enterprise-level agile transformation, initiated from its Smart Power business unit covering hardware and software R&D and product management, exemplifies this progressive path. Promoting gradually after successful pilots allows for experience accumulation, benchmark setting, and reducing the risk of overall change.

Cultivating internal agile coaches and a network of change agents is key to sustainable cultural change. These individuals not only master agile methods and tools but also understand the specific context of manufacturing, bridging the gap between tradition and agility. Developing internal agile coaches and adapting methods to the manufacturing context helps reduce transformation resistance (Fan Jianzheng, 2022)[18].

5.2. Organizational restructuring and process optimization

Organizational structure adjustments need to balance stability and flexibility. Process-wise, focus should be on optimizing high-frequency, critical links by shortening cycle times through Lean Value Stream Analysis (Xu Guangliu, 2018)[19]. Nuctech’s “core middle platform + agile front-end” model provides a valuable reference: core technologies, common capabilities, and key resources are consolidated into the middle platform to ensure technological depth and economies of scale; while product teams facing the market and customers serve as the agile front-end, granted sufficient autonomy and rapid response capabilities. This structure maintains manufacturing’s requirements for technological accumulation and scale effects while achieving flexibility to respond to market changes.

The focus of process optimization should be on identifying and simplifying key processes that hinder rapid response. For processes sensitive to response speed with high frequency, such as engineering changes, material allocation, and quality anomaly handling, enterprises can apply Lean Value Stream Analysis to eliminate non-value-added activities and shorten end-to-end cycle times. Kingdee Cloud’s proposed integrated solution for PLM and ERP change processes, which automatically synchronizes change information, accurately calculates impact scope, and generates processing suggestions with one click, significantly compresses the traditional multi-week change process.

Building cross-functional agile teams requires redesigning role definitions, collaboration mechanisms, and decision-making authority. Teams should include representatives from key functions such as product, technology, process engineering, production, and quality, and be given end-to-end responsibility for the entire product development process (from concept to mass production). Clear team goals, shared success criteria, and regular synchronization meetings (e.g., daily stand-ups, iteration reviews) are fundamental for ensuring effective team collaboration.

5.3. Technology enablement and system integration

Manufacturing enterprises need to build a digital technology stack that supports agile operations. This technology stack should possess the following characteristics:

data connectivity (breaking down system silos), real-time sensing (IoT and sensors), intelligent decision-making (AI and algorithms), and flexible execution (automation and robotics). The technology system of Hikvision's Intelligent Factory reflects this approach, achieving efficient response in complex manufacturing scenarios through an intelligent closed loop of "perception-decision-execution." Practices in other industries also indicate that applying next-generation digital technologies is key to successfully implementing agile project management, optimizing processes, and ensuring high-quality and efficient project completion (Zhang Minghai et al., 2024)[8].

A phased system integration strategy can mitigate implementation risks. A technology stack featuring data connectivity, real-time sensing, and intelligent decision-making should be constructed, advancing system integration in phases, with priority given to connecting core systems like ERP and MES (Zhang Hao, 2024)[20]. For older equipment, low-cost digital transformation can be achieved by adding sensors and IoT gateways.

The digital retrofit of existing equipment needs pragmatic advancement. For critical bottleneck equipment, sensors and networking modules can be prioritized to enable data collection and status monitoring; for a large number of ordinary devices, industrial IoT gateways can be used for protocol conversion to achieve networking at a lower cost. Shaanxi Diesel Engine Company's approach during its transformation, focusing on "rejuvenating old equipment and accelerating new layouts," is worth referencing, fully utilizing the potential of existing equipment through process optimization and layout adjustments rather than blindly pursuing equipment renewal.

5.4. Benefit evaluation and continuous improvement

Establish a multi-dimensional benefit evaluation system for agile transformation, balancing short-term indicators with long-term value. This system should cover indicators related to efficiency, flexibility, innovation, and organizational health (Zhang Guoliang, 2024)[21]. Nuctech's R&D achievement evaluation system, encompassing delivery speed, technological accumulation, and customer value dimensions, provides a reference framework for evaluating agile benefits in manufacturing.

Adopt agile funding and budgeting models to support transformation. Traditional annual budgets and fixed project investment methods struggle to adapt to the iterative nature and uncertainty of agile transformation. New financial models such as value-based investment decisions, rolling forecasts, and team self-managed budgets can be explored to make resource allocation more flexible and responsive.

Construct a continuous improvement feedback loop, which is vital for the vitality of agile transformation. Regularly organize transformation review meetings (e.g., quarterly or semi-annually), inviting employees from various levels to openly evaluate progress, identify obstacles, and adjust strategies. Treat the transformation itself as an "agile project," continuously finding the most suitable agile implementation path for the enterprise's specific characteristics through experimentation, learning, and adaptation.

Table 3. Implementation path for agile transformation in traditional manufacturing enterprises.

Stage	Core Tasks	Key Outputs	Typical Duration
Initiation & Preparation	Leadership consensus building, pilot selection, team formation	Transformation vision & roadmap, pilot project charter, agile coach team	1-3 months

Pilot Exploration	Applying agile methods in a limited scope, cultural cultivation, process adjustment	Pilot project results, refined agile practices, initial benefit data	3-6 months
Expansion & Promotion	Replicating success, organizational restructuring, advancing system integration	Multiple agile teams operating, cross-departmental collaboration mechanisms, integrated information systems	6-12 months
Deepening & Solidification	Large-scale agile implementation, evaluation system reconstruction, establishing continuous improvement culture	Enterprise-level agile operating system, strategic-aligned investment decision-making mechanism, self-renewing change capability	12-24 months

6. Conclusions

Through a systematic analysis of the application and challenges of agile project management in the digital transformation of traditional manufacturing, this study draws the following main conclusions:

First, agile project management methods demonstrate significant value in addressing the new normal of “multi-variety, small-batch, mass customization” in manufacturing. Practices of leading enterprises such as ABB, Nuctech, and Hikvision show that by constructing a dual collaborative organizational architecture, implementing iterative R&D processes, and establishing value-oriented evaluation systems, agile methods can effectively enhance manufacturing enterprises' market responsiveness, innovation capability, and customer value delivery.

Second, agile transformation in traditional manufacturing faces multi-level, systemic obstacles. These include cultural conflicts between stability orientation and embracing change, organizational contradictions between hierarchical structures and cross-functional teams, system-level challenges of information silos versus the need for data connectivity, and difficulties in benefit evaluation coupled with short-term cost pressures. These obstacles are interconnected and mutually reinforcing, making agile transformation a complex and challenging systems engineering.

Third, successful agile transformation requires a tailored implementation path. Manufacturing enterprises should not simply copy agile practices from the software industry but should combine industry characteristics and enterprise realities. By promoting synergistically from four dimensions—cultural cultivation, organizational restructuring, process optimization, and technological empowerment—and adopting a progressive path of pilot exploration, expansion, and deepening solidification, enterprises can acquire agility's flexibility and responsiveness while maintaining manufacturing's core advantages (quality, efficiency, scale).

Conflicts of Interest

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