Research on the Obstacles, Practical Challenges, and Strategies for Digital Transformation of Small and Medium-sized Manufacturing Enterprises in China

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Abstract: In the wave of digitalization where "smart manufacturing" has become a mainstream trend, there are immense growth opportunities for small and medium-sized enterprises (SMEs) in the manufacturing industry. However, given the characteristics of "small, weak, and scattered" nature of SMEs, digital transformation still faces many obstacles and challenges from a professional, investment, and practical implementation perspective. There are many difficulties in practice. This paper proposes routes and strategies for SMEs to undergo digital transformation from the perspectives of talent cultivation structure, industry differences, policy formulation during implementation, data security issues, and further improvement of relevant laws and regulations. It is suggested that enterprises should formulate and implement more comprehensive and long-term digital strategic plans based on their own actual situations. Governments should also focus on supporting SMEs' digital transformation in various aspects such as talent cultivation, policy support, laws, and regulations. Together, we should promote technological innovation and talent cultivation to lay a solid foundation for successful transformation.

Keywords: Small and Medium-sized Manufacturing Enterprises, Digital Transformation, Empowering Manufacturing Industry

1. Introduction

At the beginning of this century, with "intelligent manufacturing" as its main feature, the comprehensive impact of the trend of digital manufacturing has swept through enterprises of all sizes globally. In China's manufacturing structure, small and medium-sized manufacturing enterprises (SMEs) occupy a dominant position. Therefore, actively promoting the digital transformation and upgrading of SMEs is not only a necessary response to the new round of global technological revolution and industrial transformation but also a fundamental requirement for achieving high-quality economic growth. This holds significant importance for comprehensively promoting the "digitalization" reform of China's manufacturing industry and achieving high-quality economic growth.

2. The Importance and Necessity of Digital Transformation in Small and Medium-sized Manufacturing Enterprises

It should be recognized that the development of digitalization, on the one hand, poses severe challenges in response to external impacts, while on the other hand, it provides important opportunities for empowering the manufacturing industry to achieve digital transformation, bringing about new internal growth drivers.

Firstly, it enhances operational efficiency and cost control. Digital transformation can optimize production processes to improve productivity, reduce costs, and also utilize intelligent data analysis to better understand market demands, optimize product design, and enhance product quality.

Secondly, it enables precise market positioning and customer demand forecasting. Digital transformation assists small and medium-sized manufacturing enterprises in adapting to market changes, grasping market trends through data analysis and prediction, seizing market opportunities, and enhancing competitiveness. [1]

Thirdly, it strengthens the innovation capability of products and services. Digital transformation drives the innovative development of small and medium-sized manufacturing enterprises, enabling them to explore new market opportunities and innovate business models through data analysis and intelligent technologies, thereby enhancing their innovation capability. [2]

Fourthly, it enhances the scientific nature of decision-making. Decision-making based on data analysis can reduce the uncertainty of intuitive decisions, enabling targeted analysis and enhancing the scientific nature of decision-making.

Fifthly, it enhances the transparency and flexibility of the supply chain. Digital transformation enables fine management of small and medium-sized manufacturing enterprises, allowing them to better grasp various aspects of production and management through data analysis and intelligent technologies, thereby improving management accuracy and efficiency.

3. Current Status of Digital Transformation in Small and Medium-sized Manufacturing Enterprises

The current status of digital transformation in China's small and medium-sized enterprise (SME) manufacturing sector presents a diversified and complex situation. Overall, there is a growing awareness of the importance of digitization, and the awareness of transformation is gradually increasing, but the transformation process is uneven. Most small and medium-sized companies are still in the experimentation phase and have not deeply applied this technology. Recent industry observations also indicate that small and medium-sized companies span various industries, such as automotive, electronics, instrumentation, transportation equipment, and pharmaceuticals, where the degree of digitization is relatively higher. Consequently, companies in these industries have a more urgent demand for the intelligent upgrading of equipment and systems. However, for industries such as metal processing, fuel manufacturing, and textiles, the application of advanced information technology in the overall production process is relatively limited, and the progress of digitization and intelligence is slower. From the perspective of the degree of digitization of the main business operations of enterprises, it also appears to be relatively low, which is one of the main problems facing the current digital transformation of small and medium-sized enterprises. Therefore, although many enterprises have begun attempts at digital transformation, in practical operation, how to integrate digital technology with core business and achieve true digital transformation remains a problem that requires continuous exploration and solution.

Furthermore, there is also a lack of qualified system solution providers in the current digital transformation. Under the wave of digitization, a large number of system solution providers and

digital service providers have emerged, increasing the screening and identification costs for small and medium-sized enterprises.

Therefore, the current status of digital transformation in China's small and medium-sized enterprise manufacturing sector is in the early stages of transformation, facing numerous challenges and issues.

4. Obstacles to Digital Transformation in Small and Medium-sized Manufacturing Enterprises

4.1. Technical Difficulties in Digital Transformation of Small and Medium-sized Enterprises

Firstly, there are challenges in technology integration and operational complexity. Effectively integrating new technologies into existing workflows is a major challenge for many small and medium-sized enterprises (SMEs). Digital technologies involve artificial intelligence, big data, cloud computing, the Internet of Things, and other technologies, which are difficult to master and require enterprises to possess certain technical capabilities and talent reserves. For SMEs, they often lack sufficient technical talent and financial investment to grasp these advanced technologies. [3]

Secondly, there is a lack of technological infrastructure. Many small and medium-sized enterprises lack robust IT infrastructure support. They may not have enough servers, storage, and network facilities to support advanced digital applications. [4]

Thirdly, there is inadequate data management and analytical capabilities. Effectively managing and analyzing large amounts of data is a major challenge, and many SMEs lack the technical expertise and tools to deal with complex datasets. [5]

Fourthly, there is a mismatch between enterprise culture and organizational structure: Digital transformation requires enterprises to transition from a traditional closed culture to an open and sharing culture, requiring enterprises to have the ability to adapt to new technologies and innovative spirit. However, due to historical and cultural limitations, some SMEs often find it difficult to adapt to this change, leading to difficulties in digital transformation.

Fifthly, there is a lack of clear digital strategy and planning: Digital transformation requires enterprises to develop suitable transformation paths based on their actual situations and development needs, which is a systematic project. However, some SMEs often lack awareness and experience in this regard, leading to difficulties in digital transformation.

4.2. Overall Investment Challenges in Company's Digital Transformation

The system not only requires increased investment in research and development and talent reserves but also comprehensive enhancement of investment in infrastructure, information systems, and equipment in the production process. However, compared to large enterprises, small and medium-sized enterprises (SMEs) face significant financing challenges. According to statistics from relevant departments, the current coverage rate of office networks in small and medium-sized enterprises in China averages 89%, the utilization rate of digital equipment for key processes is 40%, the coverage of production process information systems is 40%, and the proportion of equipment networking is 35%. Survival pressures prompt them to consider the costs of transformation technology and the risks of trial and error more. The self-replenishment capacity of enterprises is weak, and the external transfusion mechanism lags behind. In the absence of utilizing funds to improve efficiency and lacking specialized support, it is difficult for enterprises to sustain themselves solely through their own investments.

4.3. Long Return Cycle for Company's Digital Transformation

Although digital transformation has effectively promoted business model innovation and reshaping of the business ecosystem, it cannot bring significant profits to companies in a short period. Therefore, small and medium-sized enterprises (SMEs) in traditional manufacturing industries still maintain a reserved attitude towards digital transformation.

Firstly, SMEs lack certainty about how digital transformation can generate profits. In the initial stages of digital transformation, business models need to face the influence of emerging information technologies and explore how to use these new technologies to drive rapid enterprise development. This requires leaders of enterprises to have sensitivity and sharp insight.

Secondly, SMEs may take a considerable amount of time to see the effects of digital transformation, so enterprises are more concerned about whether the transformation can truly solve business problems and achieve cost reduction and efficiency improvement. In the early stages of digital transformation, there are significant investments in infrastructure and technology, and companies need to invest funds to purchase or upgrade hardware, software, and other technical tools; employees need training to become familiar with new systems and tools, which not only involves direct training costs but may also include temporary productivity declines due to training.

4.4. Insufficient Digital Transformation Capability in Small and Medium-sized Manufacturing Enterprises

Firstly, there is a lack of strength. Due to the constraints on the size of small and medium-sized enterprises (SMEs) and limited financial resources, they seem to be unable to keep up in areas such as talent transformation, data collection, and implementation of emerging information technologies along the path of industry innovation.

Challenges in talent transformation: This is mainly reflected in the severe shortage of digital talents and the incomplete talent cultivation system, which is one of the main reasons hindering enterprise transformation. Results show that only 20% of the total workforce in enterprises have digital capabilities, and only 15% of companies have established an education system for digital talents. In the data collection process, SMEs have shortcomings in effectively collecting information related to production.

System compatibility: Compatibility issues between old and new systems may arise during data migration and system integration. China's manufacturing equipment is diverse, and due to differences in manufacturers and equipment types, communication interfaces and functional parameters vary, and a unified standard has not yet been established.

Nowadays, many advanced manufacturing equipment is imported from abroad, and the data interfaces and formats of these imported equipment usually follow their own standards, resulting in insufficient compatibility.

Technical selection: Choosing suitable technologies and service providers that meet the needs of enterprises may be a challenge, and wrong choices may lead to ineffective investment or even losses.

The "2021 Report on the Digital Development of Small and Medium-sized Enterprises" published by the JD Institute of Consumer and Industrial Development reveals that thirty percent of SMEs connect production equipment to the network to obtain equipment and process information. Additionally, thirty-six percent of SMEs can effectively use quality inspection equipment to obtain and track production quality information. Moreover, thirty-four percent of enterprises have the ability to collect key business data such as design, production, logistics, sales, and services.

In terms of utilizing next-generation information technology, the digital level of SMEs is relatively low. Forty percent of enterprises can collect information through identification technologies such as QR codes, barcodes, and RFID. Only twenty-three percent of joint ventures have successfully

integrated major business systems, and only five percent of enterprises utilize big data analysis technology to improve manufacturing processes and provide improvement suggestions and decision support.

Secondly, the unclear transformation path is another issue. As enterprises deepen their digital transformation, problems such as the lack of key regulatory standards, incomplete industry regulatory agencies, and incomplete solution strategies gradually emerge.

The demand for enterprise digital transformation is neither clear nor straightforward. Without key standards and implementation guidelines, some enterprises fail to clearly understand their development stage and strategic planning. They blindly conduct digital reforms even when internal data connectivity is not yet smooth, resulting in less-than-ideal outcomes of the reforms.

From another perspective, without an assessment system that accurately measures the value of transformation, companies cannot accurately determine the return on investment brought about by digital transformation.

The third one is data security and privacy. In the new landscape of the digital era, many innovative applications have emerged. Various technologies such as cloud computing, big data, Internet of Things (IoT), and artificial intelligence (AI) are rapidly developing, generating, transmitting, sharing, and exposing a large amount of application data. Additionally, with various business channels such as the web, H5, apps, APIs, WeChat, and mini-programs, new-generation applications continue to emerge, increasing the difficulty of application risk exposure and chain control. Various types of attacks, such as database collisions, vigorous cracking, web scraping attacks, and API interface abuse, have also significantly increased the risk of enterprise data leakage.

Firstly, there is an increased risk of data privacy leakage. Software application companies or associated third-party data operators hold a large amount of enterprise privacy information, such as customer information, production information, sales information, etc., which are valuable for exploitation. For example, in September 2019, Facebook revealed a data leakage incident involving 400 million user accounts and phone numbers, resulting in a fine of $5 billion. Furthermore, in April 2020, Zoom collected user data during the process of software download or activation, and due to insufficient security measures, led to the leakage of 15,000 meeting videos. Once enterprise data is attacked or leaked, it endangers national, social, and personal security.

Secondly, there is weak capability in data integration security. Currently, the security protection of company data mainly relies on conventional protection methods, such as encryption and verification for static data, and boundary protection for dynamic data. In other words, traditional security protection mainly focuses on boundary protection and cannot dynamically protect data exchanges.

Similarly, widely used basic encryption technologies may disrupt the structure of data, rendering encryption operations impossible. Even methods such as homomorphic encryption and secure multiparty computation, which can process encrypted states, still struggle to meet the demands of large-scale applications. Therefore, when dynamic data circulation and integration operations occur, relying solely on current security protection techniques and encryption methods cannot meet the demands of processing a large amount of encrypted state data, leading to deficiencies in data integration security performance.

Thirdly, there are challenges in comprehensive supervision throughout the data circulation process. The lifecycle of data includes steps such as collection, transmission, storage, processing, exchange, and destruction. However, due to the high dynamic mobility, diverse types, and various usage methods of data, comprehensive management throughout the data process faces significant difficulties, making it almost impossible to implement refined management. Additionally, with the implementation of regulations such as data protection laws and personal information protection laws, China's data market has entered a new era of compliant development, where data protection and

confidentiality are emphasized, and compliant data security has become a major challenge, making data security compliance one of the main challenges.

5. Digital Transformation Path and Strategies for Small and Medium-sized Enterprises

5.1. Construction of an Integrated Digital Talent Training System between Schools and Enterprises

The scarcity of digital talents is a significant factor leading to the transformation of small and medium-sized enterprises (SMEs) in the manufacturing industry, rooted in the lagging talent training system. Currently, there is a deviation between the talents cultivated by vocational and undergraduate education in China and the actual needs of enterprises, resulting in an inability to supply a large number of compound talents with digital literacy. Therefore, it is necessary to accelerate the reform of digital education and establish a new type of digital talent training system. **Update curriculum design.** Incorporate courses such as data analysis, cloud computing, machine learning, and the Internet of Things into the curriculum to ensure that students master cutting-edge technological knowledge. **Emphasize soft skills.** In addition to hard technical skills, attention should also be paid to cultivating soft skills such as critical thinking, innovation, teamwork, and cross-cultural communication. **Update teaching philosophy and objectives.** Strengthen practical teaching, update outdated facilities such as laboratories and practical teaching bases. Strengthen cooperation between schools and new-type enterprises, utilize cloud platforms, virtual laboratories, and other technologies to provide advanced technology, broader learning resources and tools, case studies, and project-based learning. Provide internship and practical training opportunities for students to directly participate in enterprises' digital transformation projects. Through studying real industry cases, students can gain a deep understanding of the practical application of digital transformation. Train compound engineering talents combining professional knowledge with digitalization. **Teacher training.** Provide regular training for teachers on the latest technology and industry developments, and enhance the proportion and capability of practical teachers. **Lifelong learning culture.** Given the rapidly changing application scenarios under the background of artificial intelligence, the talent training system needs to extend from school education to the concept of lifelong education. Technological and resource investment in learning support systems. Support the talent needs in the digital reform of small and medium-sized enterprises. Establish cooperation platforms between industries and research institutions to promote technology transfer and knowledge sharing.

5.2. Construction of Support Policies Based on Industry Differences

Firstly, the policy support system should be further refined. The small and medium-sized manufacturing industries are diverse, and different industries have different processes and requirements for transformation. The current policies cannot effectively address the transformation constraints of different industries. Therefore, the policy support system should be further refined, implementing industry-customized big data applications. For data-intensive industries (such as electronics, automotive parts), training and support should be provided for data analysis and management tools, helping enterprises effectively manage large amounts of production data and customer data. For labor-intensive industries (such as textiles, clothing), encourage the use of basic data tracking and management systems to improve production efficiency and quality control. Provide technical innovation subsidies and loan guarantees for small and medium-sized manufacturing enterprises to reduce the risks and costs of adopting new technologies. Expand fiscal subsidies and tax relief policies; In addition to subsidizing the purchase of digital products, innovative designs, new media brand promotion, supply chain platforms, e-commerce sales platforms, and some small

enterprises that are difficult to transform should also be included in the subsidy scope, fully utilizing digital platforms to play open and agile effects. [6]

Secondly, actively promote the establishment and promotion of industrial Internet platforms and unified identification resolution systems in different industries. Improve platform functions to achieve coupling between platforms and enterprises in supply chain, marketing, production processes, and technical processes. For example, through big data analysis tools, help enterprises better understand market demand and consumer behavior, support enterprise market expansion and precision marketing simultaneously. [7] At the same time, the government should play a supervisory role in the construction and operation of platforms, ensure data security, and simultaneously carry out the establishment and promotion of standardized identification resolution systems to achieve data traceability.

5.3. Construction of Support Policies Based on Practical Implementation Process

Based on the insufficient capacity of small and medium-sized manufacturing enterprises in the practical implementation of digital transformation, refined support based on the practical implementation process is constructed. In the implementation process, various problems will arise. Analyzing the actual situation and development needs of enterprises, providing refined technical and policy support. For example, in the early stages, we assist small and medium-sized enterprises in clarifying their core business value and determining digital strategic objectives. By utilizing various services provided by industrial Internet platforms, such as resource subscription, data sharing, and skill cooperation, we are able to achieve cost reduction, quality improvement, efficiency optimization, and balanced resource allocation.

In the execution process, through the clarification brought by information collaboration, small and medium-sized enterprises utilize technological tools such as the internet, big data, and AI to encode and model the knowledge accumulated in various stages of core business operations (such as planning, scheduling, quality, tracking, and energy). After the model is formed, predictions of events that have not yet occurred can be made, marking the beginning of digital transformation at a deeper application level. At this stage, advanced information technology seamlessly connects with the entire process of product operations management, effectively enhancing the level of scientific decision-making using data analysis and model-driven tools. Assisting in the establishment of a knowledge base or solution library for common specific scenario solutions.

In the production process, a thorough analysis is conducted on the impact of encountered problems, and solutions for dealing with special situations are devised and practical knowledge is accumulated, constructing a professional knowledge base or solution library. Utilizing these libraries as references when encountering similar problems helps alleviate the workload of teams dealing with similar transactions. Valuable knowledge is sifted from the clutter of information, integrating various types of knowledge to provide precise and timely advice for complex large-scale problems, meeting the needs of dealing with uncertainty and large-scale problems in the current industrial environment, thereby building the core competitiveness of the enterprise.

5.4. Further Improving Relevant Laws and Regulations on Data Security Issues

Data is being generated in massive quantities constantly, and how to collect (including produce), manage, analyze, apply, display, and ensure legal compliance and technical security has become a global focus.

Since September 1, 2021, the "Data Security Law of the People's Republic of China" (referred to as the "Data Security Law") has officially come into effect. China's legislation process in the field of data security has been advancing rapidly, gradually becoming more in-depth and refined, with

industry-specific data security policies, legal regulations, and other documents being successively issued. This further strengthens the vertical advancement and implementation of previous regulations, providing guidance and reference for the development and application of technology in the field of security.

Over the past two years since the implementation of the Data Security Law, legislation in this area has become more detailed, with many local regulations incorporating specific chapters on data security, gradually integrating data security into all aspects. However, with the rapid development of cloud technology and other digital transformations accelerating, the threat to digital security for small and medium-sized enterprises (SMEs) is also increasing, especially issues like data breaches are becoming more prominent.

Therefore, in order to enhance the digital defense capabilities of SMEs, we must work in the following two directions. Firstly, at the level of awareness, we need to increase the focus on digital security for SMEs, encouraging them to participate more in professional security training, making them aware that in the digital economy era, digital security issues and risks will continue to escalate, and digital security protection cannot be neglected. Relevant policies such as the Data Security Law should be utilized to strengthen SMEs' awareness of digital security protection. Secondly, at the technical level, considering the differences in digital security issues faced by SMEs and large enterprises during digital transformation, the focus should be on achieving standards and meeting basic security needs. Based on this, innovation of simple and moderately priced platform-based products tailored to the characteristics of SMEs and the current distribution and progress of "cloud" technology is crucial. Thirdly, considering the shortage or even absence of security operations personnel faced by SMEs in security operations, advocating the adoption of cloud service models is recommended. Lastly, for SMEs, local data legislation should focus on practical issues in the development of local data elements that are urgently needed, adopting small but precise, thematic legislative approaches, accumulating experience for national unified data legislation from different perspectives and angles.

6.   Conclusion

Overall, the digital transformation of small and medium-sized manufacturing enterprises is in a stage of gradual advancement but also faces multiple challenges. The digital transformation of small and medium-sized manufacturing enterprises is not only following the trend of technological development but also a necessary condition for survival and development in a complex and volatile economic environment. By effectively utilizing big data and related technologies, small and medium-sized enterprises can find new growth points and advantages in a fiercely competitive market. Enterprises need to formulate and implement more comprehensive and long-term digital strategic plans based on their own actual situations, under the dual drive of government policies and market demand. Meanwhile, strengthening cooperation with research institutes, universities, and other enterprises to jointly promote technological innovation and talent cultivation lays a solid foundation for successful transformation. Governments should also focus on supporting the digital transformation of small and medium-sized enterprises in various aspects such as talent cultivation, policy support, and legislation.

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