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Research on the Transformation Path of Intelligent Manufacturing in Manufacturing Enterprises based on the Data Middle Platform

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Abstract

Driven by the digital wave, intelligent manufacturing has become a key direction for the transformation and upgrading of the manufacturing industry. This study deeply analyzes the transformation path of intelligent manufacturing in manufacturing enterprises based on the data middle platform, elaborates on the core role and key technologies of the data middle platform, and demonstrates the effectiveness through actual cases, providing theoretical and practical guidance for manufacturing enterprises.

Keywords

Intelligent Manufacturing; Data Middle Platform; Transformation Path; Manufacturing Enterprise.

1. Introduction

The rapid development of digital technology has profoundly affected the pattern of the manufacturing industry, and intelligent manufacturing has become an inevitable trend [1, 2]. Technologies such as big data, artificial intelligence, and the Internet of Things have been widely infiltrated into the manufacturing industry [3]. Manufacturing enterprises face fierce market competition and need to improve production efficiency, reduce costs, improve product quality, and respond quickly to market changes. The data middle platform emerged as the times require, providing a new model for enterprise data management and decision support [4].

Theoretically, it enriches the related theories of intelligent manufacturing and the data middle platform, opening up a new perspective for academic research [5]. In practice, it provides a guide for the transformation of manufacturing enterprises, helping them cope with challenges and promoting the intelligent development of the manufacturing industry [6].

Abroad, remarkable achievements have been made in the field of intelligent manufacturing. For example, Germany's Industry 4.0 strategy emphasizes the application of cyber-physical systems (CPS) [3], and the United States focuses on the integrated innovation of information technology and manufacturing technology [4]. Domestic scholars have also actively explored intelligent manufacturing models and key technologies [5, 6]. In terms of the data middle platform, foreign countries focus on basic technical research [7], while domestic ones pay more attention to practical applications [8]. However, the research on the intelligent manufacturing transformation of manufacturing enterprises based on the data middle platform still needs to be strengthened [9].

This study comprehensively uses the literature research method to sort out theories and achievements [10], the case analysis method to analyze the transformation practices of enterprises such as Sany Heavy Industry [11], and the system analysis method to build a transformation path model [12].

It deeply explores the collaborative relationship between the data middle platform and intelligent manufacturing and proposes an integrated framework; through cases, it elaborates

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in detail the application and effectiveness of the data middle platform in each link of intelligent manufacturing and provides targeted transformation strategies.

2. Relevant Theoretical Foundations

2.1. Theory of Intelligent Manufacturing

2.1.1. Connotation and Characteristics of Intelligent Manufacturing

Intelligent manufacturing integrates advanced manufacturing, information, and intelligent technologies [13], realizing intelligent control and optimized decision-making throughout the entire production process [14]. It has characteristics such as high automation, intelligent decision-making, flexible production, and deep integration [15, 16, 17, 18], which improve production efficiency, product quality, and enable rapid response to market demands.

2.1.2. Key Technologies of Intelligent Manufacturing

It covers technologies such as the Industrial Internet of Things, big data analysis, artificial intelligence, cloud computing, and digital twins [19, 20, 21, 22, 23]. The Industrial Internet of Things enables device interconnection and data interaction; big data analysis uncovers data value; artificial intelligence is used for production scheduling, quality inspection, etc.; cloud computing provides computing power and resource allocation; digital twins optimize product design and production processes.

2.2. Theory of the Data Middle Platform

2.2.1. Concept and Architecture of the Data Middle Platform

The data middle platform integrates internal and external enterprise data, governs, stores, and provides data service and analysis capabilities [25]. Its architecture includes data collection, storage, governance, service, and application layers, and each layer collaborates to achieve data management and value discovery [25].

2.2.2. Functions and Values of the Data Middle Platform

It has functions such as data integration and sharing, asset management, and analysis and mining [26, 27, 28]. It breaks data silos, enables cross-departmental circulation; transforms data into assets to enhance value; provides decision support, helping enterprises identify opportunities and solve problems.

2.3. Relationship between the Data Middle Platform and Intelligent Manufacturing

The data middle platform provides a data foundation and decision-making basis for intelligent manufacturing. The development of intelligent manufacturing prompts the optimization and improvement of the data middle platform. The two mutually promote and develop in synergy [29].

3. Driving Factors for the Intelligent Manufacturing Transformation of Manufacturing Enterprises Based on the Data Middle Platform

External market competition pressure compels enterprises to enhance their competitiveness through intelligent manufacturing. Technological innovation provides technical support for the transformation, and policy support guides the direction of enterprise transformation. Internally, the needs to improve production efficiency and quality, optimize management decisions, and achieve sustainable development also drive enterprises to transform towards intelligent manufacturing. These internal and external factors work together, prompting manufacturing enterprises to explore the path of intelligent manufacturing transformation based on the data middle platform.

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4. Transformation Path of Intelligent Manufacturing in Manufacturing Enterprises Based on the Data Middle Platform

4.1. Construction of the Data Middle Platform

4.1.1. Data Integration and Governance

Integrate multi-source heterogeneous data and establish a data governance system, including standard, quality, security, and metadata management, to ensure the accuracy, integrity, and consistency of data and provide a reliable data foundation for intelligent manufacturing [30].

4.1.2. Data Storage and Management

Select storage technologies based on data characteristics, build a data warehouse or data lake, establish an indexing, metadata management mechanism and backup and recovery strategy, and conduct life cycle management to ensure efficient data storage and management [31].

4.1.3. Data Service and Sharing

Develop service interfaces to enable data acquisition and sharing on demand, establish a permission management system to ensure security and compliance, encourage internal sharing and collaboration, and promote data circulation and innovative applications [32].

4.2. Intelligent Production Transformation

4.2.1. Intelligent Upgrade of Production Equipment

Install sensors and intelligent controllers to achieve device interconnection and data collection. Utilize data to realize remote monitoring, fault diagnosis, and performance optimization, thereby improving equipment operation efficiency and reliability. Taking Sany Heavy Industry as an example, through the intelligent upgrade of equipment, the comprehensive utilization rate of equipment has increased by 20%, effectively reducing equipment downtime [33].

4.2.2. Intelligent Optimization of Production Process

Build models based on production data to optimize the process flow, apply intelligent scheduling and quality control systems to achieve precise control and optimized management of the production process, and enhance production efficiency and product quality. For instance, after a certain enterprise applied this technology, the production efficiency increased by 30%, and the product defect rate decreased by 15% [20].

4.2.3. Intelligent Management of Supply Chain Collaboration

Integrate supply chain data to build a collaborative platform, optimize procurement, inventory, and logistics through data analysis, apply blockchain technology to enhance trust, and improve the overall collaborative efficiency and stability of the supply chain.

4.3. Intelligent Management Transformation

4.3.1. Intelligent Upgrade of Enterprise Resource Planning (ERP)

Integrate ERP system data to achieve an intelligent upgrade, optimize resource allocation, integrate with production and supply chain systems, realize integrated business process management, and improve enterprise operation efficiency.

4.3.2. Intelligent Enhancement of Customer Relationship Management (CRM)

Integrate customer data to build profiles, use data mining to provide personalized services, establish an intelligent customer service system, and improve customer satisfaction and loyalty.

4.3.3. Intelligent Transformation of Human Resources Management

Integrate human resources data to realize digital management, predict requirements, provide personalized training and career development plans, and enhance employee quality and enterprise talent competitiveness.

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4.4. Intelligent Service Transformation

4.4.1. Product Intelligent Service Innovation

Integrate intelligent modules into products to achieve data collection and remote monitoring, provide intelligent services based on data, promote product innovation and service upgrade, and increase product added value.

4.4.2. Construction of Intelligent After-Sales Service System

Integrate after-sales service data to build an intelligent platform, optimize resource allocation, improve service response speed and quality, continuously improve services through customer feedback, and enhance customer experience.

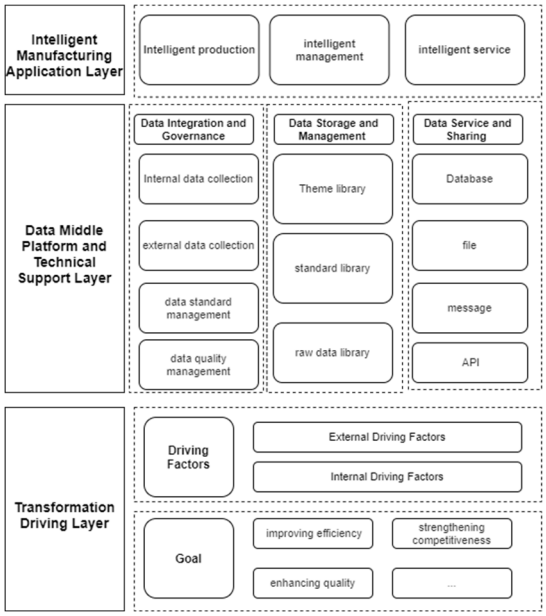

Figure 1. Architecture Diagram of Intelligent Manufacturing Transformation in Manufacturing Enterprises Based on the Data Middle Platform

5. Key Technologies and Implementation Strategies for the Intelligent Manufacturing Transformation of Manufacturing Enterprises Based on the Data Middle Platform

5.1. Key Technologies

5.1.1. Big Data Analysis Technology

Apply data mining algorithms to discover data patterns. For example, association rule mining helps optimize production processes; adopt streaming computing technology to process production data in real-time, monitor the production process, and ensure stable and efficient production [34].

5.1.2. Artificial Intelligence Technology

Apply machine learning models for production prediction, quality inspection, and equipment maintenance. Utilize deep learning algorithms to process unstructured data, achieve intelligent decision-making, and enhance the level of intelligent production [35].

5.1.3. Internet of Things Technology

Realize device interconnection and data collection through sensors and intelligent gateways. Use edge computing technology to preprocess data, reduce transmission delay, and improve data processing efficiency and device response speed [36].

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5.2. Implementation Strategies

5.2.1. Formulating Transformation Strategic Planning

Combine the enterprise's development strategy and market demand, clarify the goals and vision of intelligent manufacturing transformation, formulate a phased implementation plan, and ensure the orderly progress of the transformation [37].

5.2.2. Strengthening Organizational and Talent Support

Build an organizational structure suitable for the transformation, cultivate and introduce digital talents, establish a talent incentive mechanism, meet the talent needs of the transformation, and provide organizational and talent support for the transformation [38].

5.2.3. Promoting Data Culture Construction

Advocate a data-driven decision-making culture, strengthen employee data awareness training, establish a data sharing and innovation mechanism, create a data innovation atmosphere, and stimulate employee innovation potential [39].

6. Case Analysis of the Intelligent Manufacturing Transformation of Manufacturing Enterprises Based on the Data Middle Platform - Taking Sany Heavy Industry as an Example

6.1. Selection of the Case Enterprise

Sany Heavy Industry, as a globally renowned construction machinery manufacturing enterprise, has achieved remarkable results in the intelligent manufacturing transformation. It has rich experience in the construction and application of the data middle platform, which holds significant reference value for the same industry [33].

6.2. Practices of Sany Heavy Industry's Intelligent Manufacturing Transformation

6.2.1. Initiatives for Data Middle Platform Construction

Build a unified data platform to integrate data from the entire business process, strengthen the data governance system to ensure high-quality data, and provide solid data support for intelligent manufacturing.

6.2.2. Application Scenarios of Intelligent Manufacturing Transformation

In intelligent production, realize visual monitoring and intelligent scheduling, optimize production processes and equipment maintenance; in intelligent supply chain collaboration, optimize procurement, logistics, and inventory management to enhance the overall operational efficiency of the enterprise.

6.3. Evaluation of Transformation Effects and Lessons Learned

6.3.1. Indicators for Evaluating Transformation Effects

The production efficiency has been significantly improved, the product quality has been enhanced, the costs have been reduced, and the economic benefits have increased, which fully demonstrates the effectiveness of the intelligent manufacturing transformation. For example, for a certain product of Sany Heavy Industry, the production cycle has been shortened by 35%, the product qualification rate has been increased by 12%, and the operating costs have been reduced by 22% [33].

6.3.2. Lessons Learned and Inspirations

Top-level design and strategic planning guide the direction of transformation. Continuous innovation and application of technologies are the key driving forces. Data-driven decision-making and organizational collaborative changes ensure the success of the transformation.

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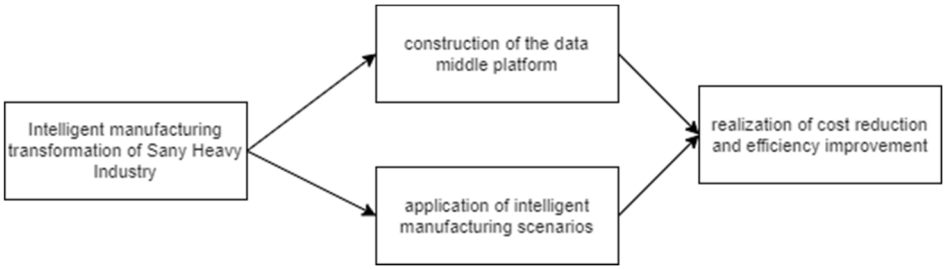

Figure 2. The Path Diagram of Intelligent Manufacturing Transformation of Sany Heavy Industry Based on the Data Middle Platform

7. Research Conclusion and Prospects

7.1. Research Conclusion

This study deeply analyzes the transformation path of intelligent manufacturing in manufacturing enterprises based on the data middle platform. The data middle platform, as the core of the transformation, provides solid support for intelligent manufacturing through data integration, governance, and services. The key technologies play a crucial role in promoting the intelligentization of each link in the transformation process, and the implementation strategies effectively ensure the smooth progress of the transformation. Through an in-depth analysis of the Sany Heavy Industry case, the feasibility and effectiveness of this transformation path have been fully verified, providing comprehensive theoretical guidance and valuable practical experience for manufacturing enterprises in the intelligent manufacturing transformation practice, helping enterprises enhance their core competitiveness and promoting the overall intelligent development of the manufacturing industry.

7.2. Research Prospects

In the future, the intelligent manufacturing transformation of manufacturing enterprises based on the data middle platform will face both opportunities and challenges. At the technological innovation level, emerging technologies such as blockchain and edge computing are expected to be deeply integrated. Enterprises should pay close attention and actively explore their application potential to continuously improve the intelligent level. For example, blockchain technology can further enhance the security and credibility of supply chain data, and edge computing can improve the local decision-making and collaborative control capabilities of intelligent devices, bringing more innovative application models to intelligent manufacturing. In terms of industry development trends, intelligent manufacturing will increasingly emphasize ecological synergy. Enterprises need to further strengthen cooperation with upstream and downstream partners and relevant institutions to achieve resource sharing and complementary advantages and jointly promote industry development. In terms of talent cultivation, efforts should be made to strengthen the construction of interdisciplinary talent cultivation systems. Universities and enterprises should cooperate in depth, formulate talent cultivation plans that meet actual needs, and offer interdisciplinary courses that integrate knowledge from multiple fields such as manufacturing processes, information technology, and data analysis to cultivate compound talents who understand technology and possess innovative thinking and teamwork ability for enterprises to meet their demands for high-quality talents. At the same time, enterprises also need to continuously enhance their competitiveness on the international competition stage, actively participate in international standard formulation, learn from advanced foreign experiences and technologies, and promote the internationalization of China's intelligent manufacturing technologies and standards. In addition, enterprises should boldly explore innovative business models, realize the transformation from product sales to service revenue by providing continuous intelligent

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services, adapt to market changes and industry development trends, and continuously promote the intelligent manufacturing transformation of the manufacturing industry to a new height.

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