Strategies for Smart Manufacturing Industry 5.0: High Quality Development for the Future

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Abstract:

The proposal of Industry 5.0 is an effort and attempt to shape a new type of industrialization using human defined values. The core elements of Industry 5.0, including human centeredness, sustainable development, and resilience, are all different forms of high-quality development. This article proposes four corporate value innovation strategies - rainforest strategy, wetland strategy, grassland strategy, and oasis strategy - to provide management suggestions for traditional manufacturing enterprises to shift to smart manufacturing Industry 5.0. Human-robot collaboration, AI and machine learning, IoT and cyber-physical systems, sustainable manufacturing, human-centered workplace designs, resilient and flexible supply chains, and digital twin and simulation technologies are covered in the text. This article presents a detailed plan for the shift towards Industry 5.0, emphasizing the advantages and real-world uses of these sophisticated production techniques. On the new journey, what kind of response can smart manufacturing Industry 5.0 makes and how can they make forward-looking strategic preparations?

Keywords: Industry 5.0, industrialization, sustainable development, corporate value innovation strategies, smart manufacturing.
Introduction

In 2021, Germany proposed Industry 4.0, and many smart manufacturing industries are currently in the process of achieving Industry 4.0, which is considered the fourth industrial revolution (Meindl, et al., 2021). The essence of Industry 4.0 is to achieve digital and intelligent transformation of manufacturing enterprises by fully utilizing Cyber Physical Systems (CPS), with a focus on digitization, data-driven, and industrial interconnection (Tao, et al., 2019). The definition of "Industry 5.0" in the report is that Industry 5.0 recognizes the power of industry, places the well-being of workers at the center of the production process by making production respect the boundaries of the earth, achieves social goals beyond employment and growth, and becomes a resilient provider of prosperity.

The European Commission has proposed three core elements of Industry 5.0, namely Human-centric, Sustainability, and Resilience (Longo, Padovano, & Umbrello, 2020). Scholars at home and abroad who have paid attention to the EU Industry 5.0 concept interpret it as an upgraded version of German Industry 4.0, believing that it is a shift from efficiency oriented to value oriented, and further naming it "Human centered Intelligent Manufacturing" (referred to as "Human centered Intelligent Manufacturing").

In contrast to past industrial revolutions, Industry 5.0 is propelled by the pursuit of value rather than solely relying on technological advancements (Maddikunta, et al., 2022). Industry 5.0 is a deliberate transformation of the industrial sector by human civilization. It is characterized by humans designing the industry according to their own requirements, rather than passively accepting technology-driven industries that may disrupt society and slowly adjust to it. The first industrial revolution, known as Industry 1.0, is characterized by the introduction of steam engine technology. This technology replaced manual labor with machines and transformed manual workshops into factory systems. The cotton textile industry, railways, and other industries have experienced fast development, marking the beginning of the mechanized age. Industry 2.0 is defined by the utilization of power technology and internal combustion engine technology, as well as the widespread adoption of electrical automation assembly lines for mass manufacturing.

The automobile, petroleum and petrochemical, steel ships, aircraft, and other industries are seeing tremendous growth, leading to the emergence of an electrified era characterized by the large-scale manufacture of standardized items. Industry 3.0 is characterized by the advancement of electronic technology, particularly in the areas of electronic computers, communication, and novel materials. This has led to the emergence of an era focused on electronic information and the mass production of diverse and adaptable products. Industry 4.0 is characterized by the incorporation of information physical system technology and the seamless integration of fundamental information technologies such as cloud computing, big data, artificial intelligence, and the Internet of Things (IoT). Its purpose is to facilitate the intelligent advancement of the manufacturing industry. The system converts and processes supply, manufacturing, and sales data in production, facilitating the analysis and exploitation of more extensive, detailed, and advanced data, so enabling personalized production on a wider scale and ushering in an era of intelligent manufacturing. From the first industrial revolution to the fourth industrial revolution, there has been a gradual improvement in human control over industry. However, this improvement has occurred in a step-by-step manner. The concept of Industry 5.0 aims to establish a novel form of industrialization based on human-defined principles (Groumpos, 2021; Mathur, Dabas, & Sharma, 2022). This move is groundbreaking and has enabled the development of Industry 5.0 in the desired direction, bringing about an era of humanization in the industrial sector. A brief overview of each industrial revolution, highlighting their key features, applications, and advantages are shown in Table 1.
### Table 1. Comparing the Different Industrial Revolutions

<table>
<thead>
<tr>
<th>Revolution</th>
<th>Key Features</th>
<th>Applications</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry 1.0</td>
<td>Steam power, mechanization of production</td>
<td>Textile manufacturing, coal mining, transportation</td>
<td>Increased productivity, mass production of goods</td>
</tr>
<tr>
<td>Industry 2.0</td>
<td>Electricity, assembly line, mass production</td>
<td>Automotive industry, consumer goods manufacturing</td>
<td>Efficiency in production, standardized products</td>
</tr>
<tr>
<td>Industry 3.0</td>
<td>Automation, computerization, electronics</td>
<td>Robotics, computer-aided manufacturing, aerospace industry</td>
<td>Precision, reduced labor costs, improved quality control</td>
</tr>
<tr>
<td>Industry 4.0</td>
<td>IoT, big data, artificial intelligence</td>
<td>Smart factories, predictive maintenance, autonomous vehicles</td>
<td>Enhanced efficiency, real-time data analysis, customization</td>
</tr>
<tr>
<td>Industry 5.0</td>
<td>Cyber-physical systems (CPS), human-machine collaboration</td>
<td>Collaborative robots, augmented reality in manufacturing</td>
<td>Improved safety, flexibility, customization, and efficiency</td>
</tr>
</tbody>
</table>

Industry 4.0 prioritizes the incorporation of cutting-edge technology to improve production processes, whereas Industry 5.0 centers on augmenting collaboration and interaction between humans and machines to achieve more efficiency and adaptability in manufacturing (Zafar, Langås, & Sanfilippo, 2024; Sindhwani, et al., 2022). Worldwide manufacturing industries can simultaneously operate in many modes of production, ranging from mass production to mass custom production and mass personalized production, even within the same enterprise (Rani, et al., 2024). The proposed shaping of Industry 5.0 (as shown in Figure 1), leading smart manufacturing enterprises need to start with value innovation, which is not only a practice of Industry 5.0, but also a leading role for Industry 5.0. This article first explains the value system of Industry 5.0, then explores how the enterprise ecosystem can create this value system, and then explores the acceptance and co-creation of users towards this value system. Based on this, it proposes the value innovation strategy of enterprises, and finally puts forward management suggestions on how smart manufacturing enterprises can play a leading role in the development of Industry 5.0.

![Figure 1. Proposed Model of Industry 5.0 Revolution in the Context of Smart Manufacturing](image-url)
Framework

Value System

For the development of Industry 5.0, prominent companies must prioritize value innovation (Ghobakhloo, et al., 2022). This practice is not only integral to Industry 5.0, but also plays a major role in driving its progress. This article initially elucidates the value system of Industry 5.0, followed by an examination of how the company ecosystem might establish this value system. Subsequently, it delves into the acceptance and co-creation of users with regards to this value system. According to this, it suggests the implementation of Industry 5.0 for businesses, which is a value network consisting of five components: efficiency, safety, human-machine interaction, benefit, and nature (refer to Figure 2).

The benefit is demonstrated through the customized worth of products/services, efficiency is demonstrated through the effectiveness value of minimizing input and maximizing output in production and operation, safety is demonstrated through the resilience value of the enterprise's supply chain, human-machine interaction is demonstrated through the value of prioritizing human-machine cooperation, and sustainability is demonstrated through the value of enterprises' impact on the earth's environment (Song, & Sakao, 2017).

Industry 5.0 generates value for people by customizing products and services, combining empowering technology with customer preferences (Zizic, et al., 2022). This procedure involves organizations granting authority to channel providers and partners to collaboratively serve end-users. Industry 5.0 will center on novel
value sources that cater to consumer demands and are tailored to individual preferences. Industrial production must possess the capability to align users with the equipment they utilize, and establish a customized value chain that is linked to users. By implementing customized customization and fostering collaborative innovation between production and consumption, we will actively engage in production processes that cater to the individualized requirements of consumers across the whole product lifecycle.

Industry 5.0 enhances value by enhancing production and operational efficiency. It builds upon the organizational and operational framework of Industry 4.0 intelligent manufacturing. It focuses on optimizing the entire lifecycle of products, manufacturing, and services through process and system integration. This approach promotes the digitization, networking, and intelligence of manufacturing, leading to continuous improvements in production efficiency and operational performance for businesses, ultimately improving the input-output ratio. Since the advent of industrialization, the industry has prioritized the supply-driven approach of the product economy. This has allowed for the achievement of large-scale production to match customer demand, so ensuring efficient production on a wide scale and maintaining high staff motivation. Industry 5.0 will enhance efficiency by integrating the enterprise supply chain with internal production and manufacturing processes. It will establish an intelligent industrial system based on industrial intelligent networking, leading to improved efficiency and better cost control.

Industry 5.0 emphasizes the importance of natural values and sustainability. It aims to integrate people, the ecological environment, and industry, while promoting the integration of green technology innovation and manufacturing digitalization. This will enhance the intelligence level of enterprises in resource allocation, process control, energy conservation, and emission reduction. Traditional industrial production evaluates firm performance using economic metrics, while industrial development relies on the extensive utilization of resources and infrastructure. The sustainable concept of Industry 5.0 entails minimizing energy consumption and carbon emissions, preventing the depletion of natural resources, and employing innovative technologies like AI and additive manufacturing to minimize waste and environmental harm during production. It also involves advocating for the recycling of energy and resources, as well as the reuse and recycling of natural resources, while fostering the development of a circular economy. These factors contribute to the progressive enhancement of the long-term worth of industrial development.

**Construction Demonstrate**

In Industry 5.0, manufacturers strive to optimize their production processes to enhance efficiency and flexibility while maintaining superior output quality. Mathematical optimization approaches are essential for reaching these aims (Shoukat, et al., 2021). Indeed! Let's examine a mathematical model of a typical situation in a mechanical company working in Industry 5.0: the optimization of production schedule to reduce expenses while satisfying demand. The plant is equipped with many production lines, each possessing the capability to manufacture various types of components. The objective is to distribute resources (such as machinery, materials, and workforce) among these manufacturing lines in a manner that maximizes overall efficiency while minimizing expenses. From a mathematical perspective, this can be expressed as an optimization problem. The objective is to minimize the total cost of production over the scheduling horizon while meeting demand. For the sake of this discussion, we will use the following notation:

\[
\sum_{t=1}^{T} \sum_{i \in I} C_{i,t} \cdot X_{i,t}
\]

\[
\sum_{i \in I} X_{i,t} = D_t \quad t = 1,2,\ldots,T
\]
where, $T$ is the Total number of time periods (e.g., hours, days) in the scheduling horizon. $I$ is the Set of production lines in the manufacturing facility. $D_t$ represents the demand for products at time period $t$ for $t = 1, 2, \ldots, T$. $C_{i,t}$ denotes the cost associated with operating production line $i$ at time period $t$. $X_{i,t}$ is the amount of production allocated to production line $i$ at time period $t$, where, $X_{i,t} \leq P_{i,t}$ (Production capacity of production line $i$ at time period $t$).

**Innovation Strategies for Smart Manufacturing**

Faced with the value system of Industry 5.0, enterprises can use value innovation strategies to achieve new industrialization (Aquilani, et al., 2020). The enterprise innovation ecosystem and users, as two important entities of the value system, are key dimensions that enterprises need to consider when choosing value innovation strategies. According to the strength of the enterprise ecosystem and the degree of user participation, enterprise value innovation strategies can be divided into four categories: rainforest strategy, wetland strategy, grassland strategy, and oasis strategy (see Figure 3).

![Figure 3. Innovation Strategy of Enterprises](image)

**The rainforest Strategy**

Enterprises may decide on a rainforest strategy when the enterprise ecosystem is robust and user engagement is substantial (Goerzig, & Bauernhansl, 2018). The rainforest strategy refers to the ability of businesses to utilize the robust backing of ecosystems and users in order to swiftly establish a varied, interconnected, and mutually reinforcing system of positive feedback. This enables them to achieve rapid and comprehensive innovation in value, ultimately evolving into an industrial 5.0 value system akin to tropical rainforests. A diverse range of categories results in significant diversity among subjects, providing a wide range of options for combining value elements of subjects, and ensuring the stable presence of ecological niches. Cross-level refers to the seamless interaction and mutual enhancement of value factors across different levels. Multi-loop positive feedback refers to a situation where several entities inside multiple value networks engage in positive feedback, mutually reinforcing each other's growth and success.

Under the rainforest strategy, enterprises can explore innovation in multiple directions while actively responding to the innovation explorations of other heterogeneous entities, with active user participation. This provides abundant innovation opportunities and the possibility of rapid growth. Because the practice of Industry 5.0 is still limited or unknown to us, this article uses some familiar scenarios to illustrate analogies, which will also help us develop Industry 5.0 from previous practices. The mechanism of the rainforest strategy is similar to open-source software, but the value elements in open-source software are few, and the value system is not as complex. The user engagement in open-source software is high, and both individual and corporate users provide positive feedback in maintaining the value system of the open-source software community. There are multiple positive feedback loops between individual users, between individual users and company users, and between company users and company users. In the open-source community, contributors and non-contributors can achieve mutual success. In the open-source
community, there is cross layer positive feedback between altruistic value and self-interest value within the same entity, between entities, and between value systems. In the early days, the open-source community, which was mainly composed of individuals, rapidly developed and demonstrated strong vitality. After that, many enterprises began to join and become active in it, and the enterprise ecosystem of the open-source community became stronger. With the widespread acceptance of open-source community practices, increased user engagement and enterprise ecosystem, some companies have begun to implement value innovation in open-source communities through rainforest strategies, either cultivating, participating in, or leading multiple open source communities.

Wetland Strategy

Enterprises might opt for wetland tactics when the enterprise ecosystem is robust and users are predominantly responsive (Kasinathan, et al., 2022). The wetland strategy entails leveraging the robust support of the ecosystem to cater to users who benefit from the value system. This involves establishing a system with multiple positive feedback loops and ample resources, enabling diverse innovation in user service. Ultimately, this strategy aims to evolve into an industrial 5.0 value system resembling wetlands. When comparing the rainforest method to the wetland strategy, the wetland technique is slightly less effective in terms of hierarchy and speed. The enterprise ecosystem is robust, consisting of diverse entities and ample resources in terms of both variety and quantity. By choosing from a range of potential advancements that are valued by users, it has transformed into an industrial 5.0 value system like a wetland. The innovative exploration of firms and diverse entities will be positively influenced by increased feedback, similar to the impact of biodiversity in wetlands. Enterprises that implement wetland strategies might employ numerous methods to encourage user adoption of different value components through innovation.

A recently established energy generation company has implemented value innovation methods that align with the wetland strategy. After undergoing years of development, alternative energy sources such as wind power and photovoltaic power have reached a point where they are now cost-competitive with traditional coal-fired power production methods, both in terms of initial investment and the price at which they can be sold to the grid. The wind and photovoltaic power generating industries have robust corporate ecosystems, comprising well-established entities such as manufacturing plants, component manufacturers, material suppliers, system solution providers, and artificial intelligence technologies. Power generation firms play a crucial role in attaining carbon neutrality objectives, given that conventional coal thermal power generation techniques have comparatively significant carbon emissions. This new energy power generation enterprise is the primary driving force for its affiliated enterprise group to transition towards a low-carbon trajectory. In conjunction with the well-established enterprise ecosystem, it forms customized value, efficiency value, adaptability value, human-centric value, and sustainability value. Users readily accept these values. This new energy power generation enterprise is dedicated to enhancing power generation efficiency and aligning the distribution of light and wind energy needed for renewable energy. It aims to deliver tailored and reliable electricity to end users, thereby contributing to carbon neutrality objectives and attaining sustainable value. This new energy power generation enterprise's investigation of human centered value innovation is particularly remarkable. The wind power generation equipment and photovoltaic power generation equipment of this new energy generation firm are strategically positioned based on wind and solar resources. In the initial stages, individuals adhered to the distribution of machinery, and the personnel performed on-site checks of the dispersed power producing apparatus. The inspection process is inefficient and places a heavy burden on personnel. To address this problem, the new energy power generation company has implemented a regional operation center strategy, which involves using video cameras to monitor the power generation
equipment. The inspection staff now observe and monitor the equipment from the regional operation center. If any abnormal situations arise, they will promptly go to the equipment site to address the issue. Simultaneously, the company's main office has the capability to oversee power producing activities in real-time by exchanging information with several regional operating centers. This recognizes the need of prioritizing individuals as the focal point. This new energy power generating enterprise greatly benefits from a robust ecosystem of other new energy power generation enterprises and the widespread acceptance of new energy electricity and its underlying value system by users, which enhances the exploration of wetland strategy. As new energy power continues to advance, the wetland strategy may create and enhance a holistic value system consisting of various parts, progressing towards the concept of Industry 5.0.

Grassland Strategy

When the enterprise ecosystem is weak and user participation is high, enterprises can choose a grassland strategy. The meaning of grassland strategy is for enterprises to form positive feedback between enterprises and users, as well as between users, by leveraging the favorable conditions of high user participation in a weak ecosystem, forming a value system for the development of Industry 5.0 (Nair, Tyagi, & Sreenath, 2021). Highly engaged users are like abundant aquatic plants on the grassland, evolving together with one flock after another, complementing each other. The situation that is more in line with the grassland strategy is user to manufacturer customization (C2M). Users actively participate and cultivate a manufacturer system in one vertical field after another. These actively participating users are generally active on online platforms, publishing general product requirements, personalized product requirements, and even self-designed product solutions through the platform. The platform or manufacturer aggregates these requirements based on this information and satisfies them. Sometimes, enterprises may encounter situations where their ecosystem resources are insufficient and require flexibility to overcome or develop their ecosystem. The active user group is the initial source of the value elements of the grassland. Enterprises that adopt a grassland strategy shape a diversified industrial 5.0 value system through multiple interactions with users and mechanisms such as feedback, selection, and linkage. Enterprises can leverage the functions of value element distributors, filters, and amplifiers.

Oasis Strategy

When the enterprise ecosystem is weak and users are mainly receptive, enterprises can choose the oasis strategy. The meaning of the oasis strategy is that, in situations where the enterprise ecosystem is weak and user participation is not high, the enterprise is like an oasis shaping the industrial 5.0 value system in the desert (Masuda, et al., 2021). In diverse, multi-directional, and cross level feedback, it selects, cultivates, and amplifies positive feedback that is conducive to the development of the oasis, forming a locally developed and vibrant innovative value element system. A scenario that is more in line with the oasis strategy is the development of service robots. The enterprise ecosystem for service robots is still developing, and users may have a willingness to participate, but there are technical barriers. Adopting the oasis strategy, enterprises are prepared to continuously provide energy and positive feedback to the oasis, and even take on the role of the source in the input and shaping of the value system, until positive feedback, mutual support, and cross layer circulation develop within the oasis. Enterprises can utilize the diversity of heterogeneous entities and the complexity of ecological niches in the industry 5.0 system to discover favorable opportunities for the development and growth of oases, and seize the inevitability through chance.

Applications

The utilization of Industry 5.0 in smart manufacturing has extensive and revolutionary implications. Manufacturers can maintain competitiveness in a constantly changing industrial context by utilizing innovative technologies, sustainable practices, and design that prioritizes human needs. Industry 5.0 not
only improves efficiency and production, but also promotes inclusivity, sustainability, and resilience in the manufacturing industry (as mentioned in Table 2).

<table>
<thead>
<tr>
<th>References</th>
<th>Application Area</th>
<th>Examples</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Di Marino, et al., 2022</td>
<td>Human-Robot Collaboration</td>
<td>Assembly Lines, Quality Control</td>
<td>Reduces physical strain on workers, increases production efficiency, ensures higher product quality, reduces waste</td>
</tr>
<tr>
<td>Van Oudenhoven, et al., 2023</td>
<td>AI and Machine Learning</td>
<td>Predictive Maintenance, Demand Forecasting</td>
<td>Minimizes downtime, reduces maintenance costs, optimizes inventory levels, meets customer demands more accurately</td>
</tr>
<tr>
<td>Niaz, et al., 2022; Shoukat, et al., 2022</td>
<td>IoT and CPS</td>
<td>Smart Factories, Remote Monitoring and Control</td>
<td>Enables real-time monitoring and optimization, improves safety and operational efficiency</td>
</tr>
<tr>
<td>Atif, 2023</td>
<td>Sustainable Manufacturing Practices</td>
<td>Energy Management, Circular Economy</td>
<td>Reduces carbon footprint, minimizes material waste, promotes resource efficiency</td>
</tr>
<tr>
<td>Panagou, Neumann, &amp; Fraggiero, 2024</td>
<td>Human-Centric and Inclusive Workplaces</td>
<td>VR and AR Training, Ergonomic Design</td>
<td>Accelerates learning, reduces risk of errors, enhances worker comfort and safety, contributes to a healthier work environment</td>
</tr>
<tr>
<td>Leng, et al., 2023</td>
<td>Resilience and Flexibility</td>
<td>Supply Chain Transparency, Flexible Manufacturing Systems</td>
<td>Enhances traceability and accountability, ensures a steady flow of materials and products, allows quick adaptation to changing market demands</td>
</tr>
<tr>
<td>Shoukat, et al., 2024</td>
<td>Digital Twin and Simulation</td>
<td>Process Optimization, Product Development</td>
<td>Identifies bottlenecks, implements improvements without disrupting production, reduces time and cost in product development</td>
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</table>

**Human-Robot Collaboration**

Human-robot collaboration occurs in assembly lines when robots aid humans in assembly activities, thereby diminishing the physical burden on workers and enhancing production efficiency. Robots are capable of managing monotonous activities, allowing humans to concentrate on the more intricate and imaginative components of the process.

Robots equipped with sophisticated sensors and artificial intelligence have the capability to do quality control in real-time. They can detect errors or anomalies that may go unnoticed by human visual inspection. This integration guarantees enhanced product quality and minimizes waste.

**AI and Machine Learning**

Predictive Maintenance: AI-powered predictive maintenance systems analyze machinery data to anticipate future faults prior to their occurrence. This strategy aims to limit the amount of time that equipment is not in operation, decrease the expenses associated with maintenance, and prolong the lifespan of the equipment.

Demand forecasting involves the use of machine learning algorithms to assess market patterns and historical data in order to make predictions about future demand. This data enables producers to control inventory levels, minimize overproduction, and fulfill client demands with more precision.

**IoT and CPS**

The IoT and CPS are used to establish networked production environments in smart factories. In these settings, machines, systems, and products are able to communicate with one other smoothly. This connectivity allows for the continuous monitoring, automation, and optimization of industrial processes in real-time.

Remote Monitoring and Control: IoT sensors enable manufacturers to remotely monitor equipment and operations. This feature is especially beneficial for overseeing activities in
dangerous or inaccessible areas, enhancing both safety and operational effectiveness.

**Sustainable Manufacturing Practices**

Energy management in smart manufacturing systems involves the utilization of IoT and AI to enhance and streamline energy consumption. Manufacturers can greatly diminish their carbon footprint by closely monitoring energy consumption and incorporating renewable energy sources.

The circular economy involves the implementation of sophisticated recycling and material recovery techniques that allow producers to effectively reuse waste materials. This practice helps to minimize resource consumption and mitigate the environmental consequences associated with traditional manufacturing processes. Additive manufacturing technologies, such as 3D printing, achieve this by reducing material waste to a minimum.

**Human-Centric and Inclusive Workplaces**

Training in Virtual Reality (VR) and Augmented Reality (AR): the VR and AR technologies offer immersive training experiences, enabling workers to acquire new skills within a regulated and secure environment. This methodology expedites the acquisition of knowledge and mitigates the likelihood of mistakes during practical tasks.

Smart production systems integrate ergonomic design principles to optimize worker comfort and safety. Automated tools and assistance technologies mitigate physical exertion and mitigate the risk of injuries, hence promoting a more salubrious work environment.

**Adaptability and Versatility**

Supply chain transparency is improved by utilizing blockchain and IoT technologies, which offer comprehensive visibility throughout the whole supply chain and enhance the capacity to track and hold parties accountable. This level of openness enables producers to promptly detect and resolve any problems, so maintaining a consistent and uninterrupted flow of materials and goods.

Flexible Manufacturing Systems: Utilizing modular production lines and reconfigurable manufacturing systems allows for rapid adjustment to accommodate shifting market requirements. This adaptability enables firms to seamlessly transition between various goods or modify production quantities with minimal interruption.

**Digital Twin and Simulation**

Digital twins and simulation enable the creation of virtual models of industrial processes, facilitating in-depth simulation and optimization. Manufacturers have the ability to conduct tests on various situations, pinpoint areas of congestion, and make enhancements without causing any disruptions to the actual production process.

Product Development: Digital twins are utilized during the design and testing stages of product development. Manufacturers can use simulations to evaluate the performance of new goods, enabling them to detect possible problems and make required modifications before creating real prototypes. This approach helps to minimize both time and expense.

**Conclusion**

Understand the ever-changing development of value innovation initiatives. The rainforest strategy, wetland strategy, grassland strategy, and oasis strategy are dynamic. Enterprises have the ability to adapt their value innovation strategies in response to changes in the company ecosystem and consumer preferences. This includes transitioning from oasis strategies to grassland strategies, or even to wetland and rainforest strategies. Enterprises have the ability to not only respond to changes and flexibly modify their strategies for creating new value, but also actively shape the ecosystem and influence users, thereby creating favorable conditions for strategic adjustments. The intricate nature of the Industrial 5.0 value system presents difficulties when adapting and executing value innovation initiatives. During the strategic implementation process, it becomes challenging to comprehend, adapt to, and
manage both active and passive forces, controllable and uncontrollable factors, intentional planning and unexpected occurrences, as well as input across different levels and networks. Enterprises must improve their strategic competencies, exploit opportunities, and transform their strategies into intangible assets through evolution.

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