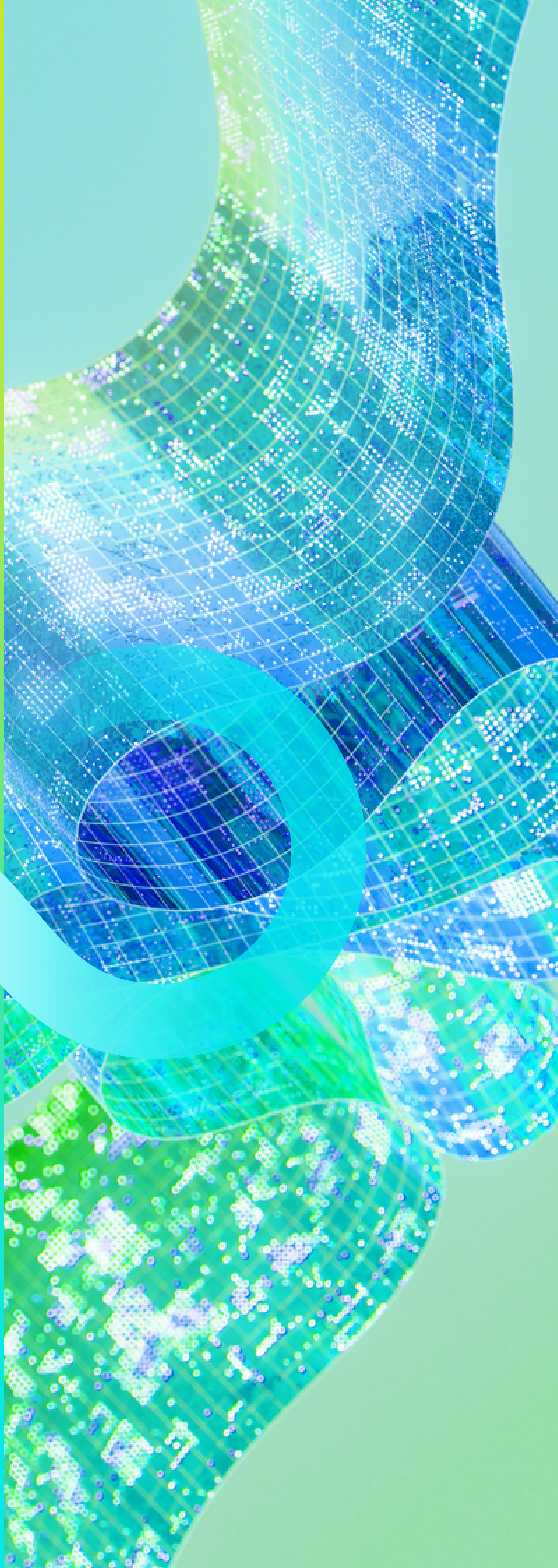
FUJITSU

The Next Generation Intelligent Manufacturing with Generative AI



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The Next Generation Intelligent Manufacturing with Generative AI

Introduction

What is the next generation of intelligent manufacturing?*1

Although the role and perception of the manufacturing industry have evolved over the years, it still contributes about 16% to the world's GDP and remains a cornerstone of the global economy.

The rapid advancement of digitalization is driving transformative changes in the manufacturing sector. "Industry 4.0" (the fourth industrial revolution), introduced over a decade ago, has made significant strides, aiming to revolutionize manufacturing processes through digitalization. While the vision of an autonomous, flexible, and self-organizing factory is still on the horizon, technological advancements in AI, robotics, and the industrial Internet of Things (IIoT) are enabling the optimization of production resources and waste reduction, with progress being made towards more interconnected factories. Notably, AI is increasingly being integrated into production processes and operations, playing a crucial role in decision-making across manufacturing, from design to production and quality control.

Traditionally, AI has primarily focused on enhancing productivity. However, as the manufacturing industry undergoes a paradigm shift, generative AI–known for its creativity, adaptability, and human-like conversational abilities–is gaining attention. Generative AI presents innovative opportunities that surpass the limitations of conventional AI, paving the way for next-generation intelligent manufacturing systems. The advancement of these systems, leveraging generative AI, is anticipated not only to boost productivity but also to accelerate the achievement of sustainability and resilience, thereby enhancing the competitiveness of the manufacturing industry.

*1 Intelligent manufacturing and smart manufacturing are closely related. Intelligent manufacturing focuses on AI machine learning, while smart manufacturing often focuses on IoT and digitalization. In addition, intelligent manufacturing focuses on process autonomy and optimization, while smart manufacturing focuses on connectivity and real-time control. Baicun Wang et al, (July 2020) "Smart Manufacturing and Intelligent Manufacturing: A Comparative Review"

1. Next generation intelligent manufacturing concepts and underlying technologies orchestrated by AI

The rapid evolution of digital technology is driving a significant transformation in the manufacturing industry. Alongside ICT technologies like 5G, a wave of next-generation digital technologies–such as cloud computing, AI, 3D printing, intelligent robots, automated guided vehicles (AGVs), AR/VR, and drones–are emerging rapidly. These innovations are creating new industries and causing digital disruption in existing ones. Recently, generative AI has captured the attention of manufacturing leaders, raising expectations for the advent of next-generation intelligent manufacturing.

(1) Technology Pyramid for Next-Generation Intelligent Manufacturing

As Industry 4.0 advances, the necessary components for AI integration are being established, including data and technology infrastructure, a skilled workforce, and operational models. Industrial AI has reached an unprecedented level of maturity, supported by robust data and technology infrastructure.[*2] This progress is paving the way for the practical application of intelligent and autonomous robots and automation systems.

McKinsey's technology pyramid (technology stack) for next-generation intelligent manufacturing (see Figure 1) includes the following layers:

1) Foundational Data, Connectivity, and Computing Tools

Examples: cloud computing, edge computing, 5G/6G communications, data lakes

2) System-Level Digitization of Planning and Control

Examples: Manufacturing Execution Systems (MES), Customer Relationship Management (CRM), Product Lifecycle Management (PLM)

3) Process Automation and Production Process Innovation Tools

Examples: collaborative robots (cobots), flexible robots, AGVs, drones, 3D printers

4) Operator or Process-Level Digital Worker Productivity Tools

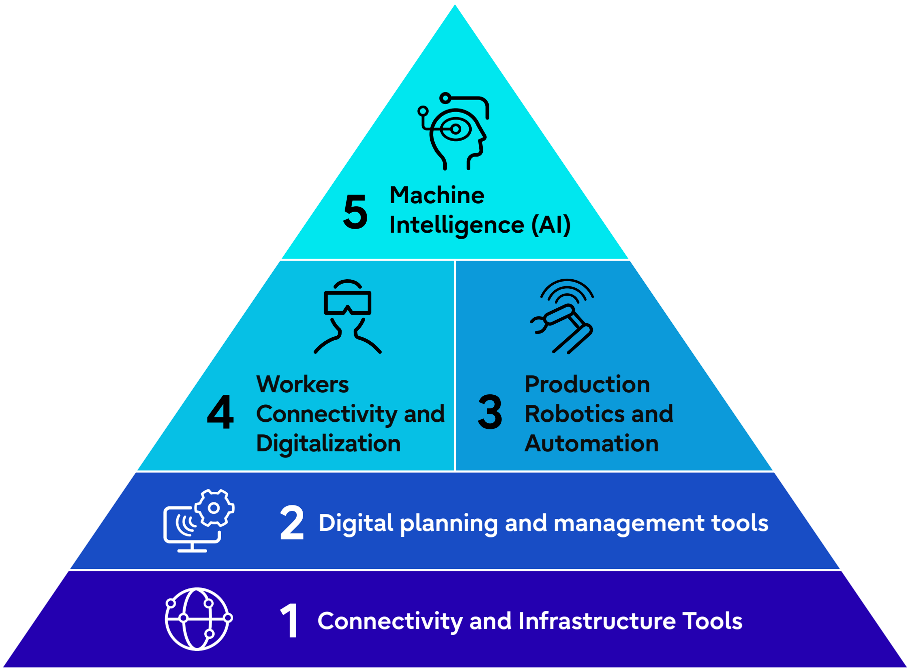
Examples: AR/VR, wearables, exoskeletons, dashboards

5) Machine Intelligence Technologies for Predicting, Optimizing, and Enhancing Decision-Making

Examples: heuristic models, applied AI, generative AI

*2 AI that, rather than seeking to simulate human intelligence, empowers machines with the specialized intelligence needed to perform complex tasks in the cyber-physical world of production. McKinsey (February 2024) "Adopting AI at speed and scale: The 4IR push to stay competitive".

Figure 1 Technology pyramid for intelligent manufacturing systems



Source: WEF (December 2023) "Global Lighthouse Network: Adopting AI at Speed and Scale"

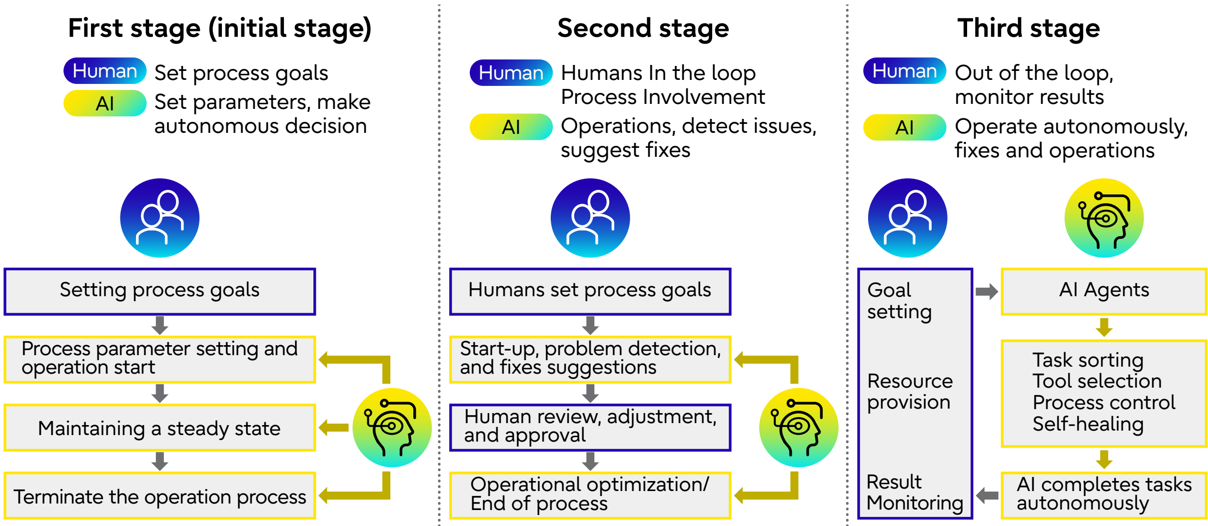
AI acts as the conductor, seamlessly integrating technologies for the next generation of intelligent manufacturing. For instance, rapid changeovers necessitate the use of flexible robots, AGVs for material transport, 3D printing for customizing line equipment, and wearables for delivering critical alerts. AI-orchestrates these technologies to provide swift solutions. However, achieving full orchestration requires both technological advancements and human collaboration to address the challenges of complex decision-making and concerns about system safety and reliability.

The manufacturing industry has experienced significant evolution with the rise of digital technologies. Beyond ICT technologies like 5G, a succession of next-generation digital technologies–such as cloud computing, AI, 3D printing, smart robots, automated guided vehicles (AGVs), AR/VR, and drones–have emerged as key enablers. While these technologies are fostering the creation of new industries, they are also driving digital disruption in existing ones. In recent years, generative AI has captured the attention of manufacturing leaders, heightening expectations for the emergence of next-generation intelligent manufacturing.

(2) Three Levels of Cognitive Process Automation

Cognitive process automation in manufacturing, much like physical automation, unfolds in stages that can be broadly categorized into three levels (see Figure 2).

Figure 2 Three stages conceptual diagram of cognitive process automation in manufacturing



Source: Author

1) First stage (initial stage)

At this level, AI autonomously sets process parameters in real time to maintain steady-state operations, requiring minimal human intervention.

2) Second stage

Here, AI suggests adjustments for machine performance degradation and modifies recipes to eliminate material impurities. Human involvement is necessary for decision-making, as they review and either approve or adjust AI's recommendations.

3) Third stage

In this advanced stage, AI enables self-healing manufacturing and supply chain operations, with humans serving primarily as monitors, intervening only in exceptional circumstances.

Currently, AI has achieved automation at individual process steps.[*3] The goal of the third stage is to implement self-healing automation across entire production lines and factories. The realization of fully autonomous manufacturing hinges on advancements in cognitive process automation technology. Progress in generative AI is fueling optimism for reaching this third stage.

*3 McKinsey (April 2024) "How manufacturing's Lighthouses are capturing the full value of AI"

2. Expanding AI adoption in global light houses: role models for intelligent manufacturing

The concept and foundational technologies of next-generation intelligent manufacturing has been widely embraced. Industry 4.0 initiatives are being advanced across various sectors. The Global Lighthouse, selected by the WEF and McKinsey serves as a model for future developments.[*4] In this context, the role of AI is gaining increasing attention.

(1) Current Status of the Global Lighthouse

The Global Lighthouse is at the forefront of large-scale application of next-generation intelligent manufacturing technologies, driving improvements in finance, operations, and sustainability. By the end of 2024, 172 sites have been certified, with 20 companies are also recognized as Sustainable Lighthouses. By industry, there are 108 advanced manufacturing sites, 34 consumer products sites, 25 pharmaceutical sites, 23 process manufacturing sites, and 1 logistics site.

Global Lighthouse Use Cases

Over the past six years, the Global Lighthouse Network has demonstrated more than 1,000 use cases. As of January 2023, 139 use cases have been adopted by 132 companies. Within manufacturing plants, these are categorized into sustainability, quality control, performance management, maintenance, assembly, and machinery. Across the value chain, they are categorized into customer connectivity, end-to-end (E2E) delivery, E2E planning, E2E product development, and supply chain network connectivity.

Economies of Scale and Network Effects

Each WEF-certified lighthouse implements approximately 20 to 40 use cases. Some lighthouse owners have already expanded these practices to other manufacturing sites to achieve economies of scale and network effects.

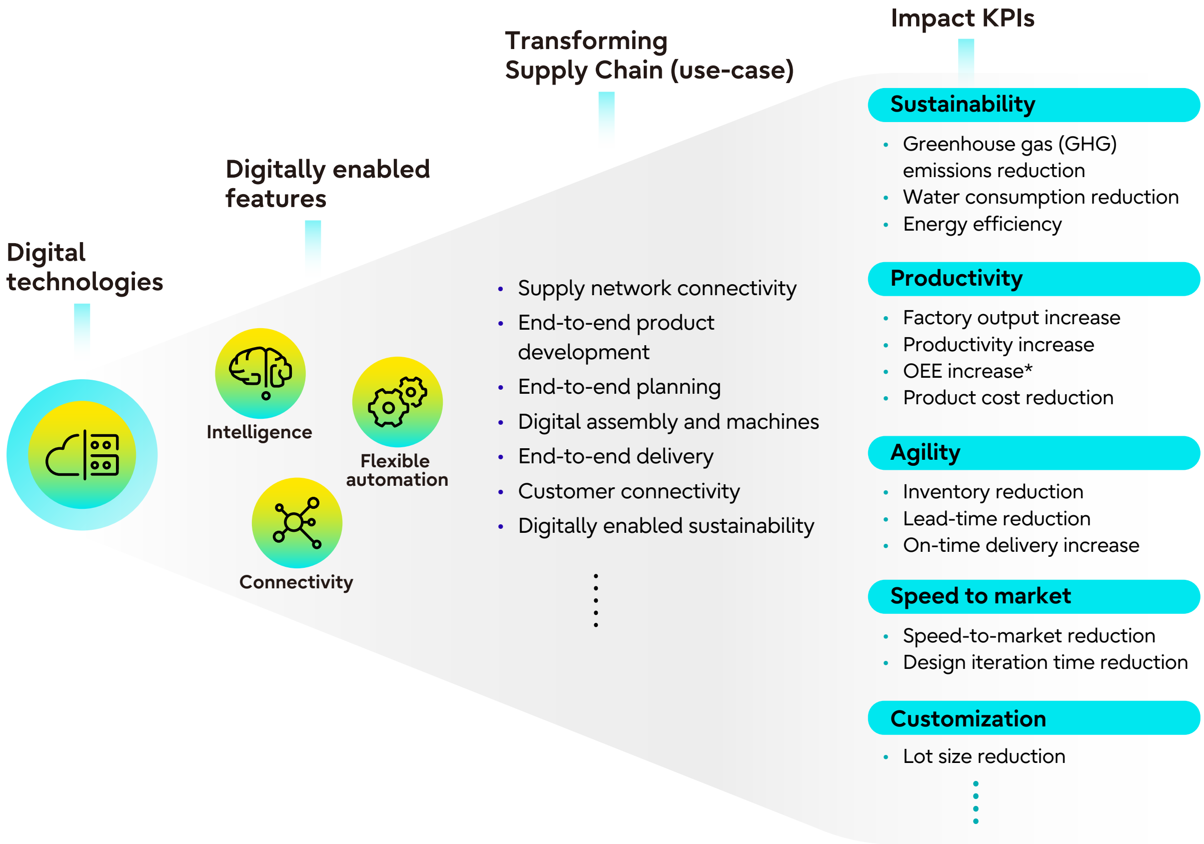
(2) KPIs for Evaluating the Success of Use Cases

The WEF Lighthouse assessment quantitatively evaluates not only the technical potential but also the impact on corporate performance and sustainability.

As illustrated in Figure 3, the WEF assessment framework comprises five major categories and 10 or more sub-categories. While the impact observed in each lighthouse varies, it has been confirmed that the expected results can be achieved with proper implementation. This information has motivated other companies to advance intelligent manufacturing.

*4 WEF "Global Lighthouse Network"

Figure 3 Intelligent Manufacturing System Transformation Journey



*OEE: Overall equipment effectiveness
Source: Created by the author. Referred to WEF (January 2023)
"Global Lighthouse Network: Shaping the Next Chapter of the Fourth Industrial Revolution" for impact KPIs.

Lighthouse Transformation and Impact

64% of the lighthouses have demonstrated a positive impact on environmental efficiency by integrating multiple use cases, alongside the four transformations of demand chain agility, customer centricity, supply chain resilience, and productivity and speed, as well as production efficiency. The Sustainable Lighthouse has shown that digital technology can drive both sustainability and competitiveness.

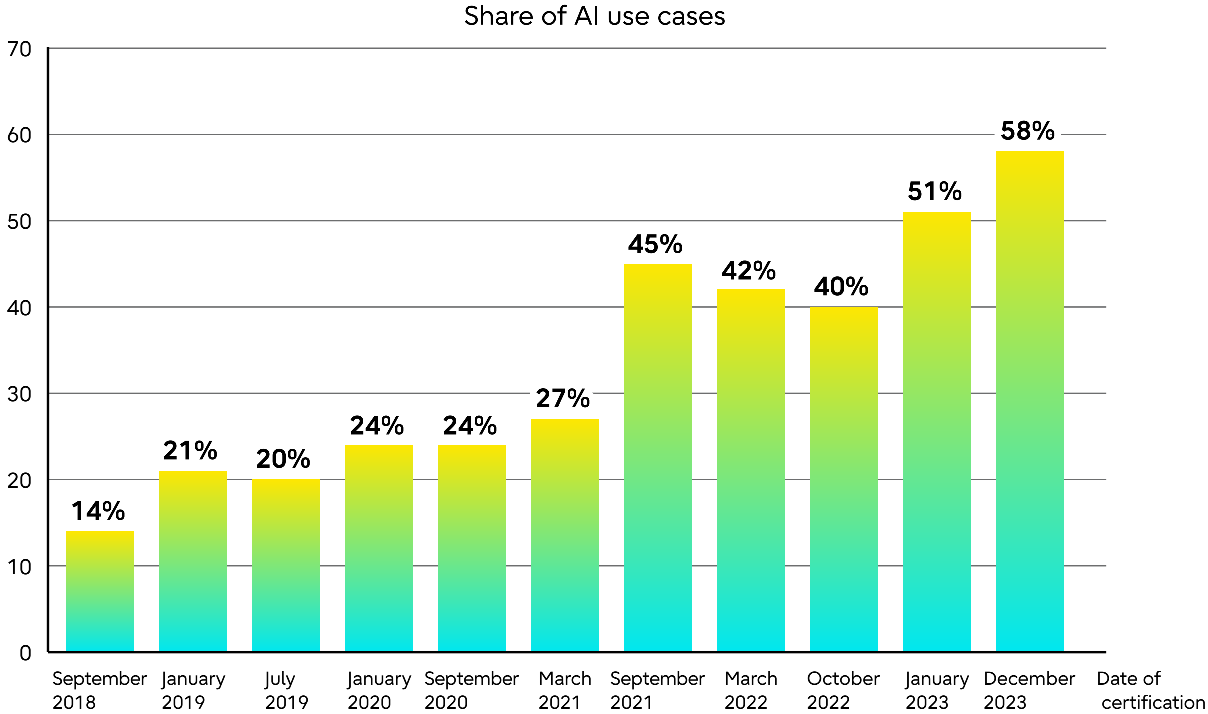
Reference Value of Global Lighthouse

The development of use cases by the Global Lighthouse, the establishment of KPIs (measurable effects), and the operational mechanisms discussed above serve as valuable reference points. They act as a role model for the introduction of generative AI, which has emerged in recent years, as well as conventional AI, particularly in the context of software infrastructure development.

(3) Accelerating the adoption of AI use cases

As discussed in Chapter 1, AI, which incorporates Industry 4.0 technologies, is gaining attention as a key driver of the next generation of intelligent manufacturing. Lighthouse is actively leveraging AI to propel digital transformation.

Figure 4 Percentage of AI use cases among Lighthouse submissions



Data Source: Created by the author with reference to McKinsey (April 2024) "How manufacturing's Lighthouses are capturing the full value of AI"

Figure 4 illustrates the proportion of AI-related use cases among Lighthouse's top five certified use cases as of December 2023. This proportion has increased from under 20% initially to nearly 60%. The implementation of AI use cases has resulted in a 2-3x boost in productivity, a 50% improvement in service levels, a 99% reduction in defects, and a 30% decrease in energy consumption.[*5] These outcomes offer compelling evidence of AI's return on investment.

Implementing AI from individual process steps to the entire production system

Global Lighthouse applies AI use cases across various stages, from individual process steps to the entire supply chain. These applications span planning, asset management, manufacturing, quality control, and delivery, and are marked by a narrow scope, low risk, and rapid iteration. Presently, over 80% of AI use cases are implemented at the process step level.[*6]

*5 McKinsey (April 2024) "How manufacturing's Lighthouses are capturing the full value of AI"
*6 McKinsey (April 2024) "How manufacturing's Lighthouses are capturing the full value of AI"

Table 1 presents examples of AI use cases across different processes in the manufacturing supply chain. In planning, Ingrasys implemented an AI demand forecasting model, enhancing accuracy by 27% over three years. For process optimization, Heng tong Alpha Optic-Electric utilized the model to automatically optimize parameters. In quality control, VitrA Karo employed computer vision to reduce scrap rates by 68%. In delivery, CR Building Materials Tech optimized routes, cutting pickup time by 39%.

Numerous lighthouses have adopted a wide range of AI-driven use cases. China's CITIC Pacific Special Steel applied AI to numerous use cases throughout the production process, predicting the internal structure of a blast furnace to optimize process parameters in real-time, thereby enhancing throughput by 15% and reducing energy consumption by 11%. In Germany, Agilent integrated computer vision technology, achieving a 49% reduction in defect rates within four months.

Some lighthouses are extending their use of AI beyond individual process steps by establishing AI control centers to oversee and adjust the entire production system. This advancement is facilitated by technologies like ML Ops (machine learning operations).[*7] For instance, Mondelez in Beijing constructed a factory equipped with an AI control center to enhance the capacity of its production lines and supply chain. Similarly, K-Water implemented an autonomous operations control center, boosting production by 31% over two years.

It's crucial for AI to accurately identify corrective actions and for its recommendations to be reliable. This necessitates advancements in AI technology and the implementation of robust safeguards. The cases of Mondelez and K-Water represent foundational steps towards achieving fully autonomous factories.

*7 McKinsey (July 2024) "Technology Trends Outlook 2024"

Table 1 Examples of AI applied to each business process in the manufacturing supply chain

Business process	Use case examples	Impacts
Supply chain planning	• Agilent uses supplier performance indicators and supply chain status information to predict material availability, enabling a cross-department proactive response to supply chain risks • Ingrasys uses order history and market data to predict customer orders more accurately than provided forecasts	inventory decrease 10-20%
Supply chain management	• Unilever has automated inventory replenishments using a model trained on data such as previous-day sale/orders, stock target, capacity constraint, and regulated product material availability • Johnson & Johnson identifies and mitigates slow-moving and obsolete risks by replacing manual data analysis with an automated, AI-enabled process to generate actionable insights	supplier service level increase 10-20%
Production scheduling	• ACG Capsules optimizes its production schedule across 4 parameters and 8 constraints using AI, including a novel color-matching algorithm, and validates it with a digital twin • GAC Aino uses an advanced optimization engine to achieve automatic scheduling and prioritization of more than 100,000 configurations, enabling a plan-driven resource distribution	on-time-in-full increase 10-20%
Process optimization	• CITIC Pacific Special Steel uses AI-driven agile manufacturing models across furnace, rolling, and cooling steps to meet multivariety and small-batch demand of special products • Heng tong Alpha Optic-Electric automatically optimizes parameters for preform and drawing processes with a model that is trained on the performance of past parameter strategies	throughput increases 40-140%
Asset management	• Aramco predicts remaining useful life of reactors through analysis of more than 140,000 data points per reactor to minimize corrosion and optimize maintenance • CATL implemented factory-wide predictive maintenance, using AI to optimize maintenance plans based on real-time sensor data	Improved Overall Equipment Effectiveness 10-30%
Quality and testing	• LONGi uses AI to precisely trace defects and perform root cause analysis with multimodal concurrent image analysis, feature- based tracing, and a closed-loop quality expert system • VitrA Karo sets computer vision rejection thresholds to automatically detect and reject undesirable tiles from entering the kiln	first-pass yield increase 30-40%
Assembly	• Haier optimizes final assembly by analyzing the efficiency of personnel skills, processes, equipment, and materials to optimize allocation of production capacity and resources	labor productivity increase 30-40%
Delivery	• China Resource Building Materials Technology leverages adaptive algorithms on top of 3D digital modeling for "no-touch pickup" of new customer orders, including flexible cement bag load planning and execution	lead time decrease 30-40%
Control Center	• Mondelez's Beijing factory built a dough production plant with 5 automated production lines, 4 AGVs and an AI control Centre to manage 9 types of raw materials, optimize the dough fermentation process and analyze consistency to increase the capacity and speed of the production line and supply chain	Process capability increase 108%
	• K-Water has implemented an 'AI operations system' to control processes such as mixing and settling, which has increased production by 31% in just two years and is being rolled out to 42 other plants	Labor efficiency increase 104%

Source: Created by the author with reference to WEF (December 2023) "Global Lighthouse Network: Adopting AI at Speed and Scale", and McKinsey (April 2024) "How manufacturing's Lighthouses are capturing the full value of AI"

Transitioning from an Efficiency-Driven Supply Chain to a Value Chain Focused on Customer Value

Initially, Industry 4.0 concentrated on enhancing the productivity of Manufacturing. However, the focus is now shifting towards creating customer value. The next-generation intelligent manufacturing system must evolve from merely optimizing manufacturing and distribution efficiency to prioritizing customer value creation.

The next-generation intelligent manufacturing system should encompass the entire enterprise, covering areas such as supply chain management, manufacturing, shipping, research and development, marketing, sales, and customer service. While conventional AI techniques are strong in predictability and consistency, they face limitations when handling unstructured and real-time data.

3. Manufacturing value chains revolutionized by generative AI: use cases and company examples

Generative AI, leveraging the recently introduced Large Language Model (LLM), offers a unique approach to understanding and processing vast amounts of unstructured data–such as drawings, text, and speech–in a manner that closely mirrors human thought and judgment.[*8] This enables Generative AI to emulate human reasoning and connections, generate new insights, automatically produce content, and engage with users in a more human-like manner.

Generative AI is poised to make a significant impact in fields such as research and development, marketing, sales, customer service, data infrastructure, and human resource management, thanks to its remarkable adaptability, flexibility, and creativity.

(1) Potential Use Cases for Generative AI in Manufacturing

Generative AI possesses fundamental capabilities like extracting insights, creating content, and interacting with users. In manufacturing, these capabilities are anticipated to be applied in areas rich with unstructured data, such as identifying new supplier profiles, pre-screening bids, and developing internal standard operating procedures (SOPs) and product manuals.

Additionally, Generative AI can be utilized to produce quality performance reports, product brochures, and audit notes. It can also function as a chatbot to simulate supplier negotiations or manage customer inquiries, leading to more efficient and effective interactions.

*8 Jianmin Jin (February 2024) "Leveraging the LLM: Strategy from Model Selection to Optimization–Insight for top management"

McKinsey conducted research on its clients and Global Lighthouse case studies, identifying over 50 high-potential generative AI use cases across six domains–design, sourcing, planning, manufacturing, delivery, and service–and two functional areas: data and technology adoption and talent and organizational empowerment within the manufacturing value chain.[*9] Table 2 provides examples of these generative AI use cases throughout the manufacturing value chain.

Table 2 Examples of potential generative AI use cases in the manufacturing value chain

Domain (Function)	Use Case Examples	Domain (Function)	Use Case Examples
Design	• "Discover" new products (e.g. new chemicals, circuit designs) • Accelerate/simulate testing phases • Predict product market fit with consumer insights • Optimize traditional part designs (e.g. component weight)	**Deliver**	• Analyze and screen carrier shipment terms to enhance negotiation • Generate and verify required documents for transportation • Interactive virtual assistant to augment driver services (e.g. voice navigation)
Source	• Pre-screen, summarize and extract clauses of interest • Generate category strategies with external sources • Role-play negotiations and prepare scenarios • Automate document generation (RFPs, contracts) • Create supplier performance reports	**Serve**	• Personalized and interactive e-commerce pages • Synthesize info for pricing decisions (e.g. competitors' prices) • Review transcripts and coach call-Centre agents • Provide step-by-step instructions to customer to self-diagnose issues
Plan	• Provide insights into inventory health and drivers of ageing • Automate supplier risk analyses • Chatbot for real-time supply-risk action planning	**Technology**	• Accelerate software generation (co-pilot) • Dynamic security scans to stabilize and accelerate code maintenance
Make	• "Technician adviser" to troubleshoot • Automate process failure analysis • Co-pilot for SOPs, performance reports, training aids	**People**	• Self-serve HR (e.g. automated onboarding) • Recruiting co-pilot (e.g. develop job descriptions) • Generate one-off/customized learning scenarios

Source: Created by the author with reference to WEF (December 2023)
"Global Lighthouse Network: Adopting AI at Speed and Scale"

(2) Adopted Generative AI Use Cases in Manufacturing

Generative AI is projected to contribute between $2.6 trillion and $4.4 trillion annually to the global economy through 63 high-potential use cases.[*10] Manufacturing, particularly the supply chain, represents about a quarter of this value. This growth is largely fueled by automation through new capabilities in content creation, insight extraction, and user interaction, all of which enhance productivity.

*9 McKinsey (April 2024) "How manufacturing's Lighthouses are capturing the full value of AI"
*10 McKinsey (June 2023) "The economic potential of generative AI"

To capture this significant value, industries are exploring various implementations of generative AI. Table 3 illustrates implementation cases from some of the leading companies studied by the authors.

Table 3 Examples of Generative AI used in manufacturing

Manufacturer	Examples of use cases for Generative AI	Features
GE Appliance	• Smart HQ App: AI-generated recipes (Flavorly AI function), additional functions, scalability • Improvement of production processes and workflows • Co-development with Google Cloud	Smarter, more personalized • Democratize innovation • Reduce food waste
GE Aerospace	• Enterprise-wide generative AI platform (AI Wing mate): Introduction (June 2024) for employees (52,000 people), virtual assistant using Azure AI (GPT-4o) • Utilizing the characteristics of conventional AI and generative AI for engine monitoring/parts inspection, predictive maintenance, fuel efficiency optimization, etc.	Integrate Generation A into the current operating model • Improve employee productivity • Establish a new style of innovation
Honeywell	• There are already 24 projects approved for full implementation, with 16 use cases implemented Use case examples: 1) MS 365 Copilot: Accessible to 5,300 employees 2) GitHub Copilot: 90,000 lines of code created per week (used by 4,500 developers) 3) Moveworks AI Copilot: Reduced incoming IT help desk tickets by 80% 4) Red Virtual Assistant: Access to massive internal data stores	AI-first strategy • Unifying data with Snowflake • Transforming the workforce (AI-driven HR) • Taking responsibility for financial impact
Bosch	• Develop and scale AI solutions for optical inspection using synthetic data from generative AI: pilot completed, scaled to 230 factories	Synergy between generative and conventional AI • Improvement of many conventional AI solutions implemented in factories
Schneider Electric	• Leverage Azure OpenAI from Microsoft's commercial and enterprise-focused platform Use case examples: 1) GitHub Copilot: Code generation 2) Resource Advisor Copilot: Integrating generative AI into existing solutions 3) Jo-Chat GPT: Chatbot for employees (Generative AI Assistant) 4) Knowledge Bot: Chatbot (GPT3.5) to support customer service agents 5) Conversational Search: Conversational product search engine for customers 6) Financial Advisor: Conversational assistant for financial and accounting support	Value-Based Generative AI Strategy • Generative AI selection: balancing outsourced and in-house development • LLM Selection: Balancing cost and environmental efficiency • Leverage in-house custom ChatGPT • Integration with existing solution products
ACG Capsules	• Developed and deployed a generative AI assistant that leverages open source LLM-based models and adapts through transfer learning and fine-tuning • Builds context from more than 200 quality, manufacturing, and printing SOPs, maintenance procedures, and case sheets	Rapid development and deployment • Custom models developed in 2 weeks • Available to nearly 3/4 of relevant employees within 5 weeks

Source: Compiled by the author based on company press releases, financial statements, public reports, etc.

Below are three case studies.

GE Appliances Case Study

While conventional AI technology has made smart appliances popular, the integration of generative AI is ushering in a new era of more intelligent, adaptive, and personalized appliances. GE Appliances' SmartHQ application incorporates generative AI to offer a smarter, more personalized user experience. The app's Flavorly feature analyzes the ingredients customers have and generates recipes based on those ingredients, simplifying home cooking, saving on grocery costs, and reducing food waste. The company is also applying generative AI technology to other home appliances, such as washing machines and vacuum cleaners.[*11] This initiative represents a step towards building a next-generation intelligent manufacturing system, where generative AI is embedded in products and machines.

Bosch Case Study

Bosch, a leading global automotive supplier, faced the challenge of collecting large amounts of data for developing automated optical inspection models. The company devised a solution using generative AI to produce the data needed to train an AI model for the stator of an electric motor part. This approach enabled the generation of over 100 times the number of synthetic images from a small amount of real data, reducing project time from several years to just six months. The quality of inspections improved, resulting in six-figure annual productivity gains. This solution has been applied to other tasks and scaled up to 230 plants worldwide.[*12] This case study uniquely illustrates the synergy between generative and conventional AI.

ACG Capsules Case Study

To address the evolving skills needs of its manufacturing workforce, pharmaceutical contract manufacturer ACG Capsules developed and deployed a custom generative AI assistant in just two weeks. The company also introduced training and gamification with leaderboards, rewards, and recognition for its frontline workforce. Within five weeks, nearly three-quarters of operators and technicians were using an assistant. The generative AI assistant informed maintenance and compliance actions, reducing mean time to repair (MTTR) by an average of 30-40%. In recognition of this achievement, the company was named a Global Lighthouse by the World Economic Forum (WEF).[*13]

*11 Kevin Nolan (CEO, GE Appliances) (December 14, 2023)
"A recipe for AI success: GE Appliances' CEO shares how they're innovating in record time"
*12 Bosch (January 4, 2024) "Generative AI in manufacturing–out of the old, emerges the new"
*13 WEF (December 2023) "Global Lighthouse Network: Adopting AI at Speed and Scale"

(3) Trends and Insights from Advanced Examples of Generative AI Applications in Manufacturing

1) Use of Custom Generative AI

Many companies are leveraging custom generative AI. Approaches include: 1) developing in-house applications (e.g., GE Appliances), 2) utilizing enterprise customization services from large tech companies (e.g., Schneider Electric), and 3) employing transfer learning and fine-tuning with open-source LLMs (e.g., ACG Capsules). Few companies develop LLM models from scratch in-house, aligning with survey results on LLM usage strategies.[*14]

2) Popularity of Employee Assistants

Employee assistants can be categorized into horizontal types for all employees (e.g., GE Aerospace) and vertical types for specific tasks (e.g., Honeywell's Copilot for the IT help desk). Some companies are also introducing customer assistants (e.g., GE Appliances' AI for recipe generation).

3) Indirect Use in Manufacturing Processes

Generative AI creates synergistic effects when combined with conventional AI.[*15] Bosch's synthetic defect data generation case, to be presented at the Hannover Messe in 2024, is expected to gain widespread use in the industrial sector. ACG Capsules' employee assistant is another example of indirect application.

4) Widespread Use of Code Generation Assistants

Code generation assistants are well-established and have demonstrated significant productivity benefits.[*16] At Honeywell and Schneider Electric, all developers use GitHub Copilot.

5) Scale-Up Phase Where Return on Investment is Important

According to a McKinsey study, by early 2024, the adoption of generative AI will reach approximately 36% for both scale-up and full adoption.[*17] As companies enter the scale-up phase, they focus on return on investment (RoI). Honeywell, Schneider Electric, and Bosch have already entered this phase, implementing value-based generative AI strategies.

6) Many General-Purpose Cases, Few Front Office/Production Site Applications

While many cases focus on back-office and productivity-related applications, there are still few innovative customer engagement and production site applications. This highlights a gap between expectations and actual adoption of generative AI, necessitating technological advances and business actions to overcome these.[*18]

*14 Jianmin Jin (February 2024) "Leveraging the LLM: Strategy from Model Selection to Optimization–Insight for top management"
*15 Jianmin Jin (January 2024) "Generative AI: Use Cases as the Pathway to Value Creation"
*16 Keystone (2023) "Sea Change in Software Development: Economic and Productivity Analysis of the AI-Powered Developer Lifecycle"
*17 McKinsey (July 2024) "McKinsey Technology Trends Outlook 2024"
*18 Jianmin Jin (January 2024) "Generative AI: Use Cases as the Pathway to Value Creation"

4. Conclusion: the future of intelligent manufacturing as envisioned by generative AI

As demonstrated in Chapter 2, many Global Lighthouse use cases apply conventional AI techniques to address specific tasks and problems. These are implemented at the process step level, requiring a separate model for each use case. Some cases also involve "lights out" operations, where the entire production system encompasses multiple process steps. However, conventional AI relies on a rule-based approach, which limits its adaptability and flexibility.

In contrast, the cases discussed in Chapter 3 highlight how the adaptability, flexibility, and creativity of generative AI elevate specific tasks and missions to new levels of productivity improvement, personalized customer experiences, and expanded human imagination. Yet, the current use of generative AI is largely confined to simple interactions where users ask questions and receive answers. This process is temporary and does not foster deep dialogue or ongoing relationships.

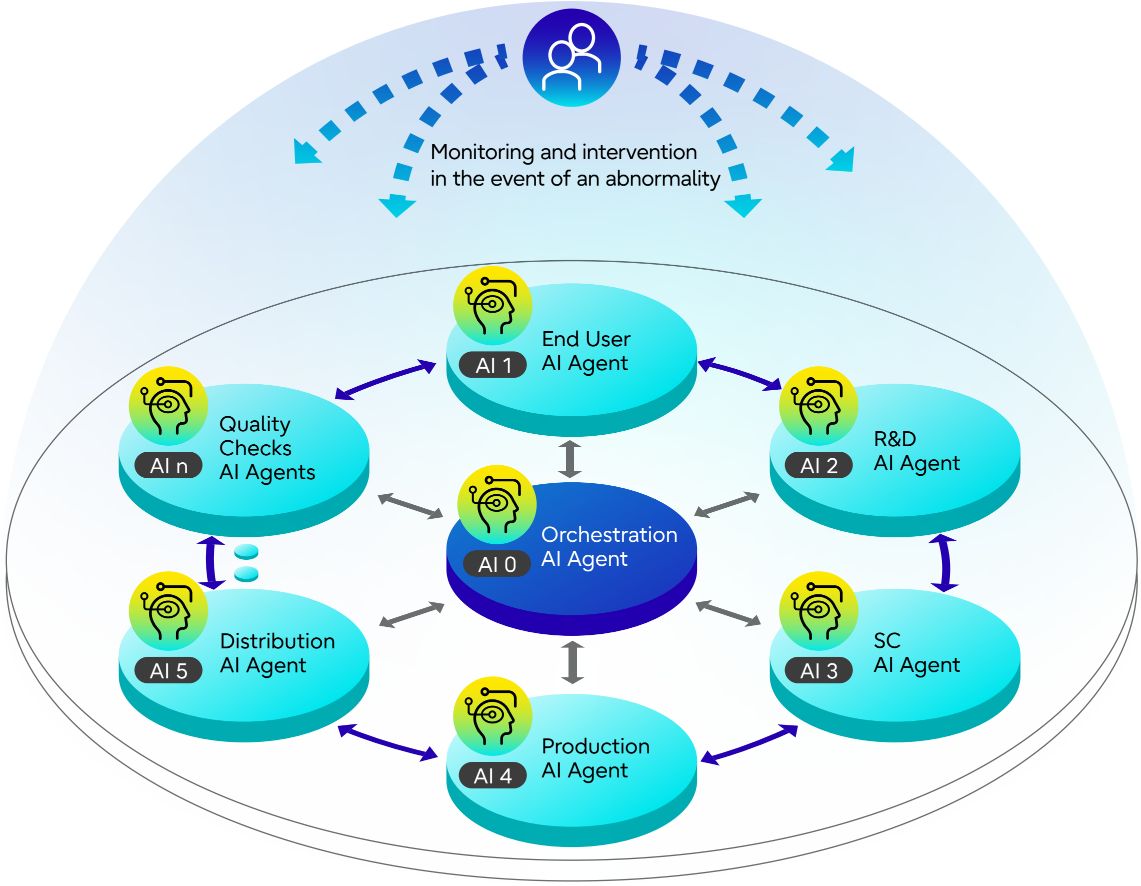
Looking ahead, generative AI is expected to evolve into AI agents capable of understanding context, planning workflows, connecting to external tools and data, and taking actions to achieve defined goals. This includes acting as skilled collaborators, orchestrating entire processes, and making autonomous decisions. Many companies and research institutes are actively developing multi-agent systems composed of AI agents, task-specific agents, and orchestration agents.[*19]

The vision of AI agents and multi-agent systems is not merely an ideal but is becoming a reality. For instance, Fujitsu has begun deploying the "Fujitsu Kozuchi AI Agent" globally.[*20] This AI agent can participate in profit and loss meetings and business negotiations, sharing relevant information and suggesting actions. For example, an AI agent attending a meeting might receive a statement like "sales in the Asian region are half of last year's" and perform data analysis. It would then display sales by region in a bar chart, showing that sales in the Asian region are 54% of last year, thereby facilitating the meeting and supporting productive conclusions. Fujitsu has also developed an AI agent for video analytics to support safe and efficient frontline workplaces and plans to gradually expand its AI agents to specialize in operations such as production management and legal affairs.[*21]

Figure 5 illustrates the future vision of next-generation intelligent manufacturing realized by AI agents. The use of multi-AI agents is expected to lead to the creation of end-to-end intelligent systems in the manufacturing value chain. This will be achieved by employing specialized agents with different expertise, an AI control agent to orchestrate them, and humans to monitor and intervene in emergencies throughout the autonomous system.

*19 Deloitte (November 2024) "Prompting for action How AI agents are reshaping the future of work"
*20 Fujitsu Press Release (October 23, 2024)
"Fujitsu to offer AI agents that can both collaborate and engage in high-level tasks autonomously"
*21 Fujitsu Press Release (December 12, 2024)
"Fujitsu develops video analytics AI agent to support safe, secure, and efficient frontline workplaces"

Figure 5 Vision of the future of next-generation intelligent manufacturing realized by AI agents



Source: Author

However, realizing an end-to-end intelligent manufacturing system requires collaboration between digital AI agents and physical AI agents (execution systems like autonomous robots with built-in intelligence). As the Fujitsu example shows, digital AI agents are becoming a reality, but physical AI agents remain in the research and development stage.[*22] The simultaneous development of digital and physical AI agents is anticipated to lead to the realization of true next-generation intelligent manufacturing.

*22 Example: Toyota Research Institute (September 19, 2023)
"Toyota Research Institute Unveils Breakthrough in Teaching Robots New Behaviors"

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About the author

Dr. Jianmin Jin

2020- Fujitsu Ltd., Chief Digital Economist
1998-2020 Fujitsu Research Institute, Senior Fellow

Dr. Jin's research mainly focuses on global economic, digital innovation/digital transformation, and Dr. Jin has published books such as "Towards the create of a Japanese version of Silicon Valley", etc.

Recent writings: the following Fujitsu Insight Paper, etc.

- Innovative Banking with Generative AI: Exploring Use Cases and Value Creation (2024)
- Leveraging the LLM: Strategy from Model Selection to Optimization–Insight for top management (2024)
- Generative AI: Use Cases as the Pathway to Value Creation (2024)
- Transforming Supply Chains to Be More Productive, Resilient, and Sustainable (2023)

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