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Sensing the future: The role of sensors and 5G connectivity in the metals industry

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Introduction

Metal production within the manufacturing sector

The manufacturing sector has undergone significant transformation through automation over the past decade. While automation itself is not new, the mindset around its implementation has generally evolved. Over the decades, automation has evolved into a standardized production tool, empowering manufacturers to achieve greater control over their operations and production processes. By streamlining repetitive, hazardous, and tedious tasks, automated systems may perform a range of functions including load/unload tasks, processing, inspection, assembling, or handling of parts unattended or with minimal human intervention.

Within the overall market landscape, the metals industry stands out as a major benefactor of both automation and other modernization tools. The metals manufacturing industry is marked by a few major global players alongside numerous smaller firms, operating in various segments including mining, smelting, refining, and manufacturing of metal products. The metals industry plays an important role in the supply chain of various sectors such as construction, automotive, aerospace, and electronics, contributing to their growth and development. Demand for metals tends to be driven by global economic growth, industrial production, and technological advancements.

However, the sector also faces several challenges. Volatile commodity prices, regulatory pressures, environmental concerns, and geopolitical uncertainties may frequently affect operations and profitability. In recent years, the industry appears to have been evolving to become more resilient to this volatility through trends in digitalization, automation, and sustainability. Many companies are increasingly adopting advanced technologies to improve operational efficiency, reduce costs, and decrease environmental impact. High labor turnover rates also appear to be driving supply chain automation to reduce the dependency on personnel tenure. This article highlights a few technological advancements that seem to be at the forefront of the evolution of the metals industry.

A rapidly growing sector

The Asia-Pacific smart manufacturing market size is estimated at US$54 billion in 2024 and is expected to reach US$80.38 billion by 2029, growing at a compound annual growth rate (CAGR) of 8.28% in this period. It is closely followed by the North American smart manufacturing market, estimated at US$58.35 billion in 2024 and expected to reach US$80.4 billion by 2029, growing at a CAGR of 6.62% in this period.[1] The automotive and aerospace and defense segments are likely to be the largest contributors to industry growth. These industries tend to place high value on the quality of the metals manufactured earlier in the supply chain, on which they base their manufacturing process.

As one dives deeper into these innovative, technical industries, specialized metals can quickly become a popular topic of discussion. Electrical steel, being one of these examples, requires a closely monitored and regulated manufacturing process, with sensors reading values such as temperature during batch annealing, and material thickness during flattening, to ensure it addresses buyer specifications to be used in high-voltage transmission cables in electric vehicle (EV) motors, transformer cores, and batteries.[2] Technological advancements in the manufacturing process within Industry 4.0 have contributed to allowing these specialized materials to be manufactured with much greater efficiency and reliability.[3]

Industry 4.0 and beyond

Manufacturing embraces the principles of the Fourth Industrial Revolution, often called Industry 4.0. This transformative wave is generally marked by the adoption of advanced and affordable sensor technologies, communication platforms, and analytics tools. Through the integration of these tools, manufacturers can gain deeper insights into their operations, potentially leading to enhanced productivity, higher-quality outputs, and improved resource utilization.

Logically following the advancements seen as part of Industry 4.0,[4] there tend to be further stages of industrialization, characterized by a harmonious collaboration between humans and advanced technologies such as artificial intelligence (AI)-powered robots. There may be heavy emphasis on resilience and sustainability, addressing challenges such as climate change and environmental custodianship. Furthermore, there also tends to be a focus on the utilization of advances in operational technology to help ensure a safe workplace. Building upon the foundation of data and connectivity laid by Industry 4.0, one may predict further advancements in information technology, including AI, automation, big data analytics, Internet of Things (IoT), machine learning, robotics, smart systems, and virtualization. By integrating this full stack of industrial technologies, there will likely be smarter, more efficient, and sustainable industrial processes that benefit both businesses and society.

Sensors for manufacturing environments

An overview of sensors
Sensors can play an important role in monitoring the manufacturing process across industries. They can gather data and transmit it to central cloud computing systems for analysis, facilitating the implementation of Industry 4.0 practices. Both human and computer-based decision-makers may access and track these results, leading to informed decision-making. Intelligent sensors tend to be highly versatile and can find applications across many different sectors. Industry 4.0 metals manufacturing facilities utilizing a closed-feedback loop of pyrometers, inductive feedback switches, and infrared sensors may experience a dramatic improvement in not only quality of materials produced, but also overall operating efficiency.

Sensors for machine monitoring
As the following case study explores, sensors may be used in specialized applications to monitor and understand the "normal state" or "signature" of an output or the whole machine. This signature may then be monitored using algorithms able to understand digital nuances at a much higher rate than humans, that may, in turn, provide feedback to the machine operators and maintenance crews and allow them to predict maintenance before critical failure. Other sensors, like pyrometers as mentioned above, may monitor product outputs, like hot-rolled steel, and attempt to ensure the output temperature at that stage of the manufacturing process addresses specifications. If the data begins to trend toward a specification limit, a control algorithm may take that trending data, convert it into control modifications, and route it back into the machine controls. When utilizing more accurate sensors, and higher-performance control algorithms implementing AI and machine learning techniques, this loop may become tighter and tighter, further improving quality and output with each iteration.

Applications in industry: A metal manufacturer
The benefits of specialized sensors monitoring the manufacturing process may be readily seen in industry. One of Europe's largest steelmaking sites required a system to monitor 100 conveyor rolls. The extreme environment in which the rolls operate presents a significant challenge in reliable operation. The combination of high heat and cooling water can accelerate wear and tear, and can make it difficult to conduct regular inspections or directly install sensors on the equipment.[5]

A monitoring software provided continuous insight into the health and performance of the rolling mill through electrical signature analysis (ESA). ESA analyzes current and voltage data of electric-driven motor systems using sensors installed in the motor control cabinet, rather than directly on the asset.[6] This approach allowed continuous monitoring of assets operating in extreme temperatures and hard-to-reach locations. As a result, maintenance teams could proactively address developing faults and prevent unexpected breakdowns.

During the initial months of the pilot, the system successfully identified several critical faults, such as mechanical unbalance and bearing degradation, at an early stage. This allowed the metal manufacturer to proactively replace the affected machines before they failed, thereby preventing unplanned downtime and associated costs. Encouraged by the pilot's success, the manufacturer expanded the implementation of the system and integrated it into its maintenance process.[7]

The journey from discrete to interconnected
Sensors may be formidable tools on their own, but when used in a networked system, they may provide an exponentially more colorful image of the manufacturing environment. Not only may each sensor type independently read its own metrics, but multiple sensor types may act as a system of checks and balances to both test cross-sensor data and provide a more holistic "environmental image" around when a data point is taken. The transition from a discrete sensor feedback system into a multi-sensor whole-environment-monitoring array utilizing several types of process feedback may prove to be an important asset in advancing to a more efficient and accurate manufacturing process. It should be noted, however, that the scaling of sensor systems cannot be done without the support of the network systems that tie them together. Attempting to scale sensor arrays without a modern approach to connectivity may bring unwanted costs and issues; therefore, it is important to consider the entire structure of the manufacturing network when implementing these sensor systems.

Connecting the dots: 5G on the factory floor

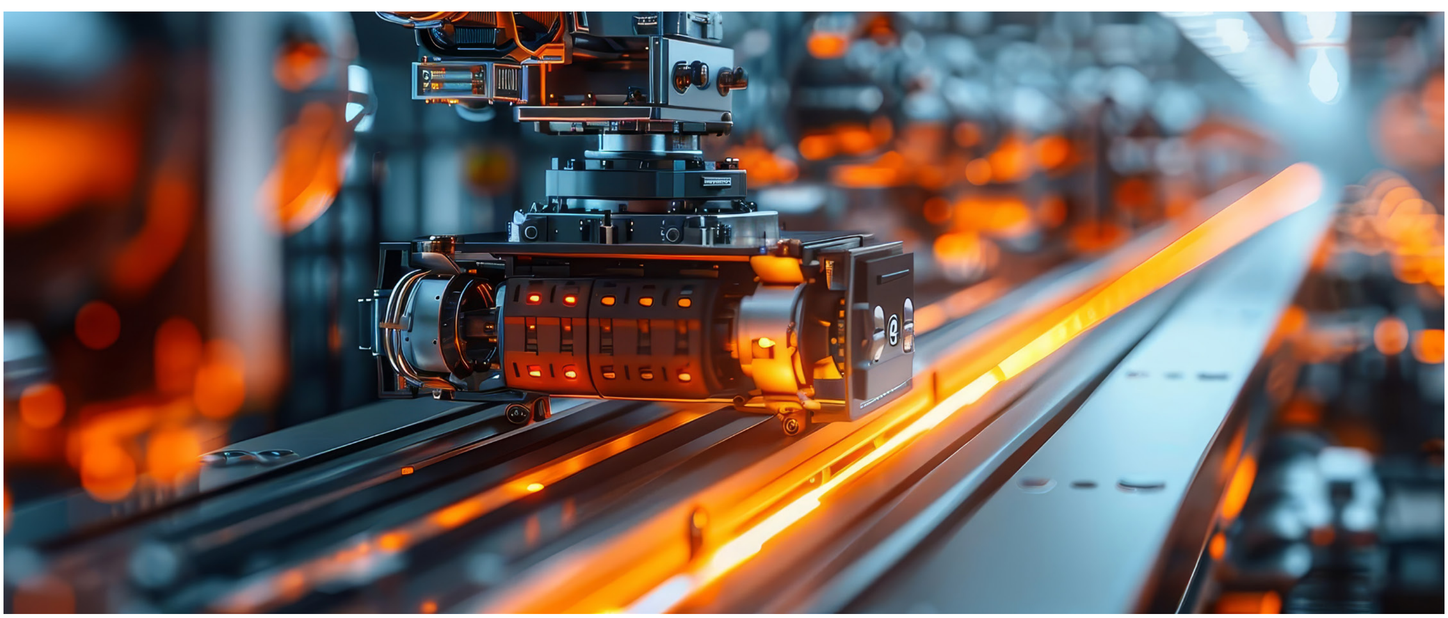
Implementing advanced sensors that require a high data throughput across modern large-scale factories is no small feat. Outdated networks and interfaces may become a significant bottleneck in both costs to scale and overall monitoring ability. Modern 5G connectivity and an IoT approach to connecting these modern sensors may provide both a palatable cost and a secure solution to get data from the machine to the controller, and back again.

The term "Industrial Internet of Things" (IIoT) differentiates manufacturing devices from consumer devices, yet the core concept remains the same. IIoT devices are wirelessly connected to internal networks and the global internet. These devices mark a new era in automation by gathering vast amounts of data from multiple facets of a process and transmitting it to a central server. This data flows into advanced analysis and action, leading to enhanced efficiency and productivity that were previously unattainable.[8]

Incorporating IoT technologies is a foundational aspect of Industry 4.0 initiatives, and their implementation can take various forms. A prevalent approach is the adoption of a smart factory strategy, where sensors and interconnected equipment communicate and exchange data to facilitate real-time improvements. This is made possible by the deployment of high-speed 5G networks, facilitating rapid data exchange, coupled with careful cybersecurity measures to safeguard connections.[9]

At large-scale manufacturing operations commonly seen in the metals industry, latency can become a concern, and the cost of scale increases exponentially without reliable wireless communication. Cabling a factory floor through legacy point-to-point cabling methodology is not conducive to an IoT approach to data acquisition, as each added sensor can incur much more cost than just the sensor itself. And even with legacy wireless solutions, high latency and low bandwidth can cause delays in the information from sensors. These delays may compound exponentially as it propagates from data to control across a closed-loop feedback supervisory control and data acquisition (SCADA) system.[10]

Advanced artificial intelligence software can leverage this data and utilize machine learning to autonomously specify workflows based on historical and predictive trends, minimizing downtime and alleviating bottlenecks. These examples highlight how IoT can provide leading practices through innovation and reshaping operational paradigms across numerous facilities.[11]



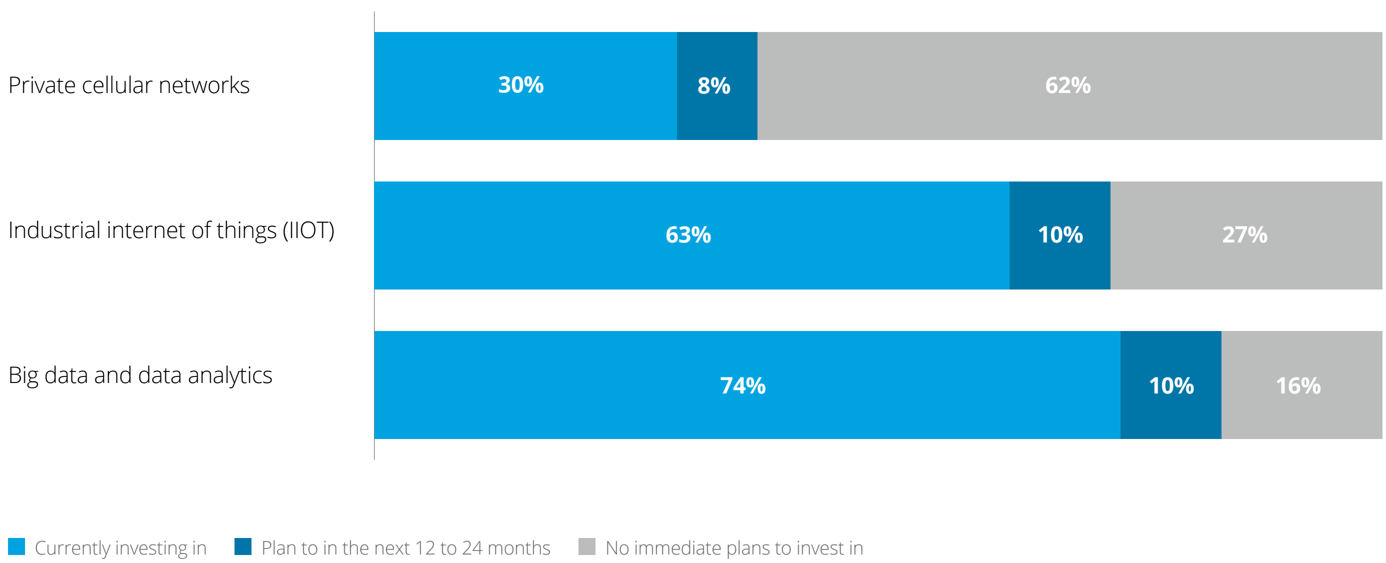
Looking forward

As seen in the subsequent example, sensors and connectivity may play a pivotal role in the modernization of the metals industry, allowing for previously disjointed systems to work more closely together and provide a mesh of reliable materials production. Between June and July 2023, Endeavor Business Intelligence and IndustryWeek, representing Ericsson, conducted a survey of more than 100 manufacturing industry professionals. These professionals were employed by companies with annual revenue exceeding US$1 billion. Notably, almost half of these respondents work for companies that generate more than US$10 billion annually. The question was asked: “Which of the following technologies are you currently investing in or do you plan to invest in?” An excerpt from the study is represented in figure 1.

In addition, a 2022 survey conducted by ABI Research and Nokia, which included more than 1,000 manufacturers, revealed that 90% are contemplating the adoption of 4G/5G private wireless technologies. The primary motive behind this consideration is to enhance the flexibility and agility of their operational processes.[13]

These trends may be interpreted as indicators that change is not coming; it is already here and actively shaping the way the metals industry creates many of its products and innovates its processes. Some players across the industry are working with technology partners to implement innovative sensors, next-gen control systems, and connectivity approaches faster than those available previously. The technical options to improve the manufacturing process appear to be broader than they have ever been before, and this trend of rapid growth in the metals sector is not likely to end anytime soon.

Figure 1. Endeavor Business Intelligence and IndustryWeek survey: “Which of the following technologies are you currently investing in or do you plan to invest in?”[12]



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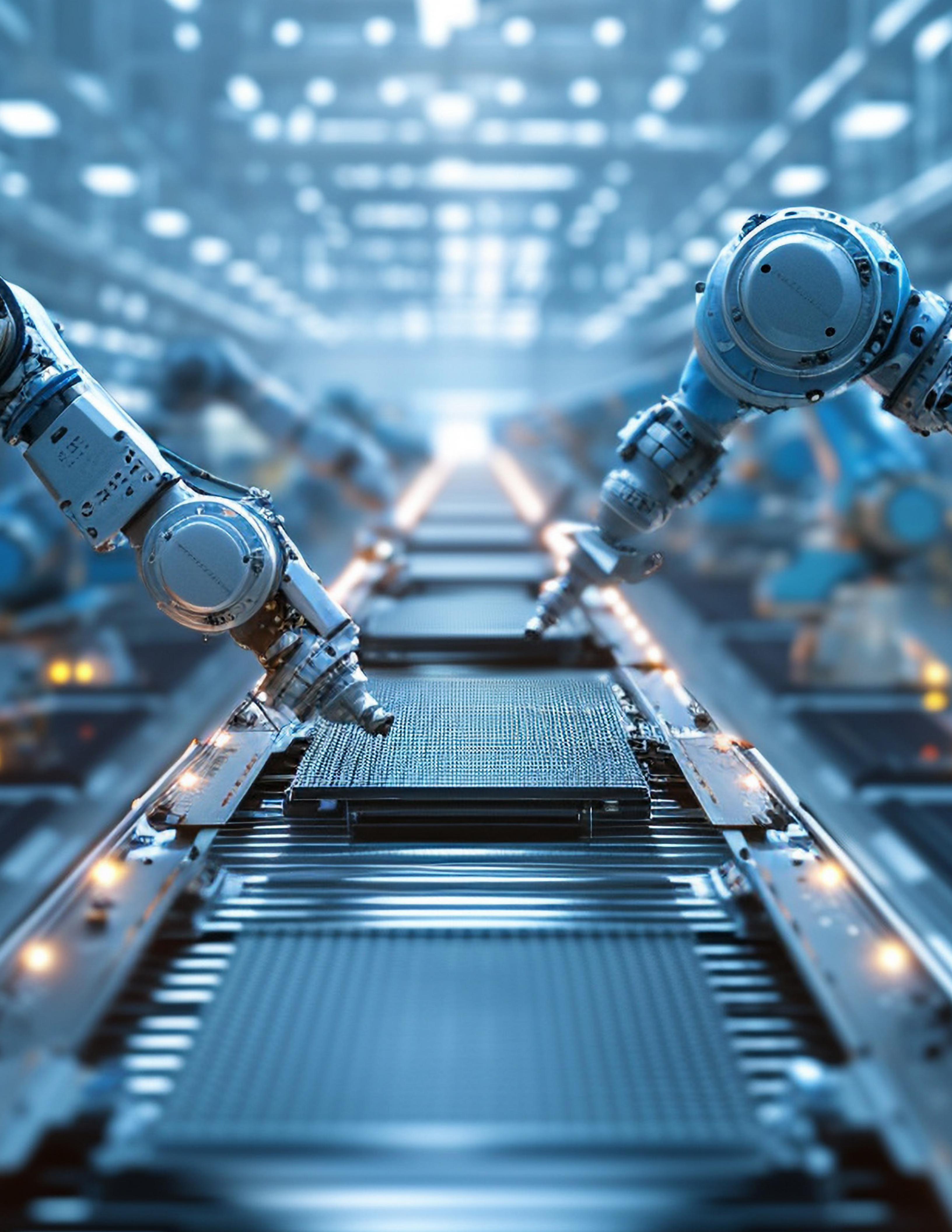

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