Supporting more agile, responsive manufacturing
Manufacturing in a customer-centric world

With productivity growth stalling, manufacturers are looking for more efficient ways to manage supply chains and logistics, create more agile production facilities and empower their workers. Connected sensors, tools and machines (IoT), digital twins, analytics, artificial intelligence (AI) and machine learning show great promise for improving real-time intelligence and control of automated processes and augmenting the performance and decision making of personnel.

Reliable wireless connectivity using 4G/LTE, and 5G in the future, enables the multiplication of sensors, faster reconfiguration of production lines, control of collaborative automated guided vehicles (AGVs) and other moving assets, as well as mobile connectivity for everything from handheld tools and control interfaces to asset tracking. To support the increased data from these connected devices, manufacturers need a multi-cloud architecture to store, correlate and analyze data for increased intelligence and insight, as well as sufficient reactivity for managing the performance and decision making of personnel. We call this the Future X architecture for the agile, responsive manufacturer. We are committed to helping manufacturers build this smart foundation and, in this way, realize their goals for taking manufacturing to the next level.

Nokia and manufacturing

Nokia is a global leader innovating the technologies at the heart of our connected world. We understand that smart, dynamic networks that connect things and people will be the foundation for the digital transformation of society, including our manufacturing sector. The Nokia Bell Labs Future X architecture is a connected, digital platform that supports and fosters new applications and services for greater productivity and innovation, richer experiences and enhanced quality of life.

As a leader in manufacturing communications, we believe that building this dynamic, connected platform is the best starting point for achieving smarter, more agile production facilities and better

AI and machine learning show great promise for improving real-time intelligence and control of automated processes and augmenting the performance and decision making of personnel.
Consumer expectations are increasingly out of sync with old-style, mass production. Manufacturers and their supply chains are directly implicated, looking for a new level of agility and predictive abilities to bolster their just-in-time (JIT) manufacturing to more accurately map to rapid shifts in consumer demand. Fortunately, many manufacturers are already highly automated. The use of assembly line robotics and automated ground vehicles (AGVs) tends to be tied, however, to static workflows. The next generation of industrial automation, sometimes called Industry 4.0, promises to optimize production for more agile workflow changes, quickly shifting constellations to match new requirements, even for small batches or fast changeovers.

This agility and freedom of movement requires robots to become more context-aware, reducing the force and scope of their movement when in close proximity to workers. AGVs must become more autonomous, capable of greater interactivity and open-path navigation similar to self-driving vehicles. Using and sharing output from their on-board cameras, sensors and processors, they will respond more collaboratively to other workers, other AGVs or unexpected changes.

Analytics can be applied to the data coming from workers, sensors, assembly line machines, robots and AGVs to help managers better understand how the production line is performing, to set and monitor tolerances, and predict maintenance issues before they occur. It can also be used to set historical baselines for new product introductions and changeovers and what velocities can be expected. Machine learning can also help to identify issues with standardization, process variability and data lacunae — spots in the workflow where they may need to put more sensors to gain increased insights.

Connecting workers to the cloud can also improve their safety, efficiency and productivity. Hand-carried, smart tools can be connected to the cloud, measuring parameters such as torque and placement precision, providing immediate feedback to the worker. When paired with augmented

| 35% | Additional revenue |
| 43% | Lower costs |
| 56% | Efficiency gains |

Context-aware robots in logistics processes produce efficiency gains of 5% to 10% in picking and 15% to 20% reduction in travel time.

Percentage of industrial companies (globally) expecting more than a 20% gain over next 5 years in:

1 Source: PWC Global Industry 4.0 survey, 2016.
For all the previous innovations to happen, everything on the factory campus needs to be connected, preferably wirelessly. Most manufacturers are already using advanced digital technologies for their automation, yet they rely on Ethernet and Wi-Fi to connect devices and processes in their plants. While Wi-Fi is fine for day-to-day business connectivity, it does not provide a sufficiently secure and reliable industrial-grade mobile network. 4G/LTE, and 5G in the future, will be required to provide the robust connectivity required to control collaborative AGVs, robots and other moving assets. Wi-Fi does not allow for hand-off between cells, so AGVs would lose connection for several seconds when moving between Wi-Fi zones. Creating greater agility, such as fast reconfiguration of production lines, will also require improved mobility, as well as connectivity for everything from mobile workers armed with smart tools and wearable sensors, to asset tracking from the warehouse to the factory floor.

This more robust wireless network needs to be paired with a high-performing, software-defined network for maximum flexibility and scalability. It will also require a distributed cloud architecture and intelligent systems for sensor and device management, digital operations, as well as analytics and machine learning. This is the platform for tomorrow’s responsive, agile manufacturer.

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<th>2025 Economic Impact of the IoT in $B^2</th>
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**Expected cost reduction from Industry 4.0 by 2020**

- **Industrial manufacturing**: 3.6% - $52 billion
- **Predictive maintenance enhanced by AI**: Asset productivity increases up to 20%, Maintenance costs reduced up to 10%

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2 Source: McKinsey Global Institute  
3 Source: PWC Global Industry 4.0 survey, 2016  
4 Source: McKinsey, Smartening up with Artificial Intelligence (AI), April 2017 and MGI “A future that works,” January 2017
The Nokia Bell Labs Future X architecture for manufacturing provides an intelligent, dynamic communications and cloud-based platform as its foundation. This smart network fabric will interconnect all of the individual systems, processes and activities, and provide integrated analytics, machine learning and digital support for innovative new applications and services.

At the deepest level of the Future X architecture lies dedicated universal broadband connectivity, both wireless and wired, making every kind of communication and information exchange possible. Built with a dynamic mesh fabric around a high-performing IP/optical core, it uses 4G/LTE access today (and 5G tomorrow) to connect with robots, sensors, inventory tracking, smart tools and self-driving vehicles, all securely and with the highest reliability.

Cloud technology is essential to the Future X architecture, ensuring the flexibility, scalability and universal availability of both data and intelligence. Placed throughout the network fabric, local and distributed edge clouds ensure
the ultra-low latencies required for video analytics, immediate robot responses and AGV navigation. Cloud-native, software-defined networks dynamically allocate capacity when and wherever it’s needed — whether to support massive digital twin files, augmented reality or on-floor video consultations.

Built into the Future X architecture are data processing capabilities and analytics, including machine learning and AI systems. These ensure that, out of the ocean of data about assets, processes, environment and workers, relevant and actionable insights can enable greater efficiencies and productivity. Analytics, sensor and device management, digital operations and machine learning provide open, digital value platforms that can be harnessed by any kind of manufacturing application.

At Nokia, we believe this Future X architecture will help manufacturers to make their already highly automated facilities even more agile and responsive. They will be able to achieve new levels of safety, productivity and efficiency and respond quickly to the opportunities of an increasingly customer-centric world.

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Use cases for manufacturing:

Environmental sensing and monitoring
Dust, gas, CO2, water and other hazardous materials can affect workers’ health, the outside environment and production quality. Their presence can also be an early warning for incidents such as fires, explosions and flooding that can lead to serious material losses, at minimum, and human lives, in the worst cases. Smart sensors not only identify these hazards, but can provide context as well, logging time stamps, location coordinates and the associated assets. Analytics programs can sift through sensor data to prioritize and even predict developing situations, and send alerts to the appropriate personnel for further action.

Collaborative AGVs
Robust wireless coverage now allows AGVs to become more autonomous and collaborative, using open-path navigation similar to self-driving vehicles. Memorizing the characteristics of the larger space, vehicles can use stored images and sensor data to position themselves relative to natural features, rather than embedded inertial navigation points, tape or wire. No longer limited to pre-programmed paths, they cannot be blocked by a broken AGV or misplaced load. They are able to respond more collaboratively to other AGVs to share the workload, and they can move more quickly having the ability to literally “see around corners” to avoid obstructions and workers. No longer does the factory or warehouse have to adapt to the pre-programmed AGV path, the AGV adapts to the context — even as it changes.

Agile production: smart machines, tools profiling and reporting
Sensor data from machines has long been used to monitor for faults and failures. With emerging technologies, machines can now monitor the environment for humidity and dust to ensure production quality. They can also self-predict and self-heal, using analytics programs that log and analyze data against historical profiles. Machine-learning algorithms use the data to adjust systems for peak performance or trigger maintenance before faults occur. Insights can then be shared across similar production facilities, but for maximum efficiency and lowest latency, these processes are best handled locally, using mobile edge computing (MEC). The use of wireless connectivity means that production line elements such as robots, machines and test equipment can be easily reshuffled to deal with the next production batch.

Hub optimization
Manufacturing execution systems (MES) and digital supply network stacks act as a layered hub for data gathering, analysis and decision making. These data hubs can be optimized with additional data from IoT sensors, enterprise resource planning (ERP) and inventory systems, and by adding cognitive analytics, AI and machine-learning capabilities. The optimized hub requires MEC processing and edge clouds because of the ultra-low latencies involved, and needs to be supported with software-defined and virtual network technologies for a programmable network fabric using high-performing IP/optical and 4G/LTE wireless technologies.
Customer case story:

Nokia Oulu factory

The Nokia Oulu factory, located close to the Arctic Circle, is a showcase for smart manufacturing methods. Built to achieve ambitious sustainability goals, it is also the home to research and development activities, as well as manufacturing. The Conscious Factory, as it is known, acts as a benchmark location for Nokia’s work on the factory of the future, implementing and trialing Industry 4.0 technologies that incorporate data analytics, sensors, smart tools, robotics and AGVs for improved safety, efficiency and productivity. It integrates the full product lifecycle from design and manufacturing, to distribution, services and disposal. This full lifecycle integration enables Nokia, for instance, to develop products optimized for robotic assembly and disassembly.

Nokia uses 4G/LTE for robust connectivity between sensors, robots and AGVs, and has already trialed 5G, which will enable even more advanced use cases. For instance, research is underway on how 5G can be used for 4K-based video analytics for manual assembly and pre-emptive quality control. This private 4G/5G campus HetNet enables Nokia to take full advantage of new flexibilities and capabilities, such as machine learning, AI and widespread automation, to efficiently transform manufacturing operations.
As a leader in manufacturing communications, we believe that the Future X architecture is the best starting point for achieving more agile manufacturing processes with greater use of 4G/LTE, sensors, automation and machine learning. Nokia is well placed to support manufacturers with many years of experience in the sector and the most complete portfolio of products and services to support your Industry 4.0 transformation.

Complementing our portfolio of manufacturing solutions, Nokia also contributes its professional services to help you leverage your technology platforms for significant transformation and growth. Bell Labs Consulting will help you with planning for the future and understanding the business case benefits of new technologies using a structured methodology for establishing quantifiable outcomes for your manufacturing operations.

networks.nokia.com/industries/manufacturing
About Nokia
We create the technology to connect the world. Powered by the research and innovation of Nokia Bell Labs, we serve communications service providers, governments, large enterprises and consumers, with the industry’s most complete, end-to-end portfolio of products, services and licensing.

From the enabling infrastructure for 5G and the Internet of Things, to emerging applications in virtual reality and digital health, we are shaping the future of technology to transform the human experience.

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