REPORT

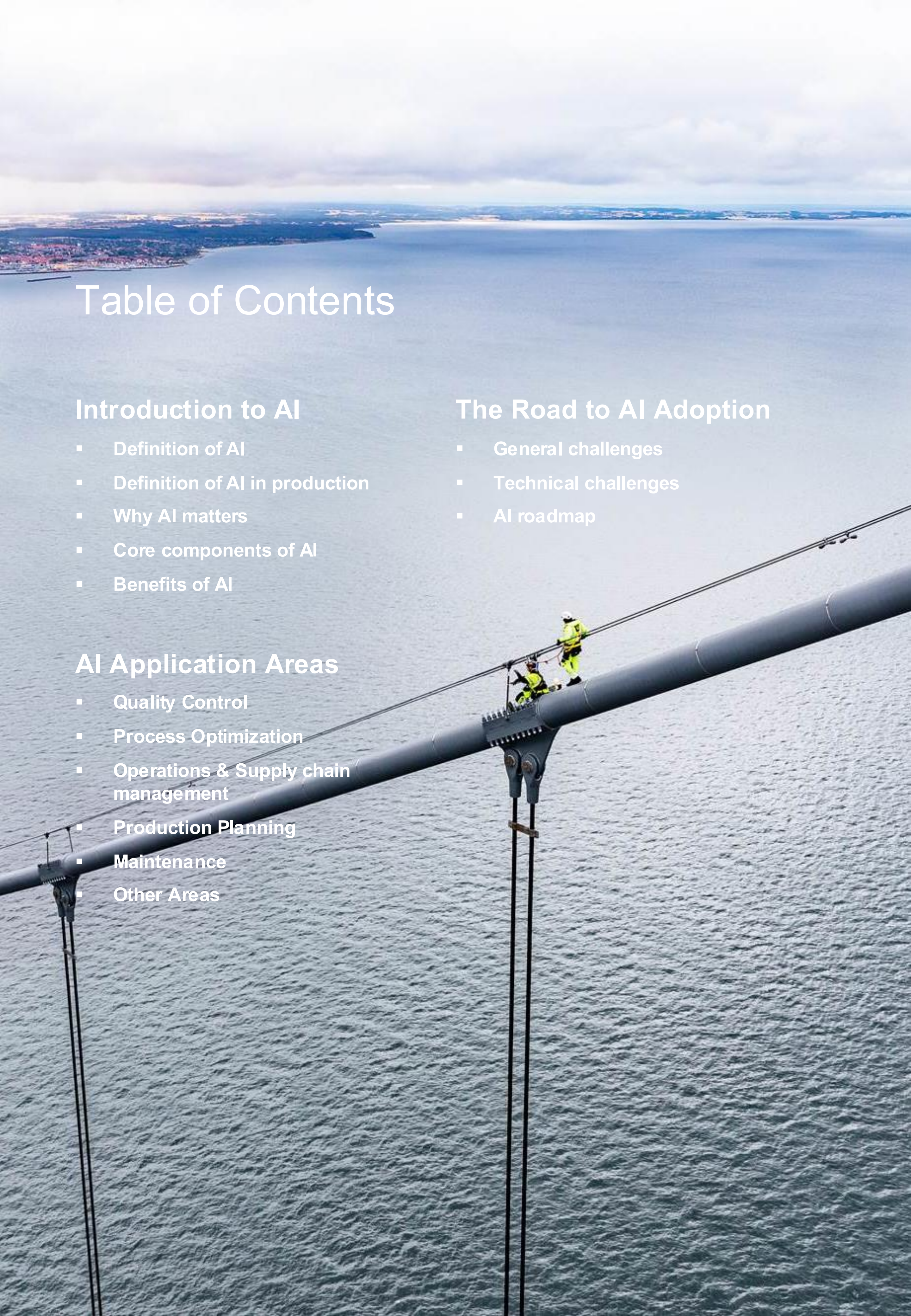
AI in Production

Exploring how Artificial Intelligence can transform your production

August 2025

Preface

In recent years, Artificial Intelligence (AI) has emerged as a transformative force for production/manufacturing companies, driving significant improvements in efficiency, precision, and decision-making across various industrial sectors. This report aims to equip companies with a practical overview of key application cases in production and their potential benefits. The content is based on a collection of AI solutions, encountered in real-world scenarios, supplemented by case studies that illustrate how organizations are leveraging AI to enhance their production processes. By sharing these findings, informed decision-making and strategic adoption of AI in production environments are expected to be gained by the companies.



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Definition of AI

From the EU Artificial Intelligence Act:

"AI system' means a machine-based system that is designed to operate with varying levels of autonomy and that may exhibit adaptiveness after deployment, and that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments" [1]

The three main functions that describe how AI works are:

- **Learning**; AI uses data to identify patterns and improve over time
- **Reasoning**; AI makes decisions based on the data it analyzes
- **Self-Correction**; AI refines its processes to increase accuracy and efficiency

Definition of AI in Production

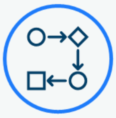
AI in production refers to the application of artificial intelligence (AI) technologies in manufacturing and industrial processes or systems to enhance efficiency, accuracy, automation, and decision-making.

AI enables machines and systems to analyze vast amounts of data, learn from patterns, and make intelligent decisions with minimal human intervention. In production environments, AI can be used in quality control, process optimization, operations & supply chain management, production planning and maintenance.

Why AI matters

AI isn't just automation; it's about making systems smarter, more adaptable, and capable of handling complex production challenges.

AI can provide numerous advantages, such as transforming traditional manufacturing into smart, efficient systems, improving precision and reducing human error through automation. Additionally, it can analyze real-time data and enhance decision-making in production lines. it can facilitate predictive maintenance practices, lowering downtime and costs and optimizing production scheduling and resource allocation.



Quick decision-making

Safety

Efficiency

Increased capacity

Lower costs

Better quality

Introduction to AI

Core subsets of AI

Artificial Intelligence in production environments brings together key domains such as machine learning, computer vision, natural language processing, and expert systems to drive greater efficiency, precision, and adaptability across operations.

Machine learning (ML):
Machine Learning is a subset of AI that enables systems to learn from data. ML algorithms generalize from patterns in data and make predictions. Commonly used in predictive maintenance, quality control, and process optimization in production.

Natural Language Processing (NLP):
NLP is a subset of AI that allows machines to understand, interpret, and generate human language. It is used in AI-driven chatbots, document processing, and human-machine interactions in industrial settings.

Expert Systems:
Expert Systems are decision-making systems that mimic human expertise to solve complex problems in specific domains. They use rule-based logic and knowledge bases to assist in decision-making. Lately, Expert Systems are undergoing a revitalization from the LLM revolution. An example of an expert system is automated production planning based on real-time data.

Computer vision:
Computer vision is one of the most proliferated technologies that fit under the AI umbrella today. As machine learning and deep learning models and methods evolve, so does the complexity of computer vision tasks. From fault detection to product pose estimation, AI-powered computer vision is at the core of many production lines already today.

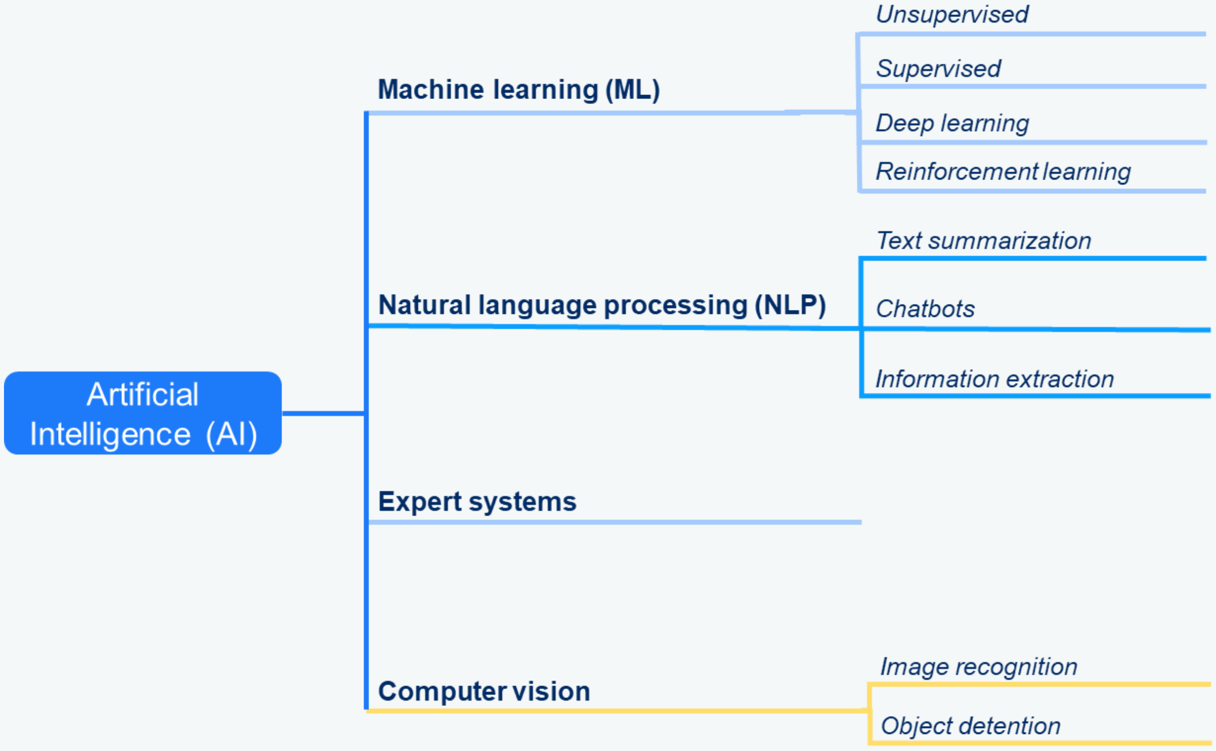


Figure 1. The AI Umbrella

Introduction to AI

Benefits of AI:

The integration of AI in production delivers important cost-saving benefits by enhancing efficiency, minimizing downtime, and optimizing resource utilization by automating processes and/or increasing their efficiency and effectiveness.

AI-driven automation significantly lowers production costs by reducing material waste, improving energy efficiency, and minimizing reliance on manual labour. This is expected to reduce production costs by 15-20% [2].

Through **AI-driven predictive maintenance**, AI enables early detection of potential equipment failures, thereby reducing unexpected breakdowns and maintenance expenses while extending the lifespan of machinery. This is expected to decrease unplanned downtime by 20-40% [3].

Additionally**, AI-powered quality control** systems, utilizing computer vision and machine learning, ensure precise and real-time defect detection, leading to lower defect rates and improved product consistency. AI also enhances inspection speed, enabling rapid, high-precision analysis that surpasses the capabilities of manual inspections. This is expected to reduce defect rates by 49% [4] and increase inspection speed by up to 40% [5].

Finally, the integration of **AI-powered Advanced Production Scheduling** (APS) capabilities significantly enhances the production line capacity by optimizing resource allocation, minimizing inefficiencies, and dynamically adapting to real-time conditions. AI-driven APS leverages machine learning, predictive analytics, and real-time data processing to create dynamic, self-adjusting production schedules that maximize machine utilization and minimize idle time. Lenovo has experienced a 24% increased production line capacity through these technologies [6].

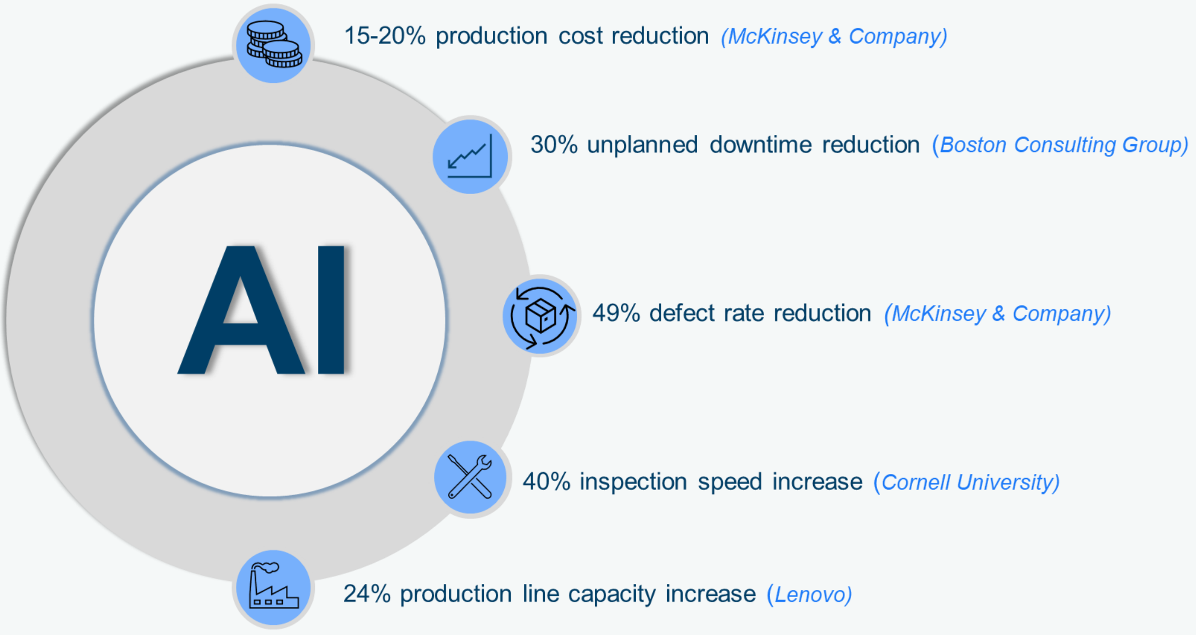


Figure 2. Benefits of AI in production

AI Application Areas

AI Application Areas

Key areas where AI is making a significant impact include quality control, process optimization, operations and supply chain management, production planning, and maintenance.

AI transforms quality control in manufacturing by enabling accurate, real-time defect and anomaly detection possibilities and verifying material (components, subproducts and products) at the different production steps. AI-powered computer vision systems use machine learning algorithms to analyze images and detect defects in products, ensuring precision and reducing waste.

AI also plays a crucial role in process optimization by continuously analyzing production data and identifying opportunities for improvement. AI-powered systems monitor production parameters such as machine performance, process parameters, energy consumption, and material usage, making real-time adjustments to enhance efficiency. This optimization can be applied to the set-up times of machines, training of robots in production, automating tasks and fine-tuning processes.

In operations & supply chain management, production planning, and maintenance, AI enables manufacturers to improve decision-making and responsiveness. The AI-driven demand forecasting models analyze market trends and historical data to predict inventory needs, reducing excess stock and preventing shortages. In production planning, AI-powered Advanced Production Scheduling (APS) optimizes machine utilization, workforce allocation, and material flow to maximize throughput. Additionally, AI-based predictive maintenance helps prevent unexpected equipment failures by identifying wear and tear patterns, reducing costly unplanned downtime.

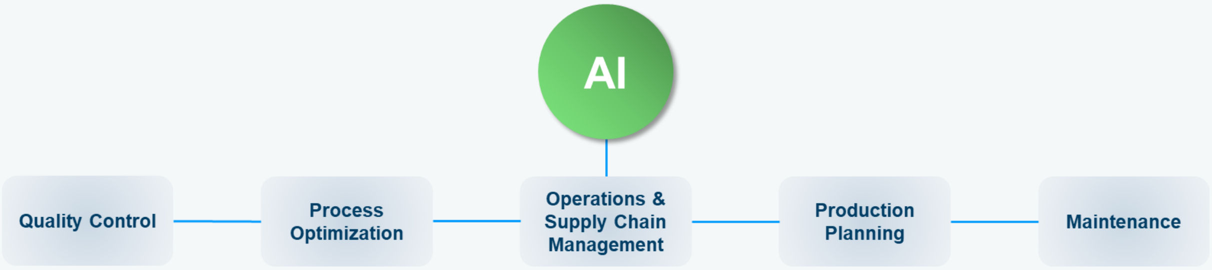
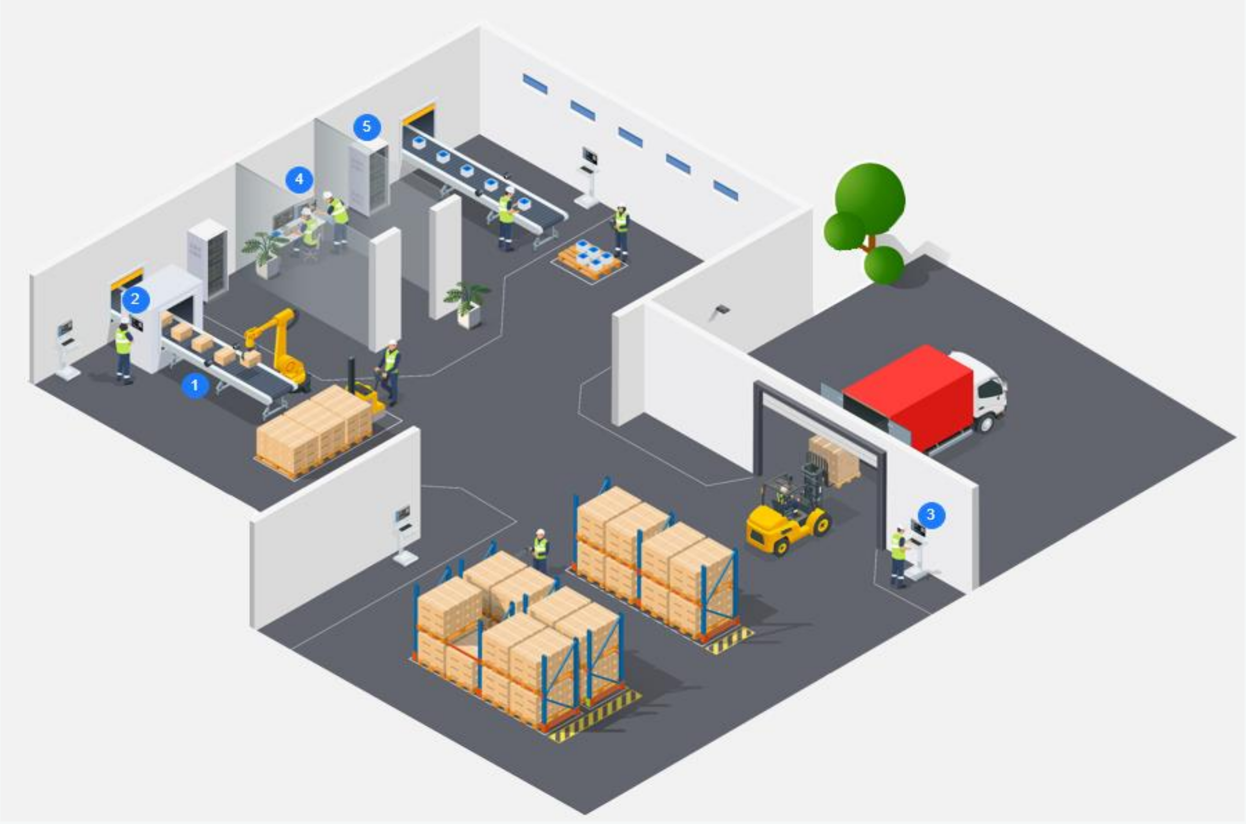


Figure 3. AI application areas in production

AI Application Areas



1 **Quality Control:**
The AI-powered computer vision system inspects each product for defects like scratches, structural weaknesses, and wrong dimensions by analyzing real-time images captured from cameras

2 **Process Optimization:**
The AI-powered system analyzes real-time data from sensors embedded in the machine to detect inefficiencies, and it automatically adjusts the machine speed, pressure and other process specifications to minimize material waste, prevent jams and pursue the optimum

3 **Operations & Supply Chain Management:**
The operator accesses the ERP system, and the embedded AI tool provides the number of trucks that need to be dispatched and the specific cargo that needs to be loaded in each truck

4 **Production Planning:**
The AI-powered production scheduling system analyzes the production demand (orders), resource availability, machine capacity, changeover times, operational constraints and order prioritization data to automatically optimize production sequences, reducing bottlenecks, minimizing downtime, and ensuring timely order fulfillment

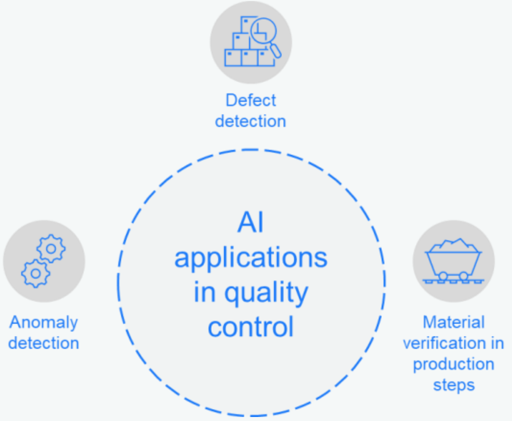
5 **Predictive Maintenance:**
The IoT sensors that are embedded in the production equipment are continuously generating data (vibration, temperature, and pressure levels), which are monitored by the AI-driven predictive maintenance solution. The data are analyzed in real-time data against historical trends and baselines so early signs of wear or anomalies are detected

AI Application Areas – Quality control

Defect detection:
AI technologies enhance defect detection by using computer vision and machine learning to identify issues in products in real-time. This technology allows systems to automatically spot defects during production, improving the accuracy and speed of quality control processes. By detecting problems early, AI reduces the likelihood of defective products reaching the market, ensuring higher product quality and minimizing waste.

Anomaly detection:
AI technologies play a critical role in anomaly detection by analyzing sensor data and operational metrics to spot any deviations from normal production patterns. This allows AI systems to identify irregularities or potential issues that might otherwise go unnoticed, helping prevent equipment failures or disruptions. Early detection of anomalies leads to proactive maintenance and more efficient operations, ultimately reducing downtime and improving overall productivity.

Material verification in production steps:
AI supports material verification throughout the production process by using technologies such as image recognition and RFID data to ensure the right raw materials and/or components are used in each production stage, reducing errors and maintaining consistency. By automating material verification, AI helps improve production efficiency while ensuring compliance with quality standards.



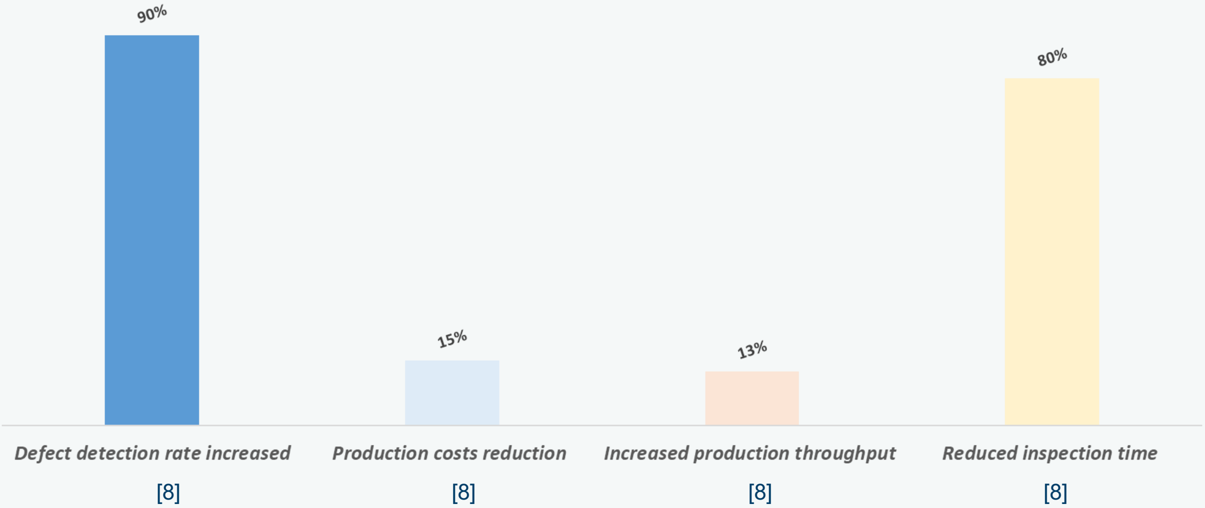


Figure 4. Benefits of AI in quality control

AI Application Areas – Quality control case

Checking the completeness and quality of variant-rich products in trays on a conveyor belt is a typical task for intelligent systems such as computer vision and machine learning algorithms. These systems can quickly and accurately assess multiple variations of products, inspecting each item for defects, missing components, or incorrect configurations. By using high-resolution cameras and deep learning models, AI can analyze visual data in real time, ensuring that each product variant meets the required specifications. Below, the AI vision system assesses the quality of the products flowing on the conveyor belt while simultaneously counting the number of products in each carton box.

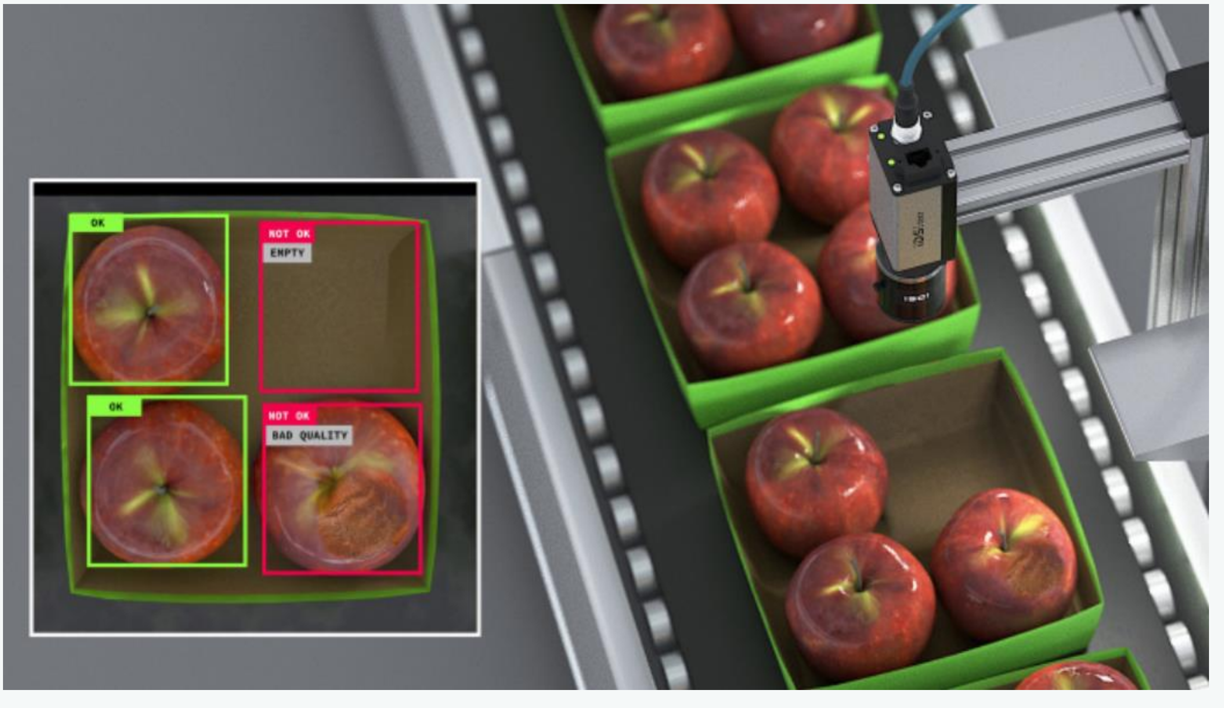


Figure 5. NXT solution by IDS [9]

AI Application Areas – Process optimization

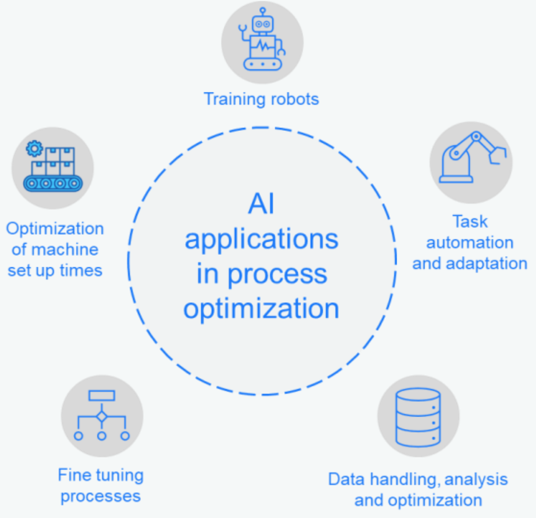
Optimization of machine setup times:
AI technologies enhance machine setup processes by analyzing historical data from past setups and recommending optimal configurations for machines. This helps reduce the time required to set up machines between production runs, minimizing downtime and boosting overall throughput.

Robots training in production:
AI technologies enable robots to improve their performance in production environments through machine learning and real-time sensor feedback. By continuously learning from past actions and adjusting based on the environment, robots can become more efficient at performing tasks such as assembly, packaging, and material handling.

Task automation and adaptation:
AI-driven automation streamlines repetitive tasks within production, contributing to enhanced process efficiency. As production demands and constraints change, AI systems continuously adapt workflows in real-time to ensure optimal performance.

Data handling, analysis, and optimization:
AI systems collect, process, and analyze vast amounts of real-time production data. By doing so, AI identifies patterns, detects inefficiencies, and makes adjustments to improve operational production efficiency.

Fine tuning processes:
AI technologies continuously monitor critical production variables, such as temperature, pressure, and speed, and make real-time adjustments to optimize these parameters. This continuous fine-tuning ensures that production processes run at peak efficiency and allows for a more consistent and controlled production environment.



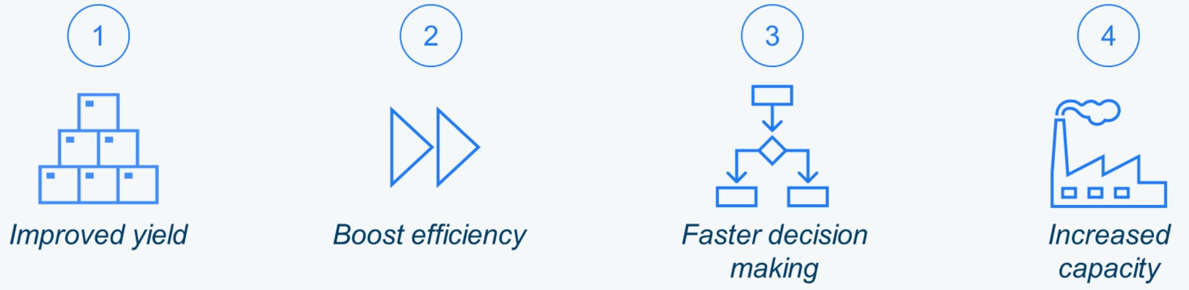


Figure 6. Qualitative benefits of AI in quality control

AI Application Areas – Process optimization case

In the turning process of a steel part, key process parameters such as feed rate, cutting speed, cutting depth, and cutting radius play a crucial role in determining the final surface roughness of the part. To achieve the desired surface finish, these parameters were optimized.

GaussML's Optimyzer solution recommended parameter values to try on the machine. After machining each test piece, the operator provided feedback on the cycle time and the measured surface roughness from the laboratory tests. Based on the results of few experiments, the AI solution adjusted the process parameters to achieve the desired surface quality while leading to optimized machining performance [10].

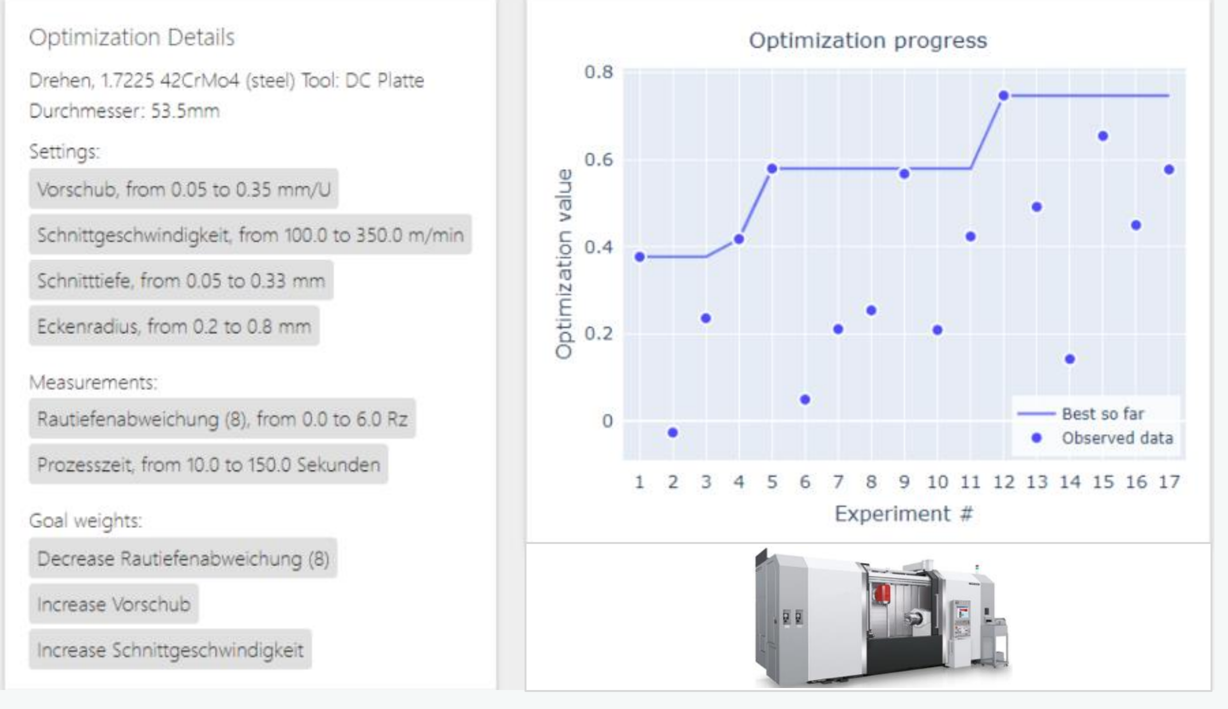


Figure 7. GaussML Optimyzer solution [10]

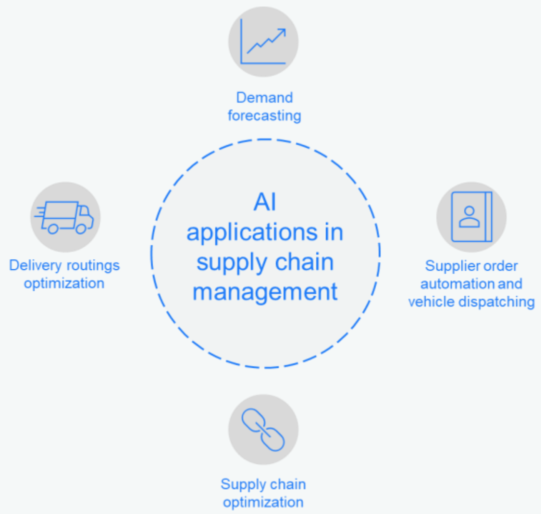
AI Application Areas – Operations & supply chain management

Demand forecasting:
AI technologies enhance demand forecasting by analyzing historical data, market trends, and external factors such as economic conditions or seasonal variations. This enables businesses to accurately predict future demand, allowing for better planning and inventory management. By leveraging AI, companies can anticipate fluctuations in demand, reduce stockouts, and optimize production scheduling.

Delivery routings optimization:
AI technologies optimize delivery routes in real-time by considering factors like traffic conditions, weather, and order priorities. This helps to determine the most efficient paths for deliveries, reducing fuel consumption, delivery times, and operational costs.

Supplier order automation and vehicle dispatching:
AI technologies automate the processing of supplier orders and vehicle dispatch scheduling, streamlining procurement and logistics. By analyzing order patterns and inventory levels, AI ensures that orders are placed with suppliers at the right time, minimizing delays. Moreover, the vehicle dispatches are scheduled based on optimized routes and availability, improving overall supply chain efficiency.

Supply chain optimization:
AI technologies improve supply chain visibility, efficiency, and decision-making by dynamically adjusting strategies for sourcing, inventory management, and distribution. With real-time data analysis, AI helps businesses respond quickly to changes in demand, supplier performance, and market conditions.



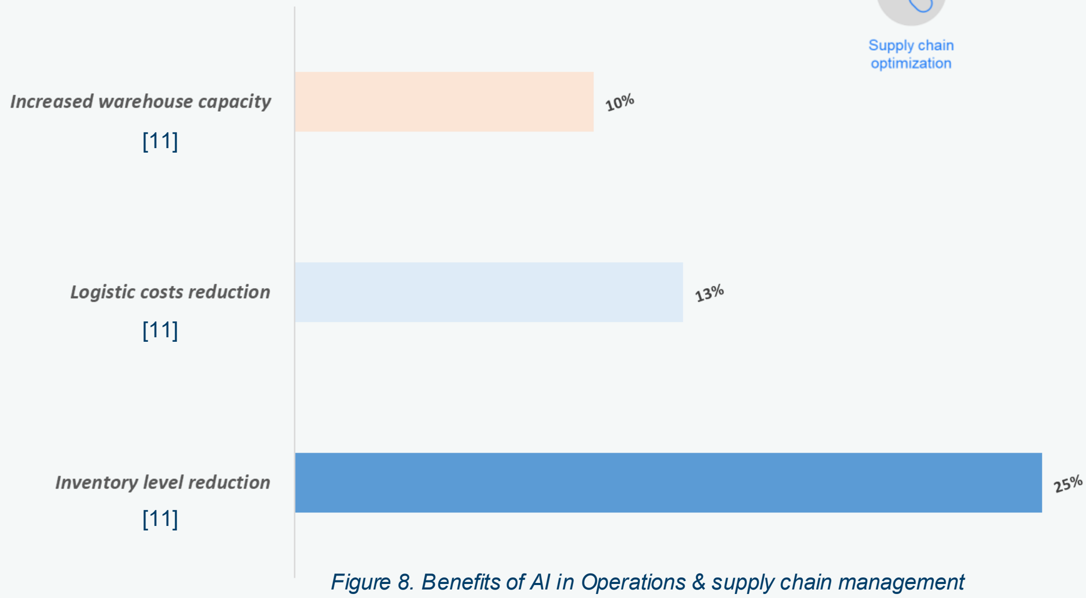


Figure 8. Benefits of AI in Operations & supply chain management

AI Application Areas – Operations & supply chain management case

UPS, a global leader in logistics and package delivery, faced challenges in optimizing its delivery routes. With millions of packages to deliver daily across both urban and rural areas, the company needed to improve operational efficiency while meeting the growing demand for faster and reliable services. Traditional route-planning methods, which relied on human judgment and static data, were insufficient in addressing the dynamic nature of delivery environments, leading to delays, fuel waste, and higher operational costs.

Additionally, the increasing focus on sustainability required UPS to reduce carbon emissions without compromising service quality. The company sought a solution that could adapt in real time to factors such as traffic congestion, weather, and package volumes. To tackle these issues, UPS implemented ORION.

UPS's AI-driven tool, ORION (On-Road Integrated Optimization and Navigation), optimizes delivery routes by leveraging real-time data, including traffic patterns, package destinations, and weather updates. ORION uses advanced algorithms to dynamically adjust routes, minimizing unnecessary mileage and responding to traffic or last-minute delivery changes. The system integrates GPS, traffic monitoring, and weather data to ensure real-time adaptability, reducing idle time and fuel consumption. Additionally, predictive analytics help UPS forecast demand during peak periods, enabling better resource allocation and preventing delays [12].

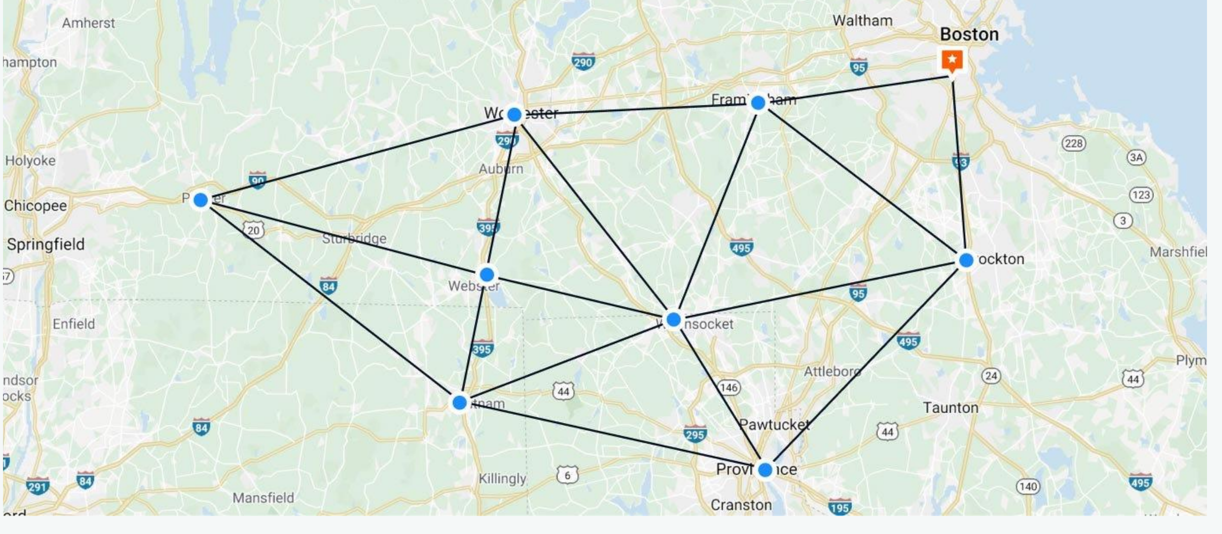


Figure 9. The Travelling Salesman Problem tackled by ORION

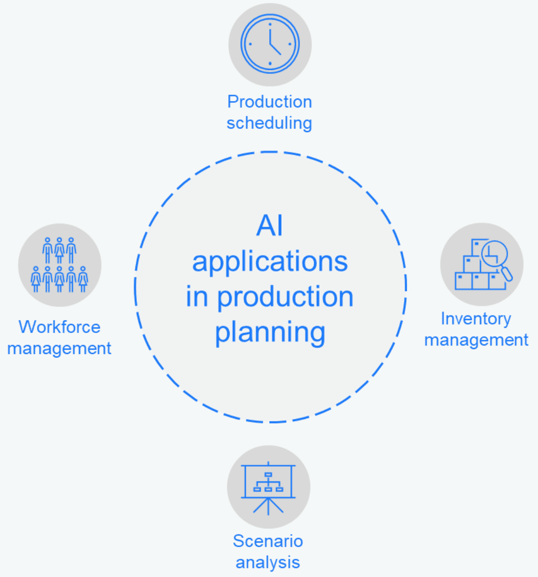
AI Application Areas – Production planning

Production scheduling:
AI enhances production scheduling by dynamically adjusting schedules based on real-time data from machines, workforce, and inventory. This allows production lines to respond quickly to changing conditions, such as machine downtime, inventory shortages, or shifts in workforce availability. AI ensures that production processes remain efficient and aligned with current demands, minimizing delays and maximizing throughput.

Workforce management:
AI optimizes workforce management by analyzing employee skill sets, availability, and production demands to allocate the right personnel to the right tasks. By considering these factors, AI ensures that labor resources are efficiently utilized, helping to meet production targets while reducing idle time. This leads to better productivity and helps avoid over or under-utilization of workers.

Inventory management:
AI improves inventory management by ensuring that raw materials and components are available in perfect sync with production schedules. Through continuous monitoring and predictive analytics, AI anticipates material needs and prevents stockouts or excess inventory. This coordination helps maintain a smooth production flow, reducing the risk of production delays caused by material shortages.

Scenario analysis:
AI supports decision-making through scenario analysis, running what-if simulations based on various conditions, such as changes in demand, supply disruptions, or machine breakdowns. By evaluating different scenarios, companies are prepared for potential challenges, production plans are optimized, and data-driven decisions are made to improve operational efficiency and resilience.



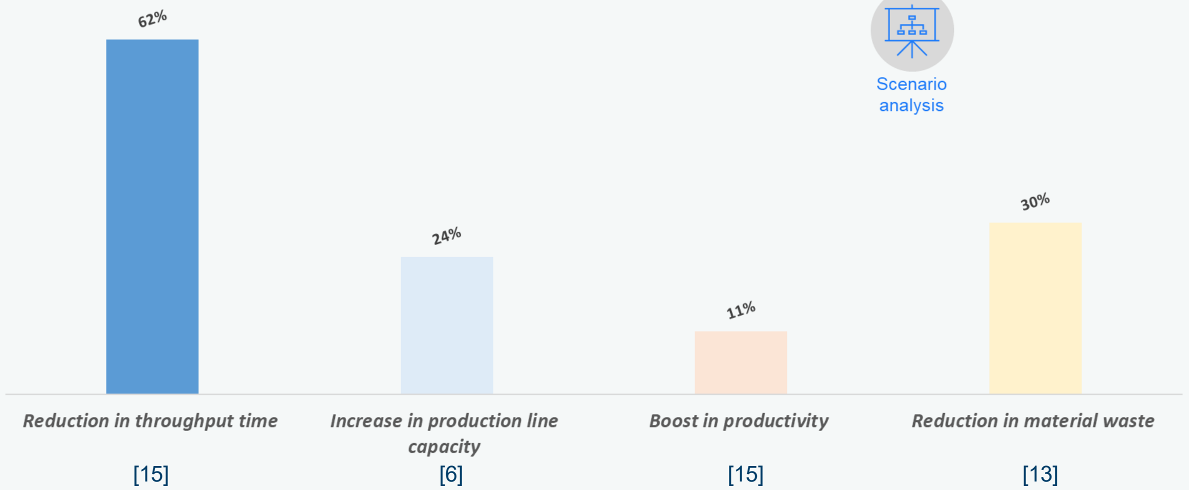


Figure 10. Benefits of AI in production planning

AI Application Areas – Production planning case

Phantasma Lab’s AI-driven planning solution was integrated into the company’s ERP system, and the user interface was adapted to embed the solution within the ERP’s existing environment. In the ERP, users accessed a list of unscheduled orders, where a new button was introduced by Phantasma Labs to run the AI solution. When users pressed the button, Phantasma Lab’s AI planning solution generated a complete production schedule, outlining all operations required to fulfil the pending orders.

This integration addressed limitations in manual planning processes by automating complex scheduling tasks, improving accuracy, and reducing planning time. By embedding intelligent scheduling directly within the ERP, the solution enhanced operational efficiency and ensured a smoother, more responsive production workflow [14].

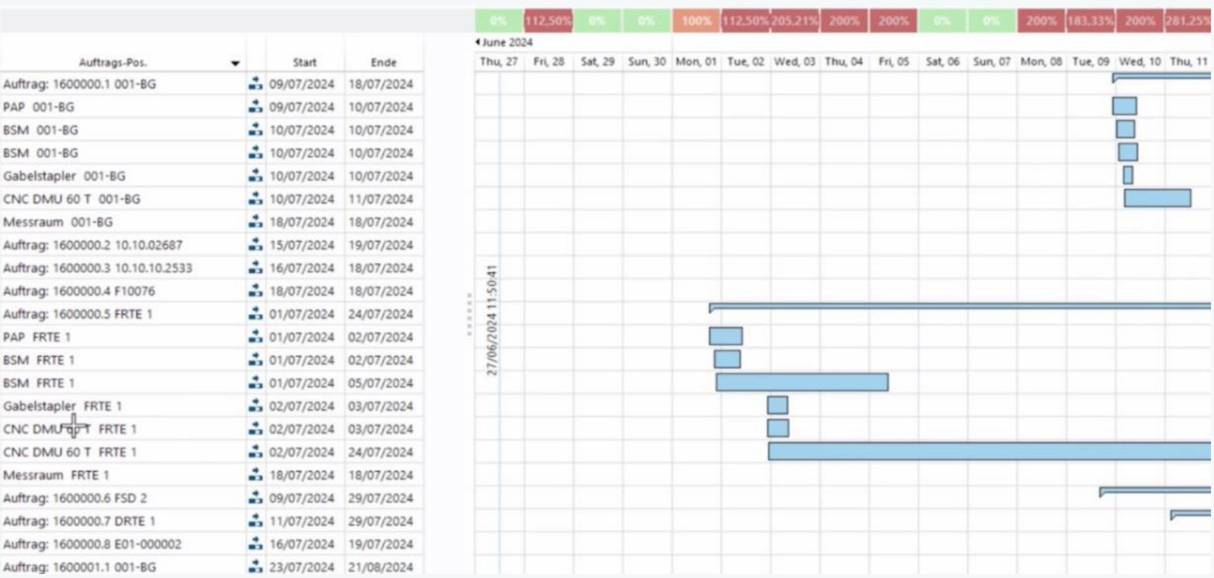
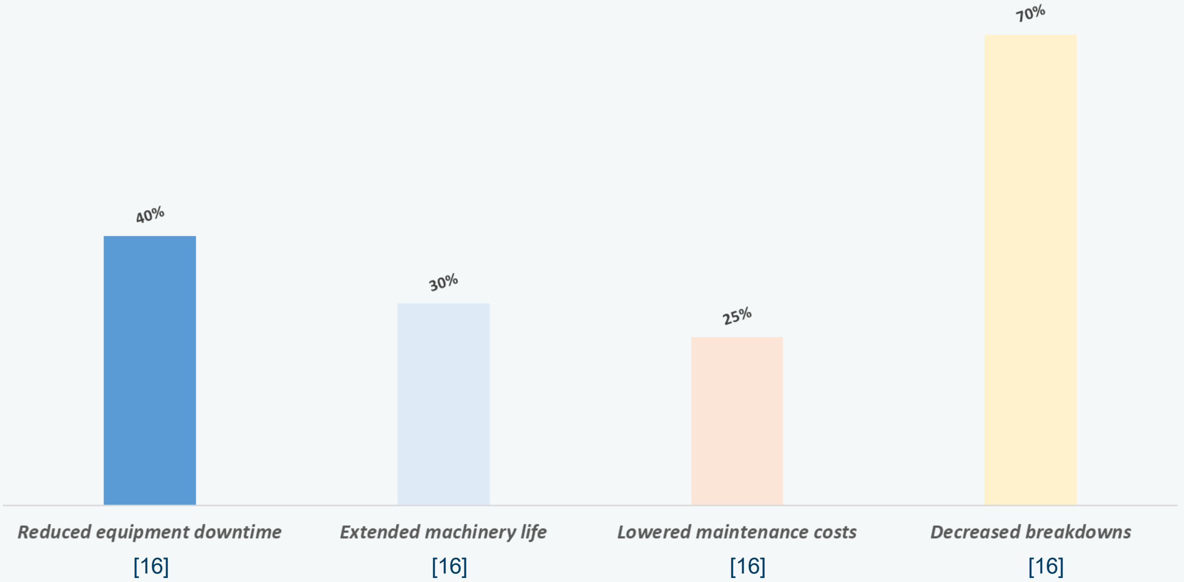


Figure 11. Production schedule generated by Phantasma Labs [14]

AI Application Areas – Maintenance

Predicitive maintenance:
AI-driven predictive maintenance leverages artificial intelligence to analyze real-time and historical data, such as temperature, vibration, torque, speed, current, voltage, and pressure, collected from a range of sources, including IoT sensors, machine data, SCADA systems, PLCs, and maintenance logs. By continuously monitoring equipment and comparing current performance against baseline operational profiles, AI models can identify subtle patterns and early indicators of wear, degradation, or potential failure. These predictive insights enable timely interventions, reducing unplanned downtime. When anomalies are detected, the system can automatically trigger maintenance workflows, such as generating tickets or notifying maintenance teams, to proactively address issues before they escalate.



[16] [16] [16] [16]

Figure 12. Benefits of AI in maintenance

AI Application Areas – Maintenance case

BlueScope Steel, a global leader in steel manufacturing, successfully implemented the Senseye Predictive Maintenance solution by Siemens to shift from reactive to proactive maintenance across its international facilities [17].

Starting with 300 assets on three metal coating lines, the company rapidly expanded its predictive maintenance program, leveraging LoRaWAN networks to monitor critical metrics, such as pressure and tank levels from hydraulic systems (which are indicators for potential leaks or failures) in both modern and legacy equipment. The Senseye cloud-based solution combined AI with human insights and automatically generated machine behavior models to help direct the attention and expertise to the production equipment needed [17].

A success of the project was the early detection of a hydraulic leak, which, without AI-driven monitoring, could have led to costly downtime and hazardous manual intervention. The Senseye PdM system's forecasting and threshold detection enabled real-time alerts, allowing maintenance teams to address the issue proactively, avoiding 24 hours of downtime and ensuring the workers' safety [17].

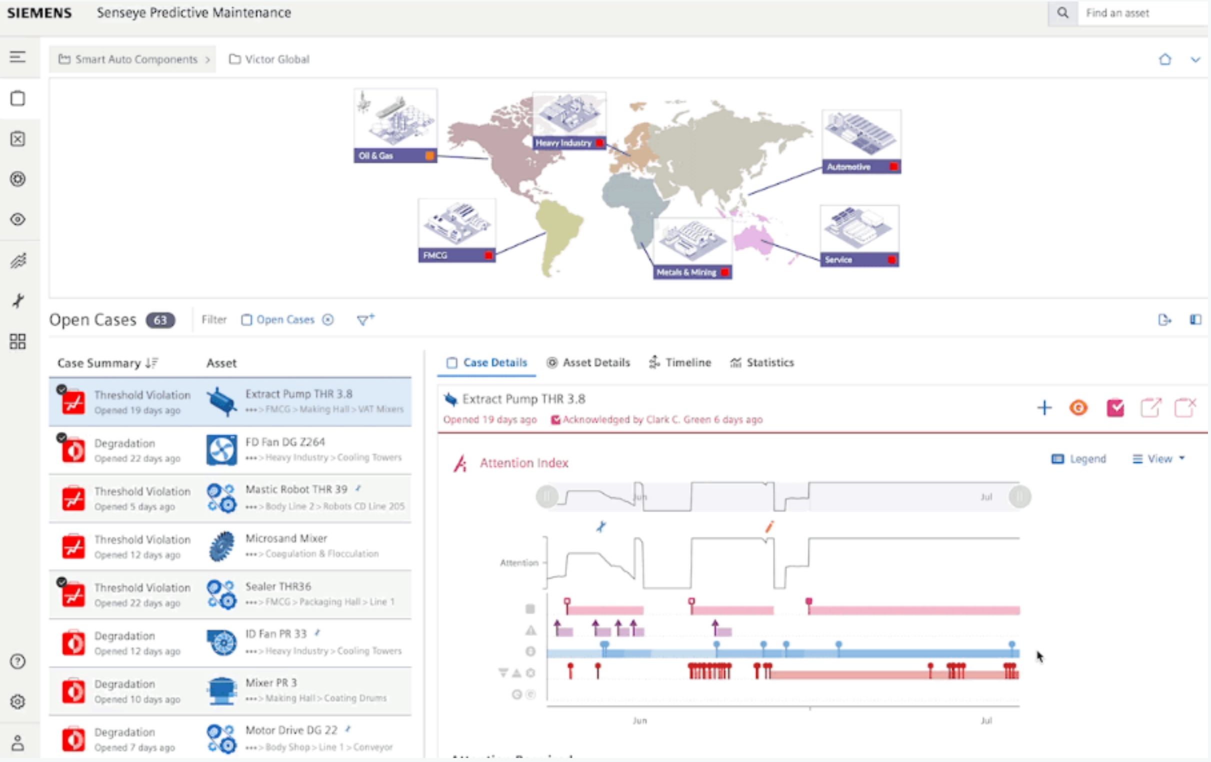


Figure 13. Senseye platform by Siemens [17]

AI Application Areas – Other areas

Workplace safety:
AI improves workplace safety by using computer vision, predictive maintenance, and autonomous safety systems. AI-powered cameras detect potential hazards, ensuring compliance with safety protocols. Worker fatigue monitoring enhances well-being by identifying exhaustion-related risks. With AI-driven safety measures in place, manufacturers can create a safer work environment, reduce workplace injuries, and boost overall productivity.

Product design:
AI technologies enable generative design, rapid prototyping, and advanced simulations through the analysis of design constraints such as material limitations, capabilities in production, performance requirements and costs. Machine learning models help in predicting potential failures, reducing time-to-market and lowering prototyping costs. AI-driven 3D printing further accelerates design iterations, making product development more efficient and cost-effective.

Energy management:
Advanced algorithms and machine learning models optimize energy consumption by analyzing data and usage patterns. This allows for accurate forecasts and improves decision-making. AI-driven process optimization adjusts machinery settings in real time to reduce energy costs by pursuing the optimum every time.

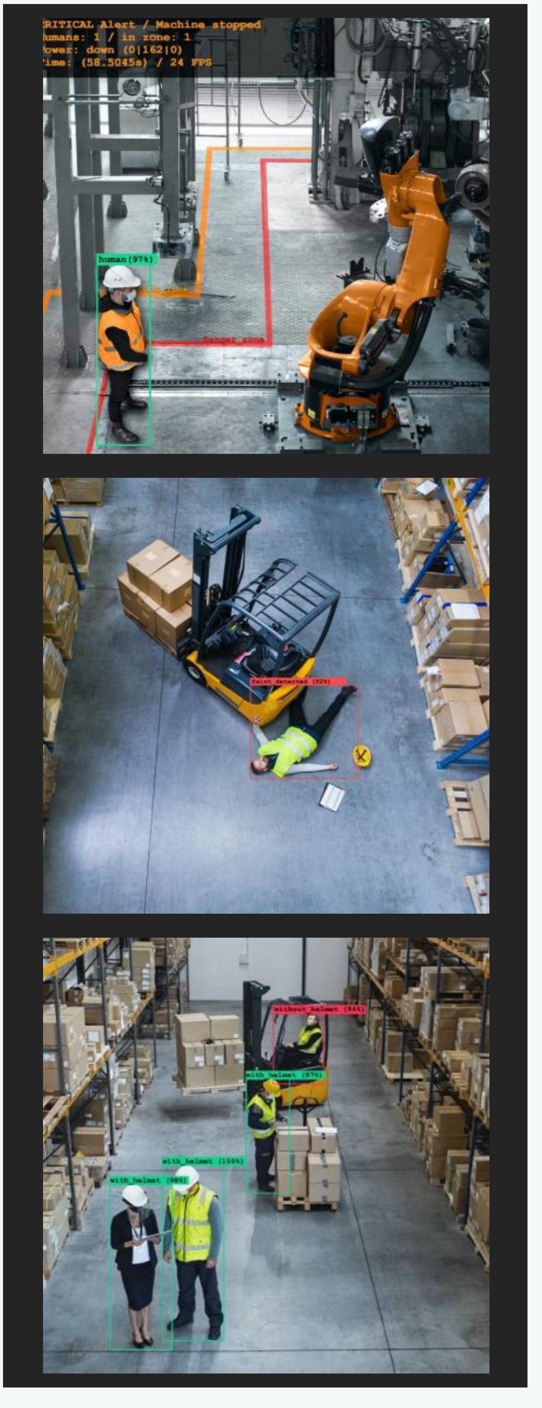
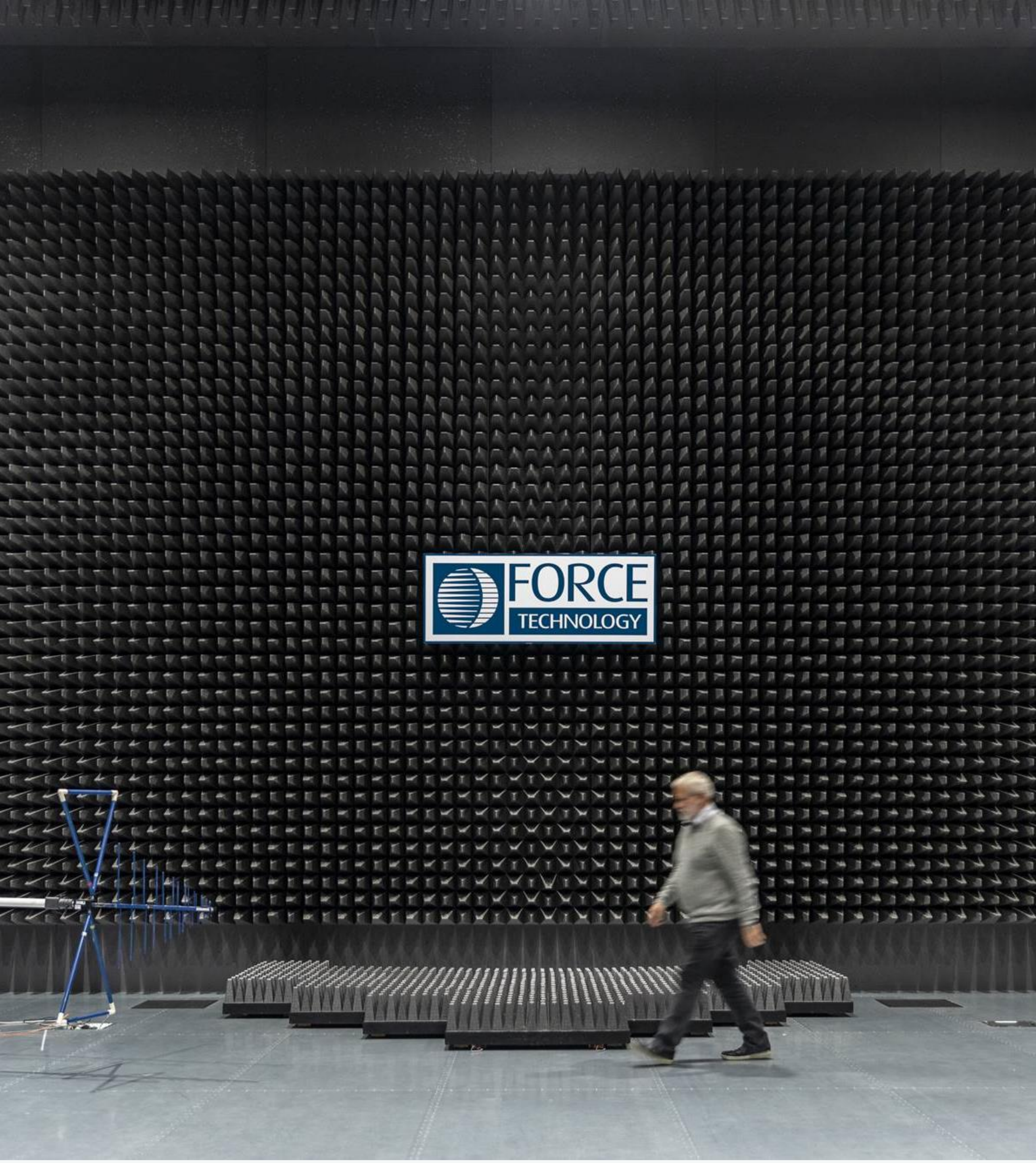


Figure 14. Invanta's solution [18]



The road to AI adoption

AI Challenges

Implementing AI technologies in an organization presents several challenges that must be managed to ensure success. The challenges are broken down into two categories, general and technical.

General challenges:

- **Resistance and cultural change**
  Organizations often face resistance from employees who fear AI will replace their roles or disrupt established workflows, requiring a cultural shift and retraining efforts
- **Poses threat to labor intensive and management positions**
  AI automation reduces the need for repetitive manual tasks and even some decision-making roles
- **Lacks empathy**
  Unlike humans, AI cannot understand emotions, making it unsuitable for tasks that require emotional intelligence, such as customer service or conflict resolution
- **Lacks moral compass**
  AI follows programmed logic and data-driven patterns but lacks ethical reasoning
- **Rapid technological development**
  AI is evolving at an unprecedented pace, making it challenging for businesses and governments to keep up with regulatory frameworks, ethical considerations, and workforce adaptation.
- **Tailored AI (in manufacturing one size fits all does not work)**
  AI solutions must be customized for specific industries and production environments, as generic models often fail to address unique operational needs and constraints

Technical challenges:

- **Data quality & availability**
  AI models require vast amounts of accurate, real-time data. Inconsistent or incomplete data can hinder effectiveness
- **Integration with legacy systems**
  Many factories use outdated machinery that lacks AI compatibility, making integration complex and costly
- **Computational power & infrastructure**
  Running AI models requires significant processing power and cloud infrastructure, which can be expensive
- **Model interpretability & trust**
  AI-driven decisions can be difficult to interpret, leading to scepticism and resistance from operators
- **Cybersecurity risks**
  AI-powered production systems are vulnerable to cyber threats, requiring robust security measures
- **High implementation costs**
  Initial AI adoption costs, including hardware, software, and training, can be a barrier for many manufacturers

AI Roadmap: Key Stages for Successful Implementation

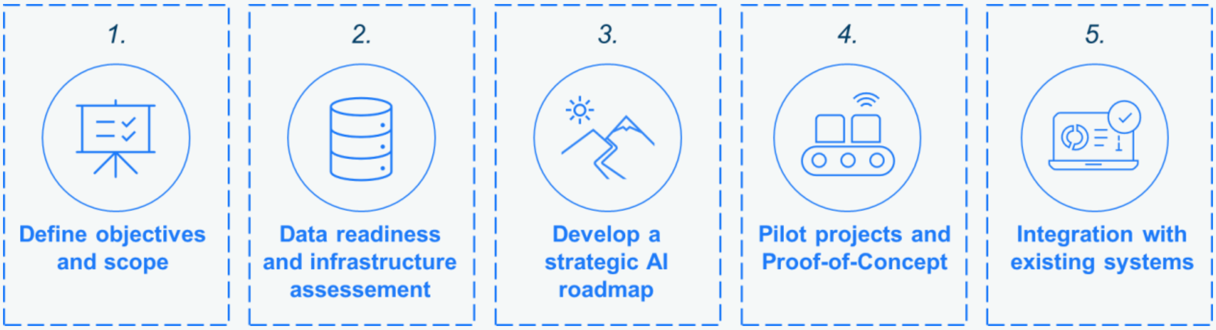


Figure 15. AI roadmap steps

Defining objectives and scope

The foundation of a successful AI roadmap begins with clearly defining objectives and scope. Organizations must identify key business challenges and opportunities where AI can add value. This involves aligning AI initiatives with business goals, such as improving operational efficiency, enhancing customer experiences, or optimizing supply chain management. By defining the scope, companies can set realistic expectations regarding AI implementation, ensuring that efforts are directed toward measurable outcomes and avoiding scope creep.

Data readiness and infrastructure assessment

AI systems heavily depend on high-quality data and infrastructure. Organizations must assess their existing data sources, data quality, and storage capabilities to determine whether they are ready for AI adoption. This involves evaluating data governance policies, data security measures, and the ability to integrate diverse data sources. Additionally, businesses need to ensure their IT infrastructure can support AI workloads, including cloud computing capabilities, data processing power, and connectivity between AI models and operational systems.

Developing a strategic AI roadmap

A structured AI roadmap outlines the steps required for successful implementation. This includes defining short-term and long-term AI goals, prioritizing projects based on feasibility and impact, and allocating resources effectively. A strategic roadmap should also include timelines, key performance indicators (KPIs), and potential risks. By having a well-defined plan, organizations can ensure that AI initiatives progress in a structured and measurable manner, avoiding ad-hoc deployments that may not align with business objectives.

Pilot projects and proof of concept

Before scaling AI across the organization, it is essential to conduct pilot projects and proof of concept (PoC) initiatives. These small-scale implementations allow companies to test AI models, assess their performance, and gather valuable insights without significant risks. Pilot projects help validate AI's effectiveness in addressing business challenges and provide a basis for further optimization. Lessons learned from these projects can inform broader AI deployment strategies and help fine-tune the models before full-scale adoption.

Integration with existing systems

To maximize AI's impact, it must be seamlessly integrated with existing business systems, workflows, and enterprise applications. This requires ensuring compatibility with current IT infrastructure, developing APIs for smooth data exchange, and providing user training to facilitate adoption. Integration also involves aligning AI models with enterprise resource planning (ERP), customer relationship management (CRM), and other operational tools to enable real-time decision-making. A well-executed integration strategy ensures AI-driven insights translate into tangible business value without disrupting existing operations.

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