

Forging the future:

# Navigating the New Era of Industrial Manufacturing

Technology Trends Radar 2024



# Foreword



In the rapidly evolving landscape of industrial manufacturing, innovation and current technology trends are driving strategic priorities and technological advancements. The industry continues to transform, emphasizing speed and efficiency in today's fast-paced world, and AI plays a pivotal role across the entire value chain.

Our research concludes that manufacturers increasingly favor Servitization As-a-Service and Direct-to-Consumer (D2C) models. Their goal is to capture lifetime customer value and meet emerging demands better in the longer term. Beyond mere product sales, manufacturers now offer bundled products, software, and service subscriptions. This gradual shift is transforming the aftermarket into the core market. The ongoing servitization blurs the lines between product sales and warranty, fueled by product subsidies.

To remain competitive, manufacturers are turning to manufacturing modernization. Implementing modernization at multiple levels enhances visibility and updates network and cybersecurity foundations. New PLCs (programmable logic controllers), scalars, and MES (manufacturing execution systems) are directly integrated for command and control on the shop floor.

The rise of AI, sensor economy, robotics, digitalization, Industry 4.0, and digital twins underscores the critical need for smart engineering in manufacturing. Customers demand

customization, complexity, and speed. Intelligent machines now operate autonomously, adjusting processes via digital instructions. The future lies in integrated production lines with real-time data from sensors and internet connectivity. This shift from manual to smart, adaptive engineering processes highlights the importance of advanced technologies, positioning us at the forefront of manufacturing innovation and excellence.

A larger number of manufacturers focus on improving worker productivity. A holistic approach combining technology, training, and worker well-being drives sustained gains. The focus on productivity influences financial success, operational sustainability, and organizational competitiveness.

Many industrial manufacturers grapple with legacy applications. Modernizing systems is paramount for enhancing operational efficiency. Notably, substantial investments are directed toward migrating to cloud-based and secure systems, bolstering efficiency and operational agility. These transformative efforts position manufacturers as industry leaders, poised to thrive in a competitive market.

We at LTM foresee the future of industrial manufacturing shaped by digitization, modernization, smart engineering, worker productivity, and core modernization.

**Naushad Khambhawala,**  
Vice President, Manufacturing



A holistic approach combining technology, training, and worker well-being drives sustained gains.

# Foreword



Innovation and proactivity go hand in hand in the world of manufacturing. By embracing this mindset, we can anticipate and drive changes, turning visionary ideas into tangible realities that define the collective industrial future. LTM Crystal Manufacturing Radar Report empowers industries to make faster and smarter decisions based on existing and emerging technology trends in the manufacturing domain.

To craft a comprehensive manufacturing radar, we initiated with an in-depth grasp of the industrial domain's needs, carefully defining the scope, segmentation, and rating parameters to align with stakeholder expectations. The pivotal phase entailed identifying pertinent technology trends and was subjected to a stringent vetting process. The acumen of industrial manufacturing SMEs was pivotal, and their profound insights

and practical know-how regarding the latest technological strides and applications enriched the report. Their real-world case studies underpinned the accuracy and pertinence of our analysis, illustrating how innovations like LTIMindtree's smart manufacturing are revolutionizing the sector by boosting efficiency, customer satisfaction, and sustainability. Our structured methodology captures the essence of being systematic and reflects our unwavering commitment to innovation and proactiveness. This commitment drives us to stay at the forefront of technological evolution, ensuring that our report is reliable and relevant to the ever-changing needs of the manufacturing industry.

**Indranil Mitra,**  
Vice President, Global Technology Office



The best way to predict the future is to create it.  
– Alan Kay



- 3 Horizons
- 4 Segments
- 66 Technologies, Industry Use Cases, Success Stories

- Gartner
- Forrester
- Deloitte
- Forbes
- McKinsey
- Newsrooms

- 25+
- Delivery, Service Line, Consulting Personnel Architects
- Next-gen technology experts

- Manufacturing CTO
- Global Technology Office Experts
- Functional Heads

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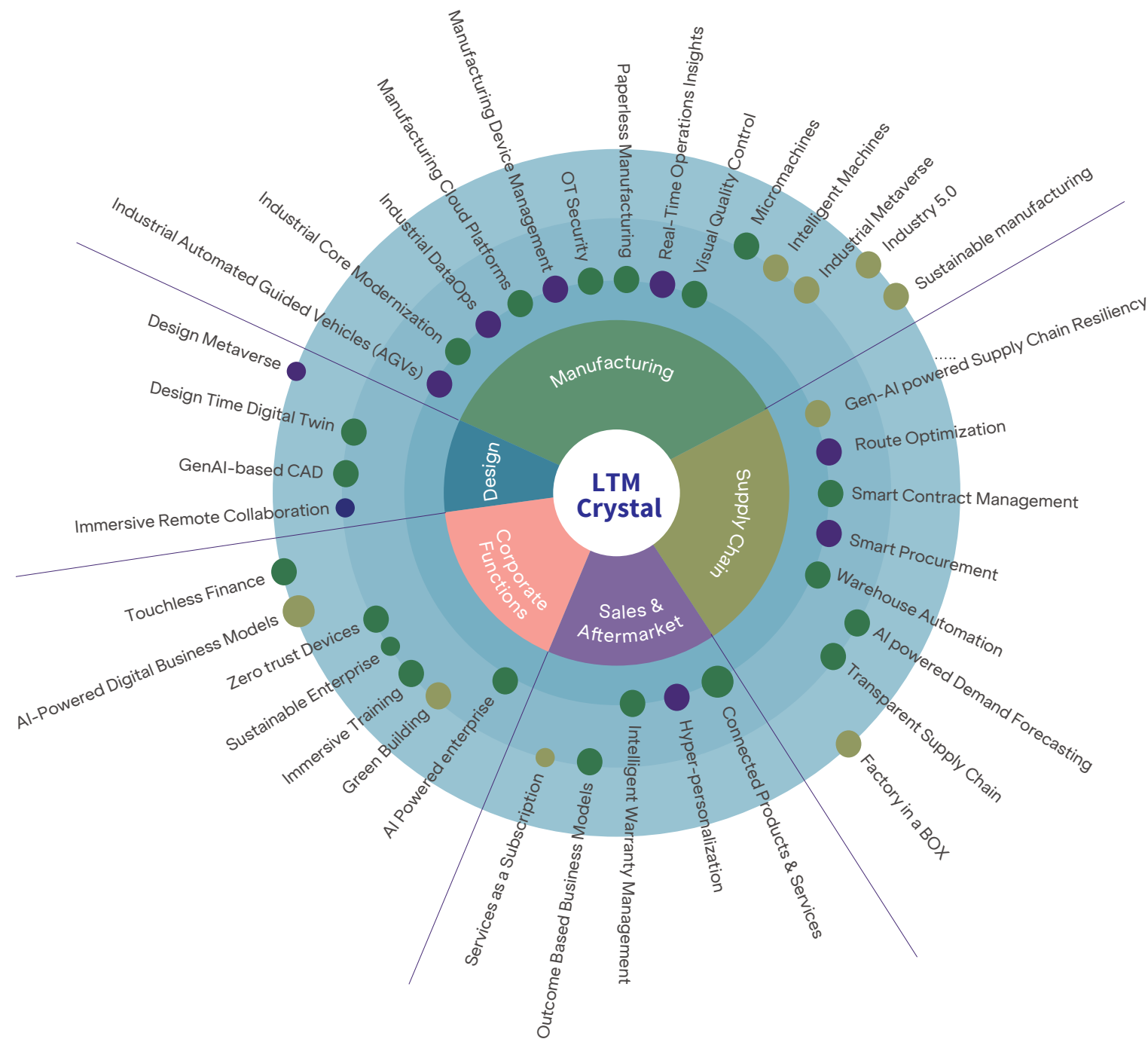
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## About LTIMindtree Crystal

LTM Crystal platform encapsulates beyond-the-horizon technologies and their insights, industry-specific use cases, inspirations, and how it is a game-changer. Through this, we intend to devise future-driven growth strategies with an early-warning system ..... 45

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# Manufacturing Technology Trends Radar



# Radar Ratings & Definition

## Horizon

Horizon refers to the timeframe between the inception of a new technology trend and its adoption by the mainstream

### Horizon 1 (0-1Year)

Relevant industry players are scaling the trend use cases

### Horizon 2 (1-3Year)

Relevant industry players have started incubating the trend, to assess the potential, risk implications and benefits

### Horizon 3 (3+Year)

Emerging technologies in research with potential for transformational change

## Market Potential (USD)

The likelihood of the technology trend to generate value across multiple functions

●  
Low

●  
High

●  
Very High

## Adoption Phase

Adoption maturity of the technology trend in the market

### Emerging ●

Trend is at its initial stages of adoption, with innovators and early adopters exploring its potential.

### Improving ●

Trend adoption is increasing with proven potential to improve efficiency and effectiveness.

### Mature ●

Trend has achieved widespread acceptance and usage among the general population or targeted audience

# Navigating the Radar

## Horizon 1

### Manufacturing

- Industrial Automated Guided Vehicles (AGVs)
- Industrial Core Modernization
- Industrial DataOps
- Manufacturing Cloud Platforms
- Manufacturing Device Management
- OT Security
- Paperless Manufacturing
- Real-Time Operations Insights
- Visual Quality Control

### Supply Chain

- Gen-AI powered Supply Chain Resiliency
- Route Optimization
- Smart Contract Management
- Smart Procurement
- Warehouse Automation

### Sales & Aftermarket

- Connected Products & Services
- Hyper-personalization
- Intelligent Warranty Management

### Corporate Function

- AI Powered enterprise

## Horizon 2

### Design

- Design Time Digital Twin
- GenAI-based CAD
- Immersive Remote Collaboration

### Manufacturing

- Industrial Metaverse
- Intelligent Machines
- Micromachines

### Supply Chain

- AI Powered Demand Forecasting
- Transparent Supply Chain

### Sales & Aftermarket

- Outcome based Business Models
- Services as a Subscription

### Corporate Function

- Green Building
- Immersive Training
- Sustainable Enterprise
- Zero Trust Devices

## Horizon 3

### Design

- Design Metaverse

### Manufacturing

- Industry 5.0
- Sustainable Manufacturing

### Supply Chain

- Factory in a BOX

### Corporate Function

- Touchless Finance



Trend Will be Industrialized  
in Less than 1 Year

# Industrial Automated Guided Vehicles

## Overview

Automated guided vehicles (AGVs) are self-navigating transport systems or load carriers that move autonomously. They eliminate the need for an onboard operator or driver within a warehouse, distribution center, or manufacturing facility. Industrial AGVs, ranging from autonomous forklifts to driverless trucks, are poised to revolutionize logistics and manufacturing processes by enhancing safety, efficiency, and overall quality

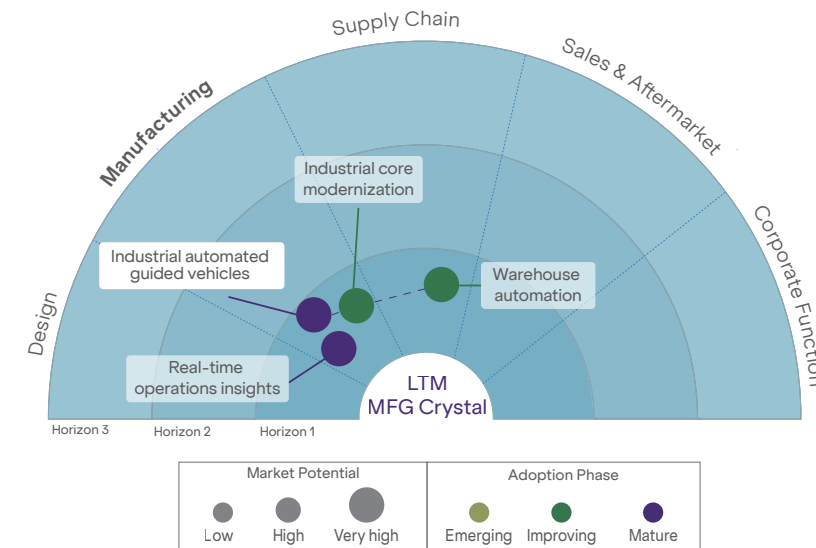
## Highlights

There have been breakthroughs in sensor and imaging technologies along with significant advancements in natural-language processing. Computer vision has paved the way for enhanced autonomy in self-driving vehicles that offer increased flexibility, precision, and reliability in various applications, including handling systems. AGVs can effectively utilize massive volumes of sensor data to monitor device status. They can gather product-related information (such as location using visual recognition or RFID tags) and track ambient parameters like temperature and humidity. With the integration of IoT, digital twins, and machine intelligence, AGVs are now capable of independently executing more complex tasks. They can seamlessly handle diverse part sizes and geometries, ranging from large components to bulk materials.

## Featured Story

A leading Japanese automaker implemented industrial AGVs to enhance efficiency and optimize performance on the shop floor. These industrial AGVs, equipped with user-friendly and instinctive navigation, followed a standardized route to ensure consistent movement of load movers. The AGV halts at designated transfer points and signals the door transfer system to automatically load fabricated doors onto individual load movers, which improves productivity and repurposes operatives.

## Radar View & Related Technologies



## Key Application Areas

### Assembly lines:

Transporting semi-finished machine parts to the final assembly line, ensuring uninterrupted operations.

### Handling finished goods:

Transporting finished goods from the shop floor to the warehouse for storage and despatch.

### Transportation of raw materials:

Transport of raw materials from warehouse to shop floor to ensure uninterrupted production.

## Key Takeaway

The functionalities and characteristics of AGVs are interconnected and can be extended beyond the Industry 4.0 setting. AGVs can be connected to cloud platforms to share their location and content in the vehicle via high-speed connectivity. This data can be analyzed and interpreted by customized monitoring applications, which provide valuable insights into resource management and optimization.

# Industrial Core Modernization

## Overview

Industrial core modernization involves updating fundamental systems and processes to enhance efficiency and adaptability. This includes integrating smart factory technologies like AI and IoT for automation and real-time data analysis. Additionally, it focuses on improving supply chain resilience and efficiency through digital integration, predictive analytics, flexible manufacturing, and advanced inventory management.

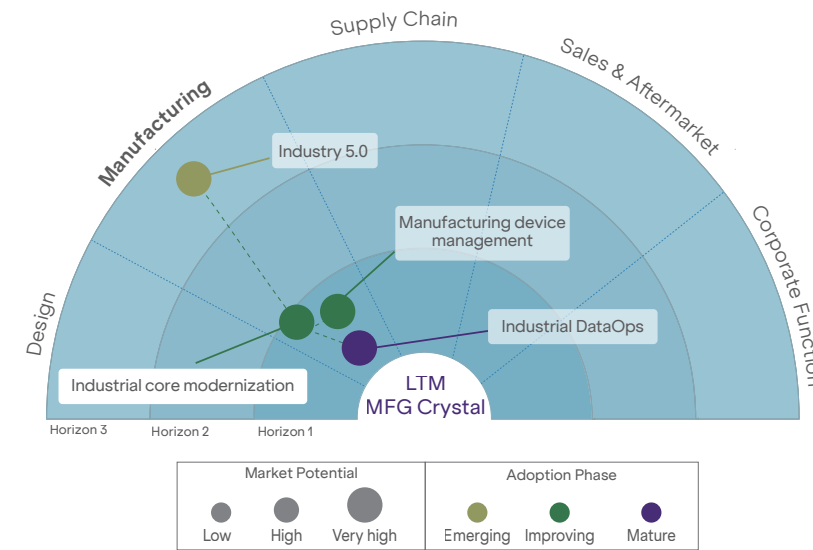
## Highlights

The industrial manufacturing sector involves highly complex operations, has extensive supply chains, requires advanced technology, and faces fierce competition among manufacturers. Therefore, industrial manufacturing is critical and requires better digital modernization solutions. Industry 4.0 has accelerated the modernization of digital factories in the manufacturing industry. It ensures efficient, sustainable, and seamless manufacturing operations while facilitating other digital modernization services. Forrester Consulting research found that 90% of manufacturing leaders believe a digital transformation strategy is critical for their company's success. Organizations anticipate the seamless integration of a physical supply chain and a digital ecosystem into the digital factory modernization production system to ensure efficient operation.

## Featured Story

A notable case study in industrial core modernization with 5G enablement involves the collaboration between Fraunhofer Institute for Production Technology and a Swedish-based networking and telecommunications company. They focused on the production of bladed disks (BLISKs) for turbines. By integrating 5G, they achieved real-time process control, significantly reducing manufacturing failures and downtime. This modernization led to annual savings of approximately EUR 27 million for a single factory.

Radar View & Related Technologies



## Key Application Areas

**Increased process efficiency and faster product delivery:** This allows for the removal or minimization of all inefficient manual processes, reducing the usage of physical resources.

**Data-driven equipment maintenance and workforce cooperation:** This technology enables real-time data exchange between human workers, machines, software systems, and other operational process components.

**Effective business management, planning, and analytics:** The flow of time series data generates automatic reports with business analytics, predictions, and planning.

## Key Takeaway

Digitalization drives manufacturing industries to adopt intelligent manufacturing strategies. These strategies are driven by internal demands like cost reduction, operational efficiency improvements, innovation, and R&D. They are also influenced by external pressures from evolving client needs and customer-experience requirements.

# Industrial DataOps

## Overview

Industrial DataOps integrates digital technology with operational processes to foster a closed-loop manufacturing approach. It aligns information technology (IT) workflows with operational technology (OT), improving data utilization and connectivity. Synchronizing production across product design and planning creates a network of information. This convergence involves process alignment, data convergence, software integration, and physical device updates, resulting in reduced downtime, enhanced asset utilization, and streamlined processes.

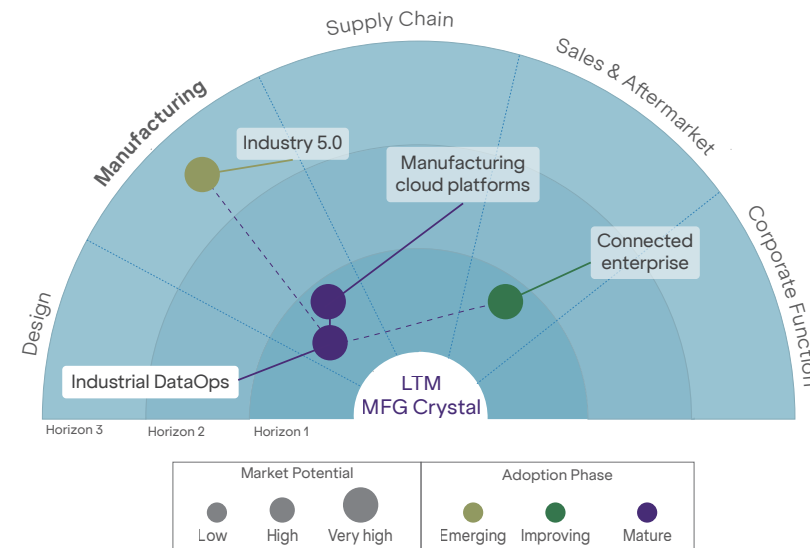
## Highlights

Today's manufacturers face hurdles across supply chains, inventory management, quality assurance, point of sale, and data security. This is because historical process isolation hinders integration, affecting IT and OT system interoperability. Breaking down such silos allows departments to collaborate more cohesively, ultimately enhancing customer satisfaction. Achieving tangible business results necessitates restructuring roles and addressing integration challenges using a unified data model to enable smooth communication and collaboration among various departments. Implementing digital twins offers significant advantages for industrial manufacturers by bridging the gap between IT and OT. These digital replicas of physical products, processes, shop floors, or machines serve as valuable assets for manufacturers and designers. This approach aligns closely with industrial DataOps, which aims to optimize the management and use of industrial data to improve decision-making and operational efficiency.

## Featured Story

A Fortune 50 automotive manufacturer wanted to move from a manual, error-prone, calendar-based maintenance system to a condition-based maintenance solution. LTM implemented a scalable AWS-based solution that automated the monitoring and maintenance of shop floor assets. The solution was integrated with Asset Management systems to trigger alerts and notifications and generate automated maintenance work orders. It helped reduce approximately 1000 hours of manual inspection per plant and improved MTTR (Mean Time To Repair) by 200 minutes.

## Radar View & Related Technologies



## Key Application Areas

### Predictive maintenance:

Using real-time data from OT systems to predict equipment failures and optimize maintenance schedules reduces downtime and costs.

### Quality control and process optimization:

Integrating IT systems with OT data to monitor and optimize manufacturing processes ensures consistent quality and efficiency.

### Inventory and supply chain management:

Leveraging IT/OT integration improves inventory visibility, automates replenishment processes, and optimizes supply chain operations.

## Key Takeaway

Industrial DataOps helps manufacturers stay ahead of their competitors by improving overall operational efficiency and enhanced data visibility to improved security and increased innovation. These further amplify the potential for transformative changes in the manufacturing industry.

# Manufacturing Cloud Platforms

## Overview

A manufacturing cloud platform is a digital solution that helps streamline and optimize manufacturing processes like production planning, supply chain management, inventory tracking, quality control, etc. These platforms provide real-time visibility, collaboration, and analytics capabilities to manufacturers, enabling them to improve efficiency, reduce costs, and enhance product quality.

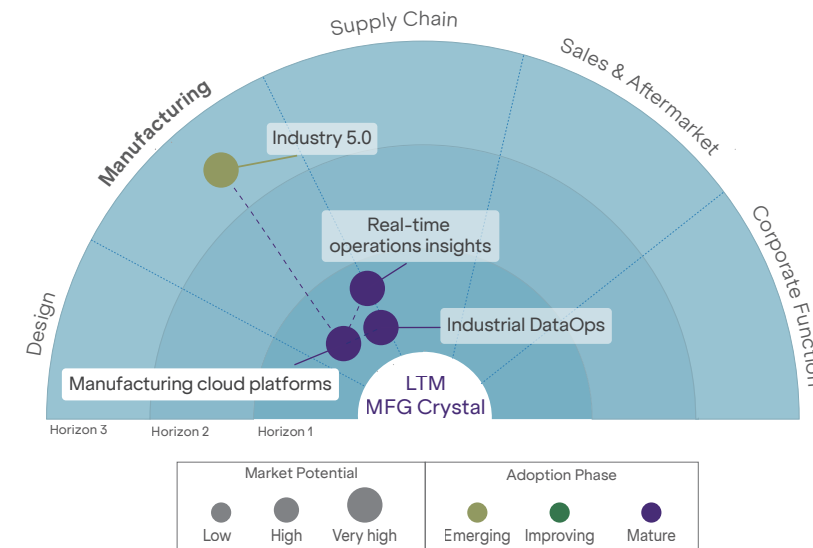
## Highlights

Cloud platforms have gained remarkable momentum in recent years, with many manufacturing organizations adopting them to transform their operations. Manufacturers are increasingly turning to cloud-based platforms to encourage data sharing, collaboration, and automation across the supply chain. It has empowered them to maintain business continuity and respond rapidly to changing market conditions while reducing manual errors and streamlining work. This leads to faster production cycles and lower costs. Manufacturers can seamlessly connect with suppliers, partners, and customers across geographical boundaries, cultivating greater transparency, agility, and responsiveness. Advanced analytics and ML algorithms flourish within the cloud environment, enabling manufacturers to uncover patterns, detect anomalies, and predict future trends.

## Featured Story

A precision dies and tools manufacturer in the UAE utilized the Oracle Fusion Cloud Procurement suite to streamline the evaluation of suppliers' financial stability and their capability to deliver quality goods and services punctually. This cloud-enabled suite has facilitated completely paperless digital procurement, reducing purchase order approval times by 40% and processing transactions nearly twice as fast as previously.

Radar View & Related Technologies



## Key Application Areas

### Supply chain management:

Monitoring and managing the flow of materials from procurement to distribution, global vendors, and contract manufacturers.

### Asset tracking and management:

Monitoring the location, condition, and performance of assets such as machinery and tools to optimize utilization

### Predictive maintenance:

Predict equipment failure, schedule maintenance proactively, and minimize unplanned downtime

## Key Takeaway

A manufacturing cloud platform helps to ensure business continuity and reduce risks through a secure, transparent, and connected supply chain. It also automates manufacturing factories and empowers the workforce with industrial IoT, data, and AI.

# Manufacturing Device Management

## Overview

A manufacturing device management (MDM) system allows organizations to align and control endpoint devices like smartphones. This ensures security and controlled usage from a single console. MDM is a core component of unified endpoint management and enterprise mobility management. The use of MDM in manufacturing has become prominent to ensure enhanced communication, optimize operations, and improve productivity.

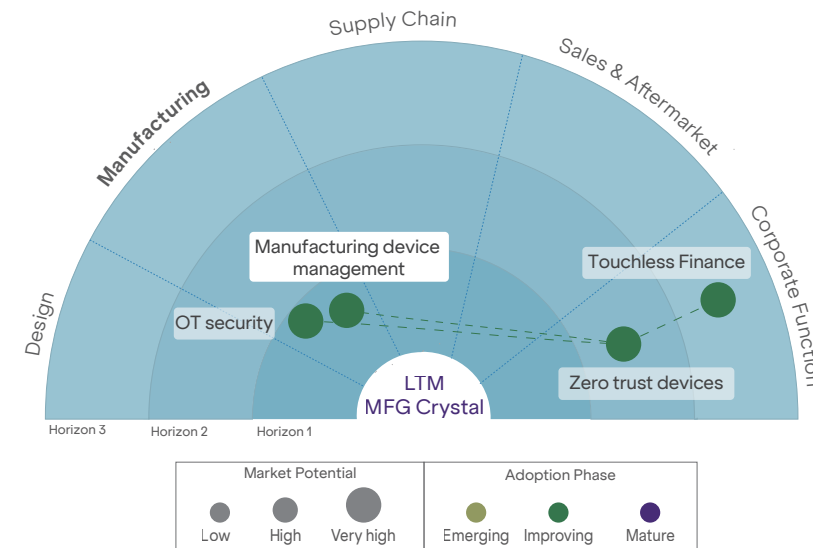
## Highlights

In manufacturing, mobile device management enables real-time monitoring of devices to ensure they are always operational. It also allows for remote troubleshooting, lowering downtime and increasing productivity. It safeguards sensitive data, and device security is crucial throughout manufacturing. MDM allows organizations to restrict the use of Android tablets for business use, lowering the risk of a data breach. The technology enables whitelisting apps to permit the installation of only approved apps. It safeguards intellectual property and trade secrets in the industrial sector, where ensuring innovation is critical for both economic gain and national security. Manufacturing device management's remote wipe feature allows the deletion of data from lost or stolen devices.

## Featured Story

An India-based pharmaceutical manufacturing and marketing company implemented mobile device management to simplify device management and provisioning with Zero Touch Enrolment (ZTE). A robust kiosk and browser solution helped the manufacturing company optimize device usage and prevent the misuse of any provisioned devices. They observed a reduction in the unauthorized utilization of third-party and social media applications, enhanced efficiency, higher productivity, and improved cost savings.

Radar View & Related Technologies



## Key Application Areas

### IoT for monitoring:

It makes the process proactive with thermal and video sensors collecting complete product data.

### RFID for inventory tracking:

It scans tags and extracts the necessary data for further processing.

### Maintenance schedule planning:

Avoid ineffective maintenance routines by leveraging industrial IoT and data science for predictive maintenance.

## Key Takeaway

The future of mobile device management in manufacturing involves zero-trust security, AI integration, unified endpoint management, user privacy, Bring-Your-Own-Device (BYOD) policies, product innovation, and collaborative governance.

# Operational Technology Security

## Overview

OT security refers to the software and hardware infrastructure required to monitor, identify, and regulate device changes, processes, and events. This technology assists industrial manufacturing companies in securing systems and networks against cyber-attacks. It also offers various security technology solutions, including powerful firewalls, security information and events management systems, and identity access tools.

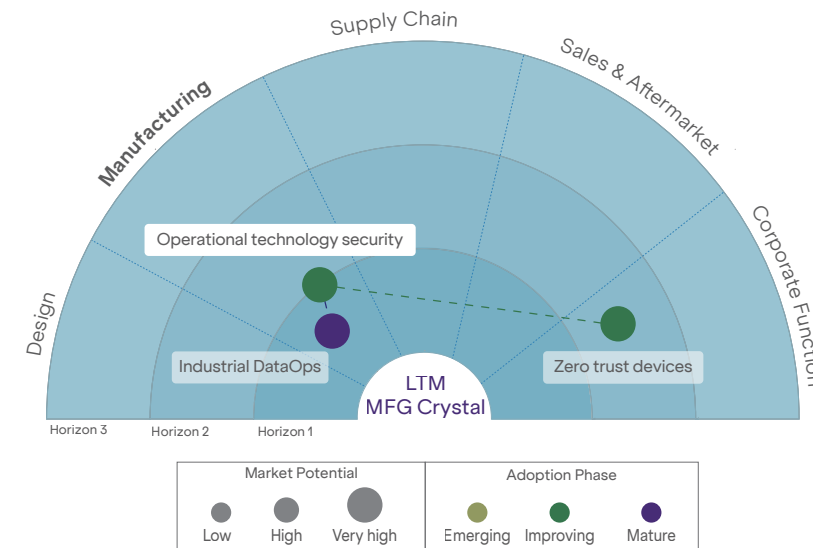
## Highlights

OT security promotes a holistic and complete approach to creating a safe and secure OT control environment for industrial businesses. This technique lays the groundwork for an OT security strategy and improvement program. The increased availability of high-speed internet and a need for data-driven insights are expected to boost the number of connected devices in manufacturing. IIoT offers benefits like real-time data collection and better operations. However, increasing the number of connected devices in an OT context presents issues. The use of OT security in industrial production is growing to combat risks such as ransomware, Distributed Denial-of-Service (DDoS), malware, online threats, and supply chain assaults. Future AI-based technology adoption will increase spam and phishing campaigns, precision assaults on edge devices, and external data gathering for improved attack planning.

## Featured Story

LTMindtree designed and implemented an OT security control framework and cybersecurity architecture for the Middle East’s largest multi-commodity mining and metals firm. The corporation required an innovative layout for its industrial plant’s information technology (IT) and operational technology (OT). This has helped the corporation centralize the management of the plant’s OT assets for a more unified view and better visibility of hazards.

Radar View & Related Technologies



## Key Application Areas

**Cyber-attack mapping:** This gives real-time visual representations of Cyber-attacks.

**OT asset management:** It helps identify and consistently manage data, personnel, devices, systems, and facilities.

**OT security monitoring:** This helps protect and control critical infrastructures such as power stations, transportation networks, and smart city appliances, predictions, and planning.

## Key Takeaway

Insecure OT devices will be vulnerable to viruses and vulnerabilities. Adopting OT security helps organizations meet dynamic, complicated, and expanding OT/IIoT cybersecurity challenges. It allows industries to automate and optimize labor and operations and simplify divisions.

# Paperless Manufacturing

## Overview

Paperless manufacturing refers to eliminating physical documents and materials while implementing digital logs and forms in the production process. This involves using paperless machines, digital data, and automation to enhance efficiency and reduce costs. It eliminates physical paper with software, driving lean initiatives and continuous improvement. Paperless manufacturing ensures a digital trail is left behind for all activities, driving error-proof manufacturing.

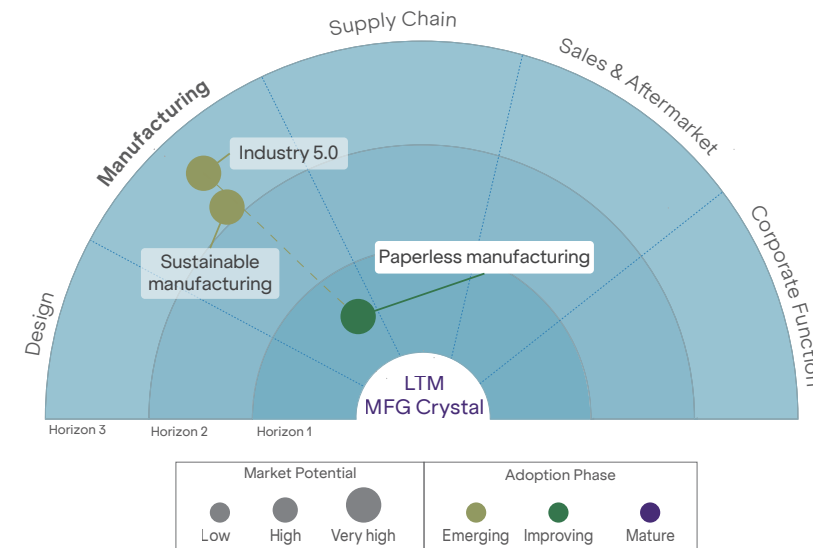
## Highlights

Manufacturing organizations are increasingly adopting paperless manufacturing to gain the maximum benefits of digitalization. It solves strategic issues with increased efficiency and is a huge technological step moving forward. Traditional paper-based systems were inefficient and could not be leveraged for storing and sharing information. They were prone to human errors, misplacement of documents, and sometimes illegible handwriting. Digital data in manufacturing overcomes most of the challenges and enables faster production with increased accuracy. It enables improved security for the storage of sensitive information and reduces the risk of a data breach without the need for physical printing. It also helps to avoid paper usage and contributes towards sustainability goals. Major challenges in implementing paperless manufacturing are the changing mindset of people in a traditional setup and the investment required in terms of hardware, software, and personnel.

## Featured Story

A leading Japanese automaker implemented industrial AGVs to enhance efficiency and optimize performance on the shop floor. These industrial AGVs, equipped with user-friendly and instinctive navigation, followed a standardized route to ensure consistent movement of load movers. The AGV halts at designated transfer points and signals the door transfer system to automatically load fabricated doors onto individual load movers, which improves productivity and repurposes operatives.

Radar View & Related Technologies



## Key Application Areas

**Improved operational efficiency:** Digital records help with data capture and reduce manual documentation.

**Increased sustainability:** Reduced paper usage drives sustainable operations and eliminates wastage.

**Added compliance:** Increased traceability, data integrity, and protection against unauthorized access leads to compliant operations, predictions, and planning.

## Key Takeaway

Paperless manufacturing is emerging as a key concept for efficiency, sustainability and competitiveness. It can simplify and improve operations while saving costs at the same time. Manufacturers that embrace digital initiatives position themselves for innovation and sustainable growth in an increasingly competitive market.

# Real-time Operations Insights

## Overview

Real-time operations insights in manufacturing refer to the process of collecting, analyzing, and interpreting data in real time. Technologies like big data analytics leverage analysis techniques such as descriptive analytics, predictive analytics, ML, etc. These techniques are used at every stage of real-time production, providing immediate insights that help operators take necessary actions.

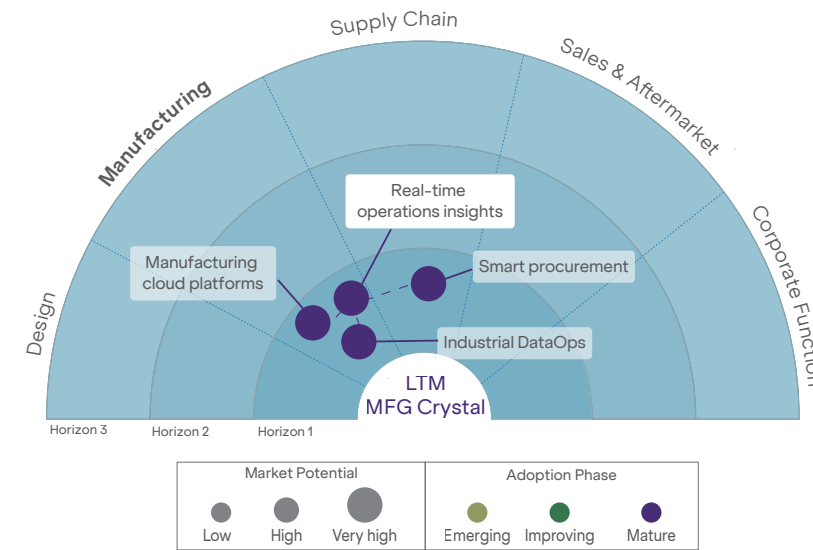
## Highlights

A real-time manufacturing analytics system supported by big data connects all departments and stakeholders involved in production processes. The system helps in standardizing methodology, terminology, and reporting procedures across all factory sites. Manufacturers leverage real-time operational data for analysis and apply it to identify and rectify bottlenecks and monitor real-time production lines. Descriptive analytics helps get consolidated insights into past design features, specifications, etc., leading to a quicker understanding of the historical design performances and benefits. Predictive analytics provides innovative and tailored designs and development methodologies based on historical and incremental data available by using inbuilt predictive algorithms. On the other hand, prescriptive analytics provides real-time and agile solutions based on the data feed. Real-time operations insights offer multiple benefits in design and product build, such as cost reduction, higher efficiency, quality improvement, and time reduction.

## Featured Story

A global escalator and elevator manufacturer faced major challenges due to non-uniformity in the sales discount process, resulting in fluctuating profit margins and profitability. LTIMindtree implemented a solution involving analytics over the sales data using Azure AutoML. As a result, the manufacturer's revenue in France rose by 40% YoY and profit by 3%. In Germany, its revenue rose by 23% YoY and profit by 4.5%.

Radar View & Related Technologies



## Key Application Areas

**Deeper insights into requirements:** Big data analytics enhances manufacturers' understanding of customer needs and forecasts into future trends resources.

**Predictive product designs:** Predictive analytics to generate the best designs based on historical and incremental data.

**Speeding up the assembly:** With big data analytics in manufacturing, organizations can now segment their production and identify the units that are manufactured faster.

## Key Takeaway

Real-time analytics leveraging big data is the secret behind manufacturers experiencing high production efficiency, better prediction of anomalies, and getting competitive advantage. To leverage the full benefit of the technology, big data needs to be integrated with technologies like IoT, sensors, and AI.

# Visual Quality Control

## Overview

Visual Quality Control enables systems to understand visual inputs from real-world scenarios. Deep learning data models then accurately identify, classify, analyze, and process the inputs into meaningful decision-making. This enables Visual Quality Control systems to identify anomalies. They detect defects or missing components in an industrial product, irregular manufacturing lines, visible wear and tear in machine parts, and other similar tasks.

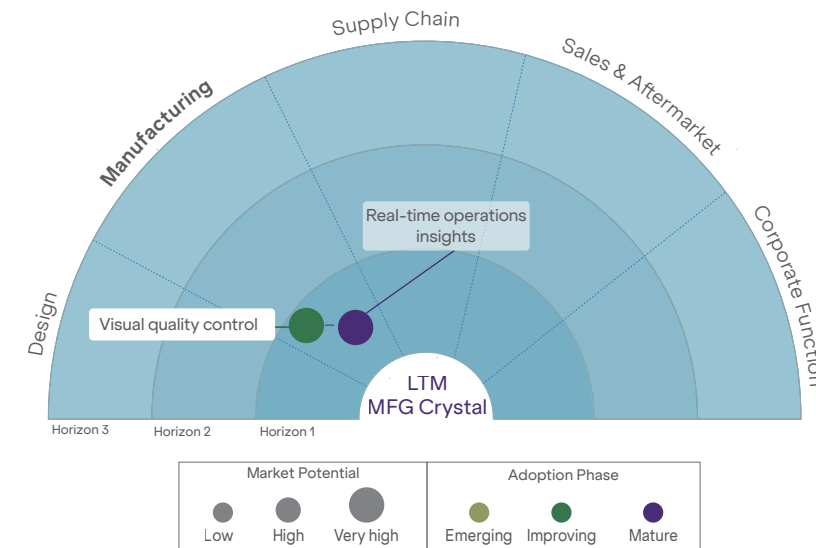
## Highlights

Traditional quality inspection relies on human judgment, perception, and availability of resources. These perceptions often fall short on subjectivity, human capability, and training time, leading to an average of 20% of potential sales due to poor quality of manufactured goods. However, AI and image recognition advancements can overcome this challenge with greater efficiency and accuracy. AI-powered Visual Quality Control provides consistent detection at remarkable speed and accuracy, significantly improving overall efficiency and reducing time for inspection. With continuous data analysis, these models can self-learn and evolve to handle complex defect patterns and deliver efficient output. Challenges for Visual Quality control in Industrial manufacturing include lack of skilled professionals, expensive hardware and high-quality data.

## Featured Story

LTMindtree implemented a Visual Quality Control-based solution for an automobile manufacturer. The company faced challenges such as inadequate quality check processes, manual errors during the inspection, and root-cause defect detection. LTM developed the solution with the help of AWS services for porosity detection. The solution helped the manufacturer with 100% defect detection, faster corrective actions, and minimized wastage.

## Radar View & Related Technologies



## Key Application Areas

**Quality inspection:** Visual Quality Control enables automated visual inspection for anomaly detection to identify defective products.

**Assembly process automation:** It simplifies part detection and orientation alignment with robots in the assembly process.

**Continuous dimension monitoring:** Tracking dimensions in real-time ensures correct product fit and size.

## Key Takeaway

Visual Quality Control offers a consistent, faster, and automated solution to a process that struggled with delayed response time, manual errors, and subjective nature. Leveraging CV reduces costs and improves product reliability, boosts competitiveness, and improves operational efficiency.

# Route Optimization

## Overview

Route optimization is a strategic approach to planning the fastest and most cost-efficient route for transporting goods from one place to another. Factors like distance, traffic conditions, delivery time windows, vehicle capacity, and customer preferences determine the optimal sequence and allocation of stops along a given route. Route optimization software can generate optimal routes for each delivery vehicle by analyzing the above factors using generative AI.

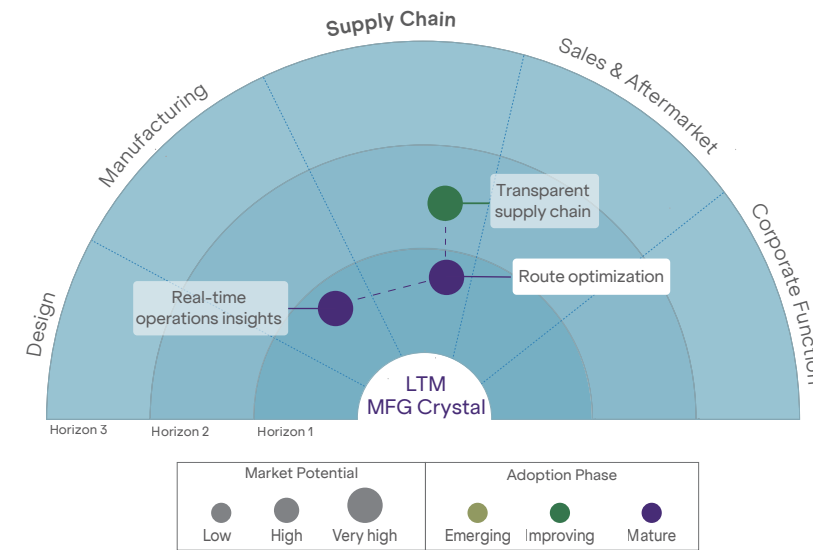
## Highlights

Route planning and optimization are facilitated by the IoT, which connects transportation, cargo, and warehouses. They also connect external data sources like weather, events, and traffic flows to enhance visibility and streamline shipping processes. Data-driven analytics from route optimization software can significantly decrease transit time while ensuring over 90% reliability. This solution offers seamless end-to-end consignment visibility, temperature-controlled features, and real-time tracking. Businesses can make informed decisions using real-time information from route optimization software to enhance their shipping operations. They can develop various strategies such as rerouting trucks, adjusting warehouse locations, reallocating resources, and more.

## Featured Story

A distribution company employed generative AI to streamline warehouse layouts, resulting in increased efficiency and decreased operational costs. The AI model creates optimal warehouse designs that minimize travel time and maximize storage capacity by examining warehouse operations, inventory flow, and space utilization data.

## Radar View & Related Technologies



## Key Application Areas

**Real-time traffic analysis:** This analysis generates optimal routes for each delivery vehicle, improving efficiency and reducing transportation costs.

**Inventory control and management:** Utilizing RFID in product tags tracks product flow, streamlines inventory management, and provides access to up-to-date information.

**Dynamic routing system:** Employing an ML algorithm solves complex routing problems, enabling last-mile delivery, lowering fuel consumption, and reducing carbon footprint.

## Key Takeaway

Strategic supply chain design and daily operational supply management are expected to merge into a unified, data-driven route planning and optimization process that yields excellent results. Developing a network structure to handle current and future supply disruptions and demand changes is crucial for the survival of logistics, supply chain, automotive, and other industries.

# Smart Contract Management

## Overview

Smart contract management involves using blockchain technology to automate and streamline contract-related processes within the manufacturing supply chain. These contracts can automate various tasks and transactions, such as purchase orders, delivery schedules, and payment terms. They also help manufacturers track the movement of goods, verify product authenticity, and ensure compliance with contractual obligations.

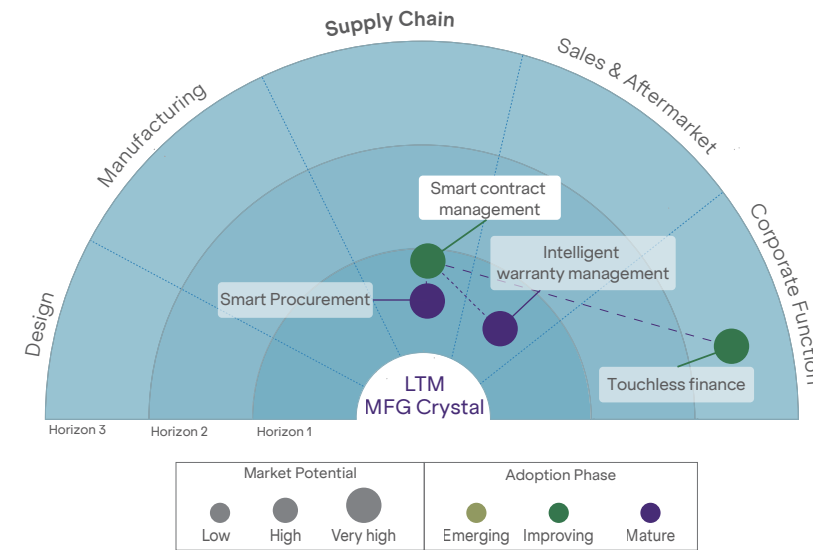
## Highlights

Manufacturers are always trying to gain a competitive edge in an interconnected and data-driven environment. Hence, smart contract management is expected to play a pivotal role in transforming the supply chain, drive operational excellence, mitigate risks, and deliver customer satisfaction. It addresses various pain areas pertaining to cost reduction. It also enhances transparency and traceability by streamlining contract-related processes such as procurement, invoicing, and payment. This leads to faster transaction speeds and improved process efficiency, as well as optimized inventory management to minimize stockouts and reduce lead time. The collaboration between technology providers, manufacturers, and supply chain partners is leading to innovative applications of smart contracts tailored to specific needs within the manufacturing industry.

## Featured Story

A global automotive parts manufacturer faced challenges such as file retrieval, lack of a standard approval and signature process, lack of a mechanism to track renewal/ expiry of contracts, etc. The manufacturer implemented smart contracts, which simplified approvers/signatories for contracts, retrieval of files, and timely reminders before the end of contract dates. It led to an automated process where all active and expired contracts were stored for usage on demand.

Radar View & Related Technologies



## Key Application Areas

**Automated procurement:** Execute purchase orders and verify supplier credentials.

**Inventory management:** Minimize stockouts, coordinate deliveries with suppliers, and reduce excess inventory holding costs.

**Quality control and compliance:** Specify the quality specifications for raw materials and automatically reject or approve deliveries.

## Key Takeaway

Smart contract management can have a transformative impact on supply chain transparency. It facilitates just-in-time manufacturing and ensures secure payment processes, thereby streamlining operations, reducing the risk of fraud, and improving compliance.

# Smart Procurement

## Overview

Smart procurement refers to using innovative technologies, such as AI, ML, data analytics, automation, RPA, etc. These technologies streamline procurement processes and free professionals from repetitive tasks to increase productivity and reduce manual errors. Industrial manufacturers are moving away from traditional systems and procurement practices to improve agility, decision-making, and operational efficiency and reduce risks and costs.

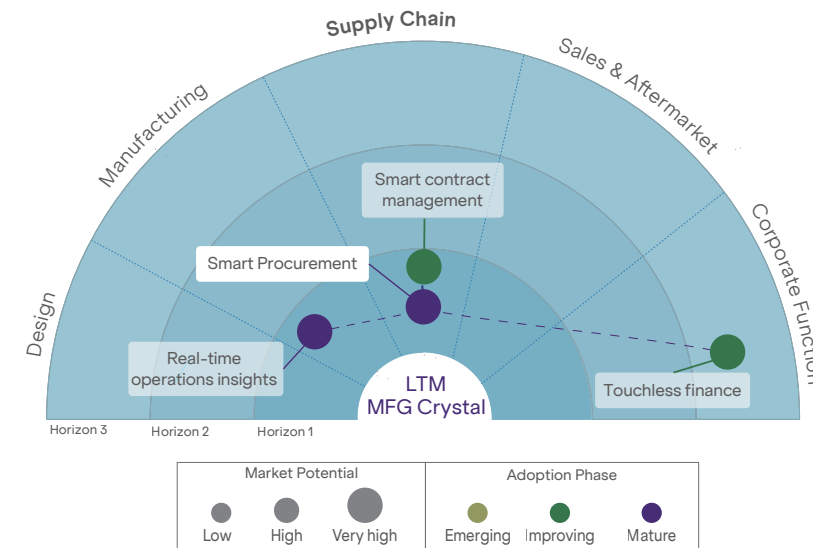
## Highlights

Industrial manufacturing firms struggle with inefficiency, higher operating costs, and risks such as manual errors. Introducing smart procurement in a macro climate that is seemingly unpredictable can help the procurement function emerge as a strategic division rather than a cost-saving department. Smart procurement focuses on building resilience, refining supply chain visibility, and agility solutions like Blockchain, AI, IoT & cloud-based platforms. This enhances supplier collaboration, risk management, and demand forecasting. Amazon Business published a Procurement Data Report in 2024. It mentions that 98% of respondents reported planning investments in analytics and insights tools, automation, and AI for their procurement operations in the next few years.

## Featured Story

A Sweden-based automotive manufacturer was leveraging disparate ordering systems with manual processes that were not user-friendly. These systems did not allow for customized raw material ordering and posed challenges in order tracking. After implementing the LTM Smart Procurement solution, the client achieved a 50% reduction in maintenance costs, real-time supplier integration, and an automated product selection and approvals workflow.

Radar View & Related Technologies



## Key Application Areas

**Sustainability and ethical sourcing:** It helps track ethically sourced materials to ensure a sustainable supply chain.

**Risk management:** Data analytics can help forecast supply chain disruptions due to unnatural causes.

**Inventory management:** It prevents stock-outs, reduces transportation costs, and ensures optimal stock levels.

## Key Takeaway

Strategic supply chain design and daily operational supply management are expected to merge into a unified, data-driven route planning and optimization process that yields excellent results. Developing a network structure to handle current and future supply disruptions and demand changes is crucial for the survival of logistics, supply chain, automotive, and other industries.

# GenAI Powered Supply Chain Resiliency

## Overview

Manufacturing organizations are increasingly deploying GenAI into their supply chains for demand planning and procurement to gain insights. GenAI implementation helps manufacturing organizations analyze operational data, plan for procurement, optimize inventory, mitigate risks, and improve customer service. It can perform root-cause analysis to reduce defects and unlock untapped productivity. These insights can unlock untapped productivity, leading to greater production output.

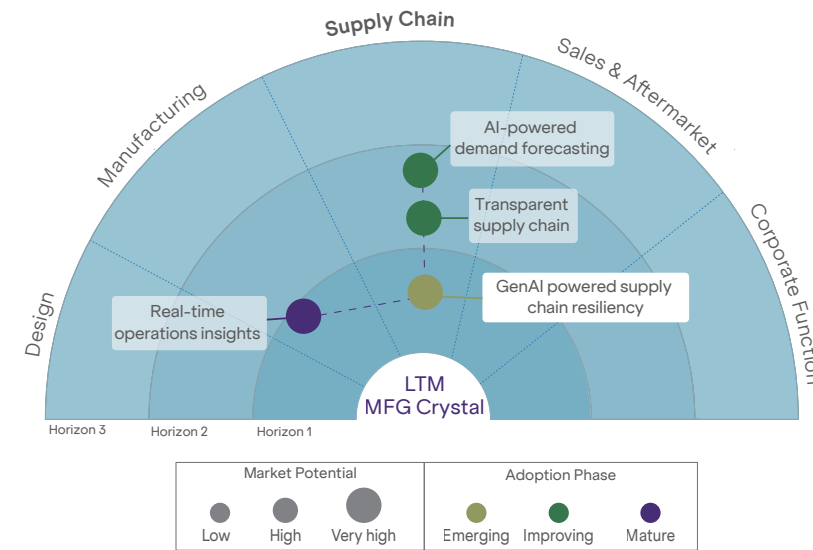
## Highlights

Supply chain disruptions are impacting manufacturers in multiple ways. In addition to long-term supply chain issues, industrial manufacturers are expected to source materials more responsibly, ethically, and sustainably. To achieve this, supply chain visibility is the top priority of supply chain executives. GenAI acts like a supply chain consultant, enabling greater visibility across multi-layered networks and recommending best-fit suppliers based on key KPIs. Some of them are bill of materials (BOM), raw material availability, delivery schedules, and sustainability metrics (Sustainability KPIs). GenAI powered Supply Chain improves demand forecasting and inventory optimization. Enhances customer confidence and satisfaction and improves compliance & better risk management. According to a Gartner survey from Jan 2024, half of supply chain leaders from 127 global companies plan to implement GenAI in the next 12 months. About 14% of them are already in the implementation stage.

## Featured Story

An American multinational retailer implemented an automated supplier negotiation solution that could read contracts, understand priorities, and negotiate through a chatbot. The solution leveraged historical price trends, competitor costs, and commodity values. After the pilot run, the solution tail-ended 64% of supplier contracts and extended payment terms by an average of 35 days. It could run 2000 negotiations simultaneously, which led to increased procurement productivity.

Radar View & Related Technologies



## Key Application Areas

### Demand forecasting:

Leveraging historical and external data to create probabilistic models improved accuracy in demand forecasting.

### Inventory optimization:

Analyzing lead times, market trends, and sales data prevented stockouts.

### Supplier selection:

Selecting the right supplier based on quality, cost, lead time, and geographical location was made easier.

## Key Takeaway

Implementing GenAI powered Supply Chain has tremendous resilience and scalability potential. Its application is gaining traction; however, aspects such as integration, talent, and data are some of the challenges that need to be addressed for a successful outcome.

# Warehouse Automation

## Overview

Warehouse automation uses technologies like robots, computer systems, and automated material handling equipment to enhance productivity and safety and streamline operations. It is gaining popularity in modern logistics, and technologies like AI and IoT will play a vital role in the advancement of warehouse automation. Key innovations include goods-to-person systems, automated storage and retrieval systems, autonomous mobile robots, pick and put-to-light systems, voice picking, and automated sortation systems.

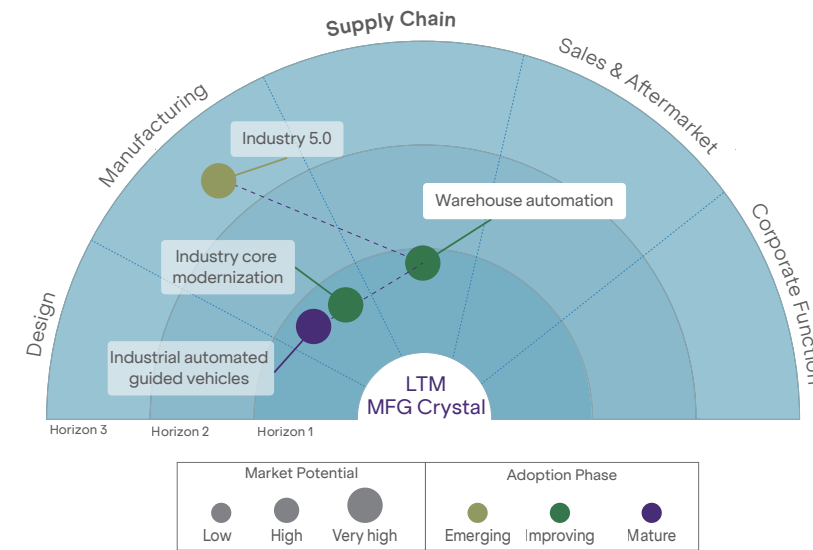
## Highlights

Technologies like Automated Guided Vehicles (AGV) and Autonomous Mobile Robots (AMR) for agile operations, Advanced Automated Storage and Retrieval (ASRS) with robotic arms, and AI and AI/ML for predictive analytics will transform warehousing. Blockchain will enhance supply chain transparency, IoT will provide real-time inventory data, and cloud-based warehouse management systems (WMS) will offer remote management. In addition, data analytics will drive performance optimization, ensuring competitive and efficient warehouse operations. Warehouse automation significantly enhances operations, achieving 99% inventory accuracy and reducing labor costs by 3%. Smart warehouses leveraging IoT and AI, boost productivity and cut costs. According to Deloitte, 96% of industry leaders think innovation will be a crucial factor in warehouse automation, and 52% of warehouse managers are looking to increase investment in automation and robotics.

## Featured Story

LTIMindtree harmonized warehouse processes for a Denmark-based stone wool insulation manufacturer. We conducted a global business Blueprint workshop for 36 warehouses in 30 countries. They implemented handling unit management with SSCC number, RFID, and GPS solutions for operational efficiency and developed a custom Fiori app for forklift operations. Additionally, they integrated warehouse control with SAP MFS, ensuring a smooth master data cutover and Go-Live.

Radar View & Related Technologies



## Key Application Areas

**Automated storage and retrieval systems (AS/RS):** Efficiently store and retrieve products using robotics and conveyor systems.

**Warehouse management systems (WMS):** Optimize inventory management order processing and source allocation.

**AI and ML:** Predict demand, optimize routes, and improve decision-making process

## Key Takeaway

Embracing automation and data-driven insights futureproofs warehouses. It also boosts competitiveness and ensures success in evolving logistics, positioning businesses to thrive in the dynamic warehousing landscape.



Trend Will be Industrialized  
Within 1 to 3 Years

# Design-time Digital Twin

## Overview

A design-time digital twin in a manufacturing set-up allows the integration of digital twin technology in the early stages of product development. This allows the customer to fully test the product by carrying out multiple simulations in a virtual environment before being finalized by the customer. Since complex machines can incorporate multiple libraries of digital twin models of key components, it becomes increasingly beneficial to combine and check for the best product fit.

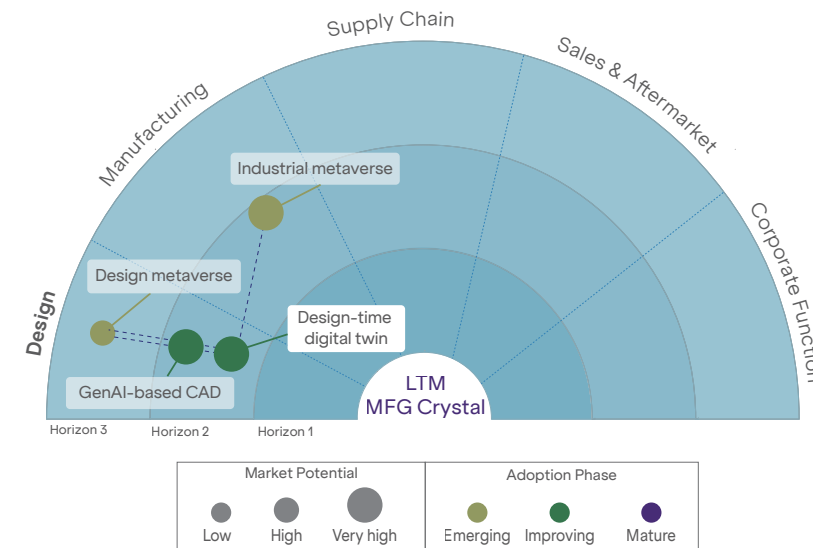
## Highlights

Implementing digital twins in the design stage of industrial manufacturing allows the manufacturer to explore various design options without getting into the costly physical prototyping stage. It improves time-to-market up to 50% and product quality up to 25%. The design stage incorporates visualization and scientific modeling techniques with the creation of 2D drawings and 3D models leveraging various powerful design tools. It helps in what-if scenario planning and aspects such as fluid flow, biochemical processes, structural deformation, etc. According to a McKinsey survey from 2022, 86% of respondents said digital twins are applicable to their organization. While 44% have already implemented a digital twin, 15% plan to deploy one.

## Featured Story

LTIMindtree implemented digital twins for a leading US-based pump manufacturer. The implementation led to increased real-time condition monitoring of pumps, with time to predict failures. Predictive analytics enabled service prioritization and better outage and spare parts planning. This led to 99% asset availability, 8% reduction in unscheduled maintenance, and 12% reduction in production downtime.

Radar View & Related Technologies



## Key Application Areas

**Faster product development cycle:** Speeds up design and engineering cycles while cutting down on costs.

**Possibility of multiple prototypes:** Manufacturing firms can create multiple versions to check the best-fit product.

**Promotes innovation:** It allows prototyping and testing of new products, saving costs and driving innovation.

## Key Takeaway

Digital twins in design and development significantly improve product development by reducing development times by 20% to 50%. They have also been reported to have 25% lesser quality issues and a higher chance of succeeding commercially.

# GenAI-based CAD

## Overview

GenAI can analyze vast databases of existing designs and historical data to suggest innovative design options based on project requirements, industry standards, and user preferences. ML can interpret design patterns and predict components needed. This allows automating drafting tasks, like creating repetitive elements or generating bills of materials, reducing manual work and minimizing errors. This can accelerate the design process and spark creative solutions.

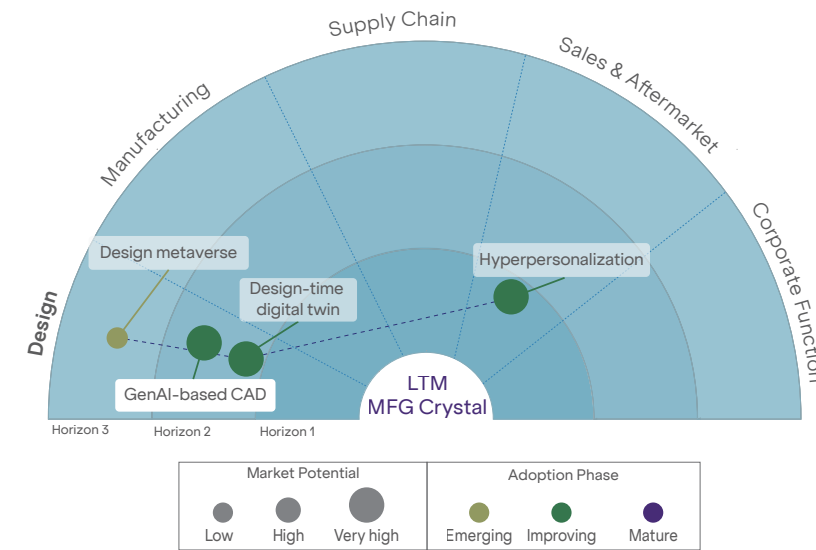
## Highlights

In the rapidly evolving technology landscape, AI has emerged as a driving force behind transformations across the manufacturing industry. GenAI, known for its content creation and enhancement capabilities, is playing a significant role in shaping the advancement of manufacturing practices. In a diligent fusion of art and science, GenAI utilizes ML algorithms to assess every possible design solution for a specific problem, subsequently generating an array of design alternatives. This technology-driven approach unveils design possibilities much beyond human cognitive abilities, uncovering innovative designs and structures. It can enable rapid prototyping and mass production in assembly lines where many different parts are manufactured every day. This results in a transformative shift in product innovation, creating new-age creations that are efficient, cost-effective, and unique. The shift effectively positions businesses at the forefront of the industries.

## Featured Story

A well-known car manufacturer designed an electric mini-bus using a generative AI design. To eliminate excess weight and material while maintaining strength, the team used a design provided by generative AI for lightweighting. The team innovatively explored multiple methods to reduce wheel mass, carefully evaluating various manufacturing techniques. As a result, the manufacturer successfully achieved an impressive 18% reduction in wheel weight.

Radar View & Related Technologies



## Key Application Areas

**Material science and synthesis:** Assist in analyzing properties of new materials and synthesize with their operational qualities.

**Product design and optimization:** ML algorithms help in generating optimized designs based on specific performance criteria.

**Prototyping and wireframing:** Innovative prototypes can be created by simulating their form, function, and performance in a virtual environment.

## Key Takeaway

GenAI is evolving as a catalyst in modernizing the design and manufacturing of industrial products. It can surely speed up the design process and transform it into a highly innovative, unique, and error-free product design.

# Immersive Remote Collaboration

## Overview

Immersive technologies, such as AR and VR, extend and deepen the potential of manual collaboration in industrial manufacturing. They allow users to see beyond their natural vision and imaginative capabilities. Providing technicians and engineers with an immersive reality experience is transforming design and manufacturing efficiency and effectiveness.

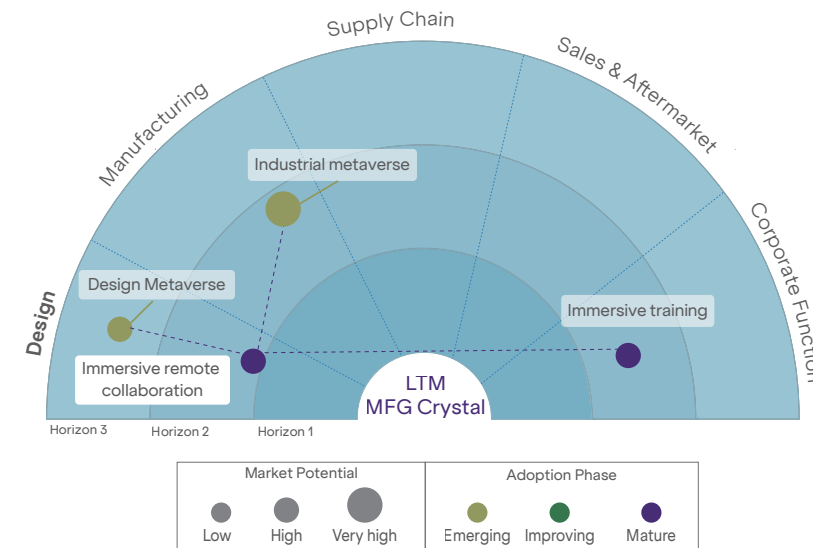
## Highlights

The global pandemic has impacted every industry, including manufacturing. Immersive technologies like AR, VR, and Mixed Reality (MR) top the list of highly envisioned technologies in the remote collaboration space in manufacturing industries. In recent years, immersive technologies have enhanced holographic technology from being a mode of amusement to a full-fledged interactive application in manufacturing service lines. Immersive applications connected with IoT and sensors provide real-time manufacturing updates and alerts to technicians working on the floor or remotely. If technicians encounter any issues, they can use holographic visualization to recreate the problem and produce innovative solutions. Immersive technologies can also help manufacturers inspect the machinery, maintain, and keep digital logs instead of paper based.

## Featured Story

An American aerospace and defense manufacturer utilized Augmented Reality (AR) to enhance efficiency in constructing the Artemis II spacecraft. By using AR goggles, instructions were superimposed in 3D space directly onto the physical spacecraft, eliminating the need to interpret procedures from text or 2D screens. This approach allowed them to finalize the manufacturing process in 90% less time across four different locations compared to conventional techniques.

Radar View & Related Technologies



## Key Application Areas

**Safety and regulatory compliance:** Safety incidents are avoided when technicians can troubleshoot problems in a virtual environment without disassembling the equipment.

**Reliability engineering:** Design for reliability and asset optimization initiatives can thrive when there is a virtual playground for experimentation and improvement.

## Key Takeaway

Digital twins in design and development significantly improve product development by reducing development times by 20% to 50%. They have also been reported to have 25% lesser quality issues and a higher chance of succeeding commercially.

# Industrial Metaverse

## Overview

A digital environment allows us to detect and rectify errors faster than the physical world. An Industrial Metaverse enables gauging a 3D representation of the manufacturing environment with the amalgamation of various technologies such as AR, VR, and connected devices. It can be used to create a virtual layout of the factory and plan before proceeding with the costs associated with building it. According to a Big 4 consulting firm survey, manufacturers anticipate that the industrial metaverse could lead to a 12% gain in labor productivity, which might help address the ongoing labor shortages.

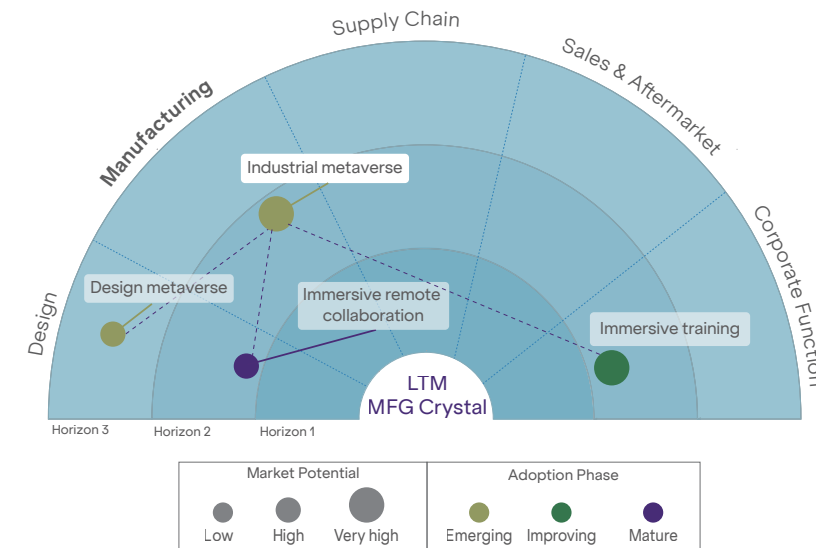
## Highlights

The manufacturing industry is well-positioned to adopt the industrial metaverse due to its continued emphasis on digital transformation and its journey towards the smart factory. According to a World Economic Forum (WEF) Survey from 2024, most manufacturing companies have already deployed core technologies that drive the industrial metaverse. Most companies are either implementing technologies such as data analytics, cloud, AI, 5G, and IoT technologies across multiple projects/ processes, or they are experimenting with one-offs. About 79% of executives in industrial manufacturing believe their organization’s vision or long-term strategy is already inspired by primary metaverse technologies. According to a Manufacturing Leadership Council study - 2023, around 80% of manufacturing leaders believe that metaverse will reform manufacturing within the next five years .

## Featured Story

A global leader in aircraft manufacturing plans to leverage the industrial metaverse by integrating 3D digital models, collaborative robots, and mixed-reality headsets for global mechanics. The digital system will unite design, production, and services, enabling real-time simulations and enhanced collaboration. By using this approach, the aircraft manufacturer aims to prevent issues observed in its commercial aircraft, streamlining manufacturing processes and improving quality control for future aircraft development.

Radar View & Related Technologies



## Key Application Areas

**Facility design and engineering:** Create structural virtual designs to identify issues before investing in building it.

**Virtual product R&D, prototyping, and testing:** Create virtual product prototypes to save costs and time in actual prototype.

**Predictive maintenance:** Helps determine whether equipment requires maintenance.

## Key Takeaway

Manufacturers are optimistic about the industrial metaverse’s continued potential, which could help them unlock measurable value and build new markets. However, a cautious approach is required since it requires robust cybersecurity measures, without which the consequences could be significant.

# Intelligent Machines

## Overview

Intelligent machines employ automation, data collection, AI, machine learning (ML), or other technological integrations to establish ideal production conditions. Additionally, it involves monitoring the performance of every production process element, including assessing the overall equipment efficiency (OEE).

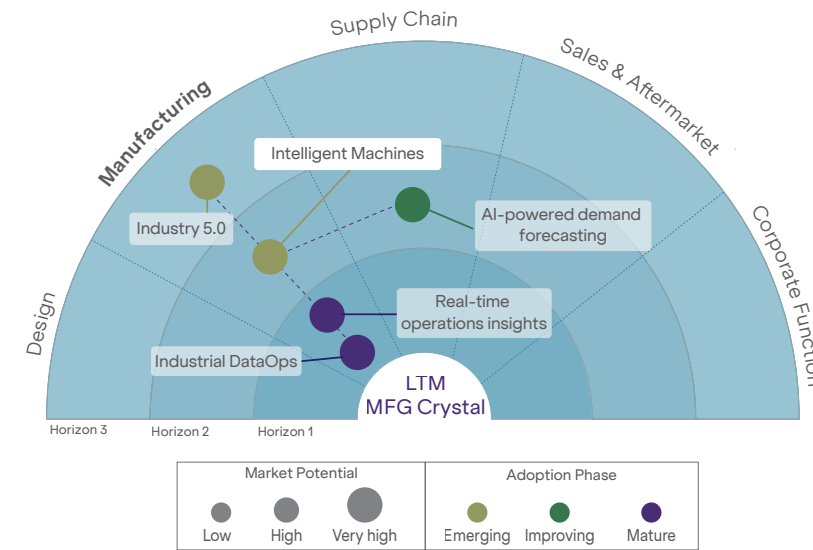
## Highlights

Intelligent manufacturing focuses on optimizing data usage across processes through automation, networking, ML, and AI. The World Economic Forum (WEF) forecasts that the worldwide market for AI in manufacturing will be worth USD 20.8 billion by 2028. Intelligent machines collect and analyze data to evaluate the state of manufacturing lines. This will help businesses migrate to the ideal environment, ensuring high-quality output. Intelligent machines also provide alerts about serious concerns that demand attention. These difficulties might include malfunctioning equipment, poor function execution, or faults in finished items. Manufacturers highly emphasize AI in their pursuit of intelligent manufacturing and developing intelligent, networked, and efficient production processes.

## Featured Story

LTIMindtree developed an integrated platform for battery technology solution providers, including connected operations and an end-to-end battery traceability system. The platform collects process-specific data from both the production and after-sales value chains. Using manufacturing, aftersales, and business analytics, we created a linked operation to eliminate claim fraud and speed up the reverse supply chain.

Radar View & Related Technologies



## Key Application Areas

**Predictive maintenance:** IoT-enabled devices coupled with predictive analytics identify patterns and detect anomalies.

**Optimized supply chain:** Optimization makes supply chains resilient and disruption-proof.

**Increased asset performance:** Reduce downtime in the event of equipment failure and boost output.

## Key Takeaway

Digitalization drives manufacturing industries to adopt intelligent manufacturing strategies. These strategies are driven by internal demands like cost reduction, operational efficiency improvements, innovation, and R&D. They are also influenced by external pressures from evolving client needs and customer-experience requirements.

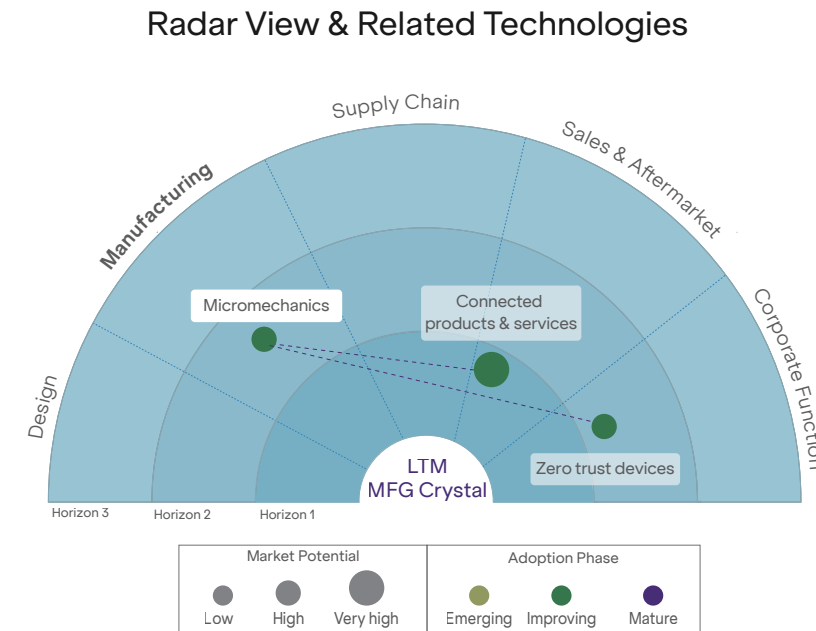
# Micromachines

## Overview

Micromachines or Micro-electro-mechanical Systems (MEMS) are also known as Microsystems Technology (MST) or micromachines. Micromachines is a broad phrase that includes many designs, methods, and processes used to produce tiny mechanical parts at the microscopic level via microfabrication. Connected micromachine technology integrates mechanical components, sensors, actuators, and electronics using microfabrication.

## Highlights

Micromachines are critical for boosting industrial automation by expanding the capabilities of goods like industrial robots. Companies may hesitate to adopt this technology due to high initial expenses and a lack of established practices. Micromachines offer the advantage of widespread sensor connectivity. It is useful for industrial and consumer applications due to its low power consumption and cheap mass manufacturing cost. The increasing number of devices and enhanced functionality enabled by this technology will help the growth of the micromachines market. Its applications in industrial manufacturing include miniature diagnostic sensors, consumer electronics, automotive technology, energy harvesting, and Internet of Things (IoT) applications. Micromachine-induced 3D printing has emerged as a feasible technology for designing creative new structures, allowing for faster and more cost-effective production of current systems.



## Key Application Areas

**Measure physical parameters:** The technology allows increased measuring of physical parameters to implement monitoring and control applications.

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**Measure physical parameters:** The technology allows increased measuring of physical parameters to implement monitoring and control applications, predictions, and planning.

## Key Takeaway

Micromachines are gaining popularity due to ongoing innovations within IoT technology. This will enhance cost, size, and performance in various applications and is expected to expand as industrial manufacturing processes progress toward smaller features and components.

# AI-powered Demand Forecasting

## Overview

AI is vital in enhancing supply chain resilience by improving decision-making and efficiency. AI powered Demand Forecasting in industrial manufacturing can forecast customer demand, optimize inventory and production, and manage the supply chain. The rising popularity of AI and ML has propelled advanced analytics to the forefront of demand forecasting. By scrutinizing vast datasets, these technologies uncover valuable insights into customer behavior. These insights empower organizations to make informed decisions and stay ahead in the competitive manufacturing landscape.

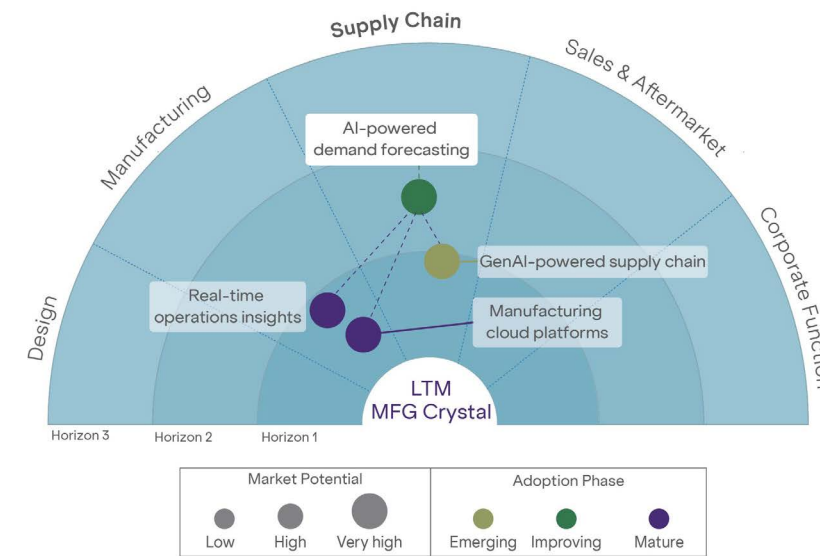
## Highlights

Newer processes and operations always improve the quality, speed, and reliability of the products; but also results in higher chemical and industrial waste discharge in air, water, and soil. Hence, it has become immensely important for industries to track, monitor, and reduce harmful emissions into the environment. International standards, like ISO 14001, have been institutionalized for environmental management. Following these standards, industries can enhance their environmental performance and meet their improvement goals. Another simple but effective model for EMS is the Plan-Do-Check-Act, a basic framework that lays the foundation for setting goals (including compliance goals). Once established, an EMS can always be improved for better efficiency. In addition, embedding IoT sensors receptacles allows AI and machine learning to accurately sort waste, enhancing recycling efficiency and reducing human errors in industrial manufacturing.

## Featured Story

A leading US-based printing and graphics company implemented EMS with the objective of identifying and addressing environmental aspects and developing policies. The company conducted comprehensive activities like setting up a dedicated council to manage EMS, waste ink management, haze removal, and water use. As a result, the company enhanced its compliance with environmental regulations and significantly reduced waste.

Radar View & Related Technologies



## Key Application Areas

**Facility design and engineering:** Before building anything, a virtual design of new equipment or a structure can be created.

**Supply chain integration:** Supply chain partners integrated into the design and production process can provide inputs on component design.

**Simulation and analysis:** Aerodynamic simulations and performance analysis can be performed without a physical prototype.

## Key Takeaway

EMS can benefit industrial manufacturing organizations by providing the framework to allow meaningful and long-lasting changes to be made. Implementing a system of continuous improvement gives organizations the opportunity to consistently raise environmental standards and policies and make a positive impact on people and the planet.

# Transparent Supply Chain

## Overview

A transparent supply chain is the ability to make information from the supply chain accessible to various stakeholders. It helps to understand where and how products are being transformed and transferred. Such a supply chain verifies the origin and movement of materials, components, and final products. Stakeholders such as investors, regulators, customers, and external stakeholders can openly access and leverage the information that helps build trust.

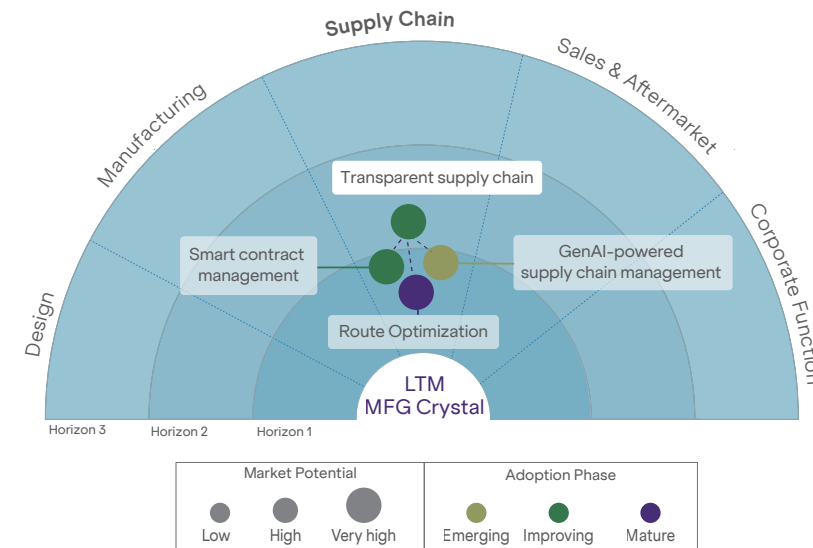
## Highlights

A non-transparent supply chain generally damages reputation and causes the loss of business time and resources. A fully transparent supply chain builds consumer confidence and promotes environmentally friendly sourced and manufactured products. It leverages technologies such as advanced analytics, blockchain, and AI to track and trace goods in the supply chain. An increasing number of customers demand sources of raw materials and are willing to pay extra for sustainably acquired raw materials. According to an IBM survey from 2022 across industries, 73% of consumers voted traceability important to them, and 71% agreed to pay a premium. Newer regulations are constantly being introduced in the industrial manufacturing sector. These regulations require manufacturers to comply with ethical labor practices, due diligence, and sustainably sourced raw materials. This helps increase trust in the manufacturer.

## Featured Story

A Swiss steel wheel manufacturer deployed cloud-based supply chain management solutions and integrated IoT technology embedded with AI capabilities. The aim was to improve visibility across the supply chain and analyze sensor data to predict failures. With fully integrated supply chain and ERP applications, the manufacturer easily streamlined data flow to headquarters, enabling real-time financial management and invoicing.

## Radar View & Related Technologies



## Key Application Areas

**Increased sustainability across the value chain:** The technology promotes sustainable and ethical manufacturing and brand image.

**Improved regulatory compliance:** It helps in navigating regulatory frameworks and compliance.

## Key Takeaway

Many organizations have started incorporating sustainability into their corporate strategy, and this number is expected to grow in the upcoming years. Transparent supply chains are indomitable in enabling sustainability across many industrial manufacturers and their customers.

# Outcome-based Business Models

## Overview

Automated guided vehicles (AGVs) are self-navigating transport systems or load carriers that move autonomously. They eliminate the need for an onboard operator or driver within a warehouse, distribution center, or manufacturing facility. Industrial AGVs, ranging from autonomous forklifts to driverless trucks, are poised to revolutionize logistics and manufacturing processes by enhancing safety, efficiency, and overall quality.

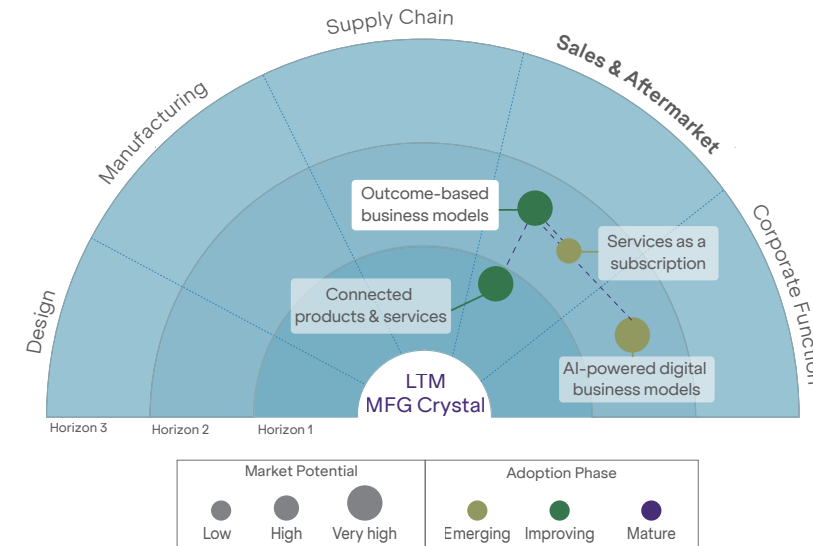
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Radar View & Related Technologies



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EMS can benefit industrial manufacturing organizations by providing the framework to allow meaningful and long-lasting changes to be made. Implementing a system of continuous improvement gives organizations the opportunity to consistently raise environmental standards and policies and make a positive impact on people and the planet.

# Services as a Subscription

## Overview

Service as a subscription (SaaS) is a business model that allows industrial manufacturers to offer their products and services as recurring, flexible, and scalable subscriptions. In response to Industry 4.0 and IoT, manufacturers have increasingly adopted data driven strategies including data analytics for customer insights. The COVID-19 pandemic accelerated these efforts, leading many to shift towards digital, customer-centric approaches, resulting in the rise of subscription service models in industrial manufacturing.

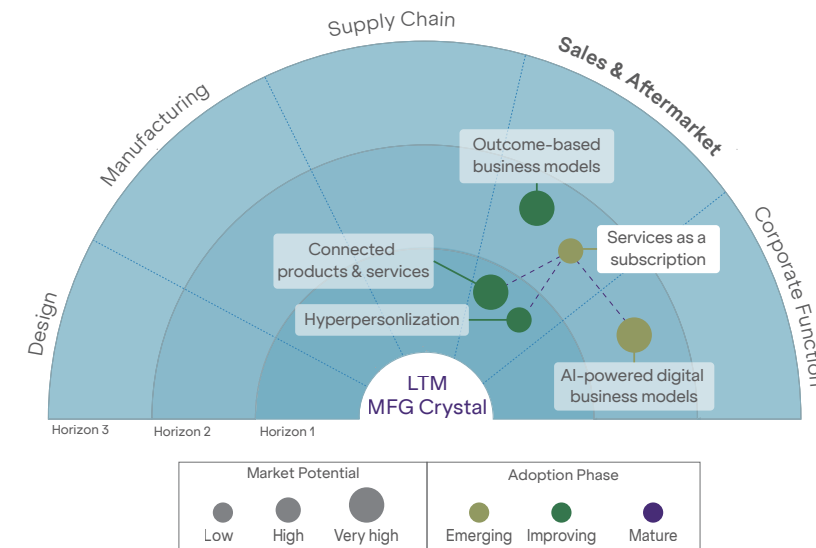
## Highlights

In industrial manufacturing, subscription models are driving recurring revenue by leveraging data to better understand customer needs, fostering loyalty and enabling cost predictability. According to the Business Innovation Observatory of European Commission, over 70% of manufacturers view services as a key differentiator, with service-based models leading to 5 to 10% annual growth and generating half of their revenue. Common subscription-based services include maintenance, equipment monitoring, safety analysis, and location tracking, which help extend product lifespan and reduce operation costs. The rise of IoT and software integrations demand continuous collaboration between manufacturers and customers, emphasizing mutual dependency. In future, as services as a subscription model grows, emerging trends will likely standardize contracts, blending aspects of hire, maintenance, and software subscriptions.

## Featured Story

A U.S. based leading construction and mining equipment manufacturer offers a subscription-based service that provides remote monitoring, predictive maintenance alerts, and performance analytics for their machinery. Customers benefit from real-time insights into equipment health and usage enabling them to optimize operations, reduce downtime, and manage cost effectively. The subscription also includes regular software updates and dedicated technical support for uninterrupted performance.

Radar View & Related Technologies



## Key Application Areas

|   |   |  |
|---|---|--|
| <p><b>Predictive Maintenance:</b> Schedule repairs using IoT data, minimizing downtime.</p> | <p><b>Equipment Monitoring and Optimization:</b> Track performance to enhance efficiency and longevity.</p> | <p><b>Software and Analytics Access:</b> Provide subscription-based access to advanced analytics tools</p> |
|---|---|--|

## Key Takeaway

Before investing in a subscription model, industrial manufacturers should prioritize customer centricity by ensuring uptime, competitive pricing, and adaptability to shifting demands and crises, maintaining reliability and service excellence.

# Green Building

## Overview

Green building involves using resource-efficient and environmentally responsible processes throughout a building's life cycle, from design to renovation and deconstruction. It aims to reduce energy consumption, water usage, and waste generation while minimizing harmful emissions. Green buildings prioritize the use of locally sourced material with low embodied energy, recycled content, and certifications such as Forest Stewardship Council for wood products.

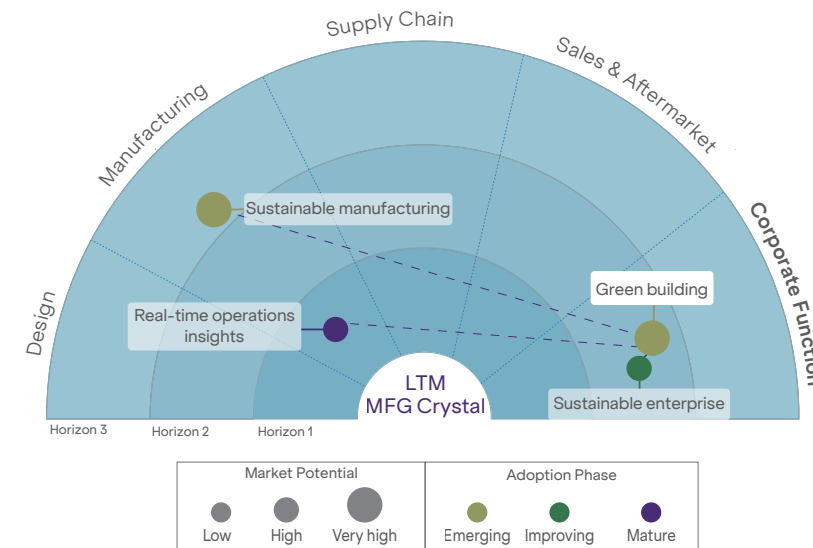
## Highlights

According to a recent report by Anarock, a leading Indian real estate services company, green buildings can minimize energy consumption by 20-30% and water usage by 30-50%. Green buildings have a lower carbon impact on the environment compared to traditional structures and cost about 3% - 5% higher than conventional buildings. They are designed to maximize operational efficiency and productivity. Features such as efficient lighting, HVAC systems, and automation improve workflow, and facility performance. Technologies such as generative AI can potentially change the way green buildings are designed and built. With the use of AI algorithms, the orientation of a building can be optimized to maximize energy efficiency and minimize energy consumption. Additionally, generative AI can also be leveraged to optimize the use of materials and resources in building construction. This will help reduce waste and improve the sustainability of the building.

## Featured Story

A well-known HVAC manufacturer implemented green building practices by selecting energy-efficient air-conditioning systems tailored for different areas. They used multi-split VRV systems with adjustable power consumption for offices and an air-cooled inverter liquid chiller for factories. Standalone wall-mounted split systems were used for individual function rooms, all designed for optimal comfort with minimal carbon emissions.

Radar View & Related Technologies



## Key Application Areas

**Energy efficient design:** Features such as insulated building envelop and high-efficiency lighting systems reduce energy consumption.

**Water conservation:** Installing water-efficient fixtures and closed-loop water systems reduce water consumption and minimize wastewater generation.

**Waste reduction and recycling:** Landfill waste is minimized, leading to resource conservation.

## Key Takeaway

Integrating green building principles in manufacturing facilities can help industrial manufacturers enhance environmental performance and comply with regulations. They can save costs and also contribute to long-term sustainability by reducing energy and water consumption.

# Immersive Training

## Overview

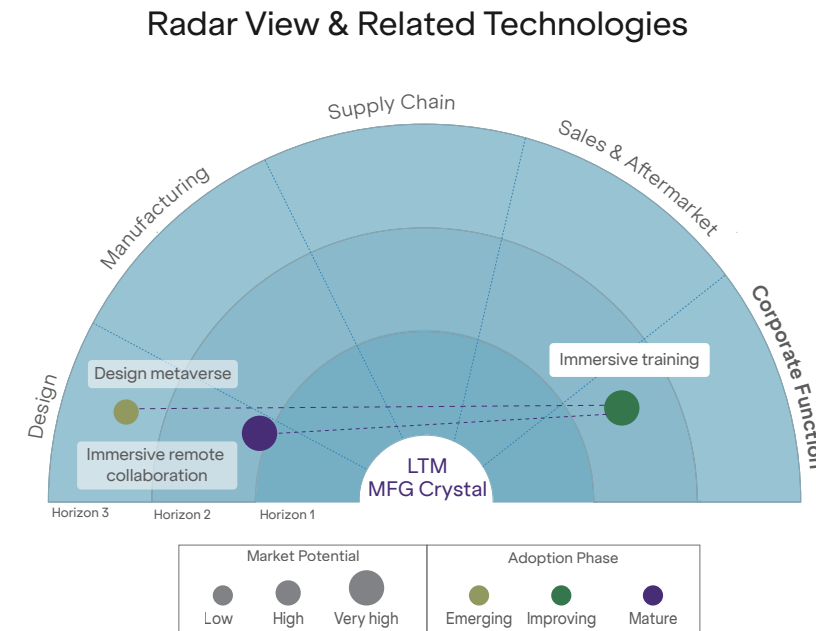
Immersive training is a strategy that uses both AR and Virtual Reality (VR) to imitate real-world scenarios while teaching workers in a safe, engaging, and immersive training environment. Its benefits are many, ranging from cheaper training costs and improved knowledge retention to quicker item delivery and more efficient assembly lines and maintenance activities.

## Highlights

There is a significant transformation occurring in the user experience about how workers are receiving training in the digital space. Users' perspectives are changing due to AI and interactive technologies like AR, VR, and MR. In the industrial business, this transformation is creating multisensory user experiences. Training workers for tasks like simulation training, product training, expert coaching, facility management training, safety product training, and expert capture can be quite challenging. Employers frequently educate employees on safety precautions through instructional videos and written manuals. Utilizing AR and VR in training and preparation significantly reduces the occurrence of workplace accidents. According to Ford's research, leveraging VR training significantly reduced employee injuries by 70%.

## Featured Story

A Swiss multinational food and drink manufacturing firm leveraged immersive solutions to arrange virtual reality tours of its premises. The tours gave salesmen the opportunity to see how the company makes its pet food items. This gave them a better grasp of the manufacturing process, educated them, and hence inspired more trust in their customers. The scattered team may now convene in the same virtual space and conduct training sessions and meetings using dynamic tools such as whiteboards.



## Key Application Areas

**Safety training:** Virtual reality simulations enable learners to demonstrate safety practices in a controlled setting.

**Employee instruction and training:** It is possible to create simulations of work settings or tasks that workers will have to accomplish.

**360-degree virtual factory tours for onboarding:** New hires may use a VR headset to explore the manufacturing facility's layout, process, and key areas.

## Key Takeaway

Augmented and virtual reality are transforming industrial training. Interactive equipment simulations and virtual factory tours help workers learn and prepare more effectively. Immersive training will become more vital as technology advances and new relevant applications emerge in various fields.

# Sustainable Enterprise

## Overview

Environmental management systems (EMS) are comprised of the practices, policies, and procedures that organizations undertake to comply with local, state, and/or federal environmental legislation. This includes monitoring and regulating the release of chemicals and other by-products of industrial processes into the local air, water, or waste streams. It is one of the most efficient ways to reduce an organization's negative impact on the environment.

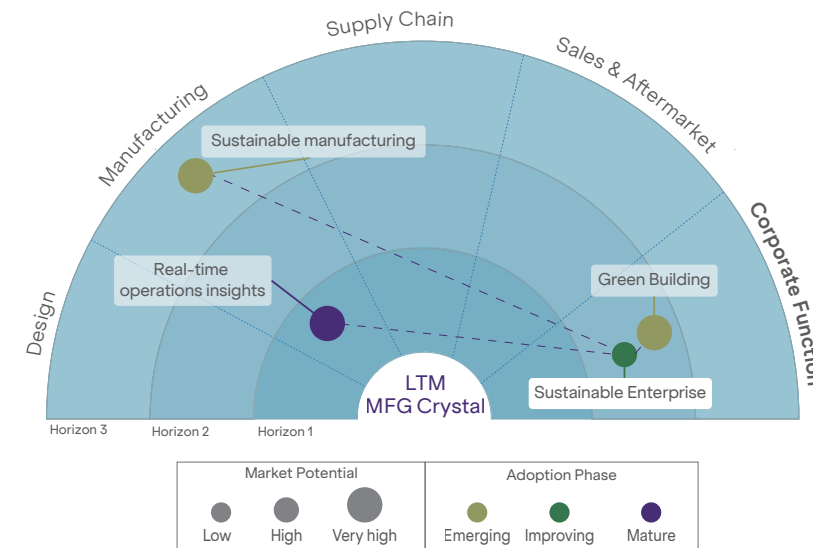
## Highlights

Newer processes and operations always improve the quality, speed, and reliability of the products; but also results in higher chemical and industrial waste discharge in air, water, and soil. Hence, it has become immensely important for industries to track, monitor, and reduce harmful emissions into the environment. International standards, like ISO 14001, have been institutionalized for environmental management. Following these standards, industries can enhance their environmental performance and meet their improvement goals. Another simple but effective model for EMS is the Plan-Do-Check-Act, a basic framework that lays the foundation for setting goals (including compliance goals). Once established, an EMS can always be improved for better efficiency. In addition, embedding IoT sensors receptacles allows AI and machine learning to accurately sort waste, enhancing recycling efficiency and reducing human errors in industrial manufacturing.

## Featured Story

A leading US-based printing and graphics company implemented EMS with the objective of identifying and addressing environmental aspects and developing policies. The company conducted comprehensive activities like setting up a dedicated council to manage EMS, waste ink management, haze removal, and water use. As a result, the company enhanced its compliance with environmental regulations and significantly reduced waste.

Radar View & Related Technologies



## Key Application Areas

**Regulatory compliance:** A robust EMS helps organizations adhere to compliance requirements from local/state authorities.

**Emission tracking:** It helps in tracking and recording industrial waste.

**Industrial hazardous materials tracking systems**

## Key Takeaway

EMS can benefit industrial manufacturing organizations by providing the framework to allow meaningful and long-lasting changes to be made. Implementing a system of continuous improvement gives organizations the opportunity to consistently raise environmental standards and policies and make a positive impact on people and the planet.

# Zero Trust Devices

## Overview

Increased usage of IoT, cloud computing, and other technologies in the manufacturing space has led to a large number of connected devices. These devices could be unsecured or prone to attacks, resulting in risks to the business. A zero-trust approach incorporates various safety measures such as device trustworthiness, embedded security, certificate lifecycle management, authentication, etc. A holistic zero-trust implementation ensures trusted digital credentials at every step of the supply chain.

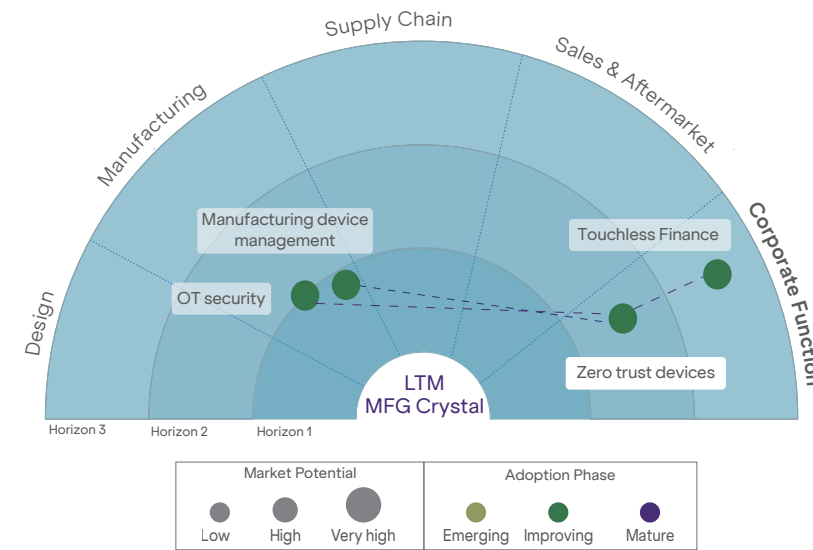
## Highlights

According to an IBM report, the average global cost of a data breach in the manufacturing sector in 2022 amounted to USD 4.35 million. Manufacturing facilities are becoming more interconnected, with numerous devices, sensors, and endpoints communicating over networks. Therefore, it is imperative to prioritize the implementation of a zero-trust approach within manufacturing plants to safeguard sensitive information and operations. Zero-trust policies at the device level mandate continuous verification of identity, authorization, and context before allowing any modifications to the control system. It safeguards against the misuse of stolen credentials, ensuring that users are limited to specific programmable logic controllers (PLCs) and functions based on their assigned roles. To enable troubleshooting, identity credentials can be issued, granting access solely to designated PLCs for specific functions. Any attempts to operate beyond the permitted parameters are automatically blocked.

## Featured Story

A leading Japanese multinational manufacturing company undergoing restructuring adopted the Secure Access Service Edge (SASE) framework. It was set up alongside a cloud-based security system offered by a leading digital communication organization. Through SASE, the manufacturing company successfully linked over 155,000 devices to the cloud securely and efficiently. Additionally, they utilized the digital communication organization's cloud-delivered security service edge (SSE) solution to authenticate all network-connected devices.

Radar View & Related Technologies



## Key Application Areas

**Facility design and engineering:** Before building anything, a virtual design of new equipment or a structure can be created.

**Supply chain integration:** Supply chain partners integrated into the design and production process can provide inputs on component design.

**Simulation and analysis:** Aerodynamic simulations and performance analysis can be performed without a physical prototype.

## Key Takeaway

It is crucial for manufacturers to prioritize zero-trust protection based on the potential impacts. When considering investments, as operational reliability of the plant floor hinges on the reliability of its PLCs. Once zero-trust is in place, the control systems, IoT devices, sensors on the plant floor are completely secure, enabling the manufacturer to enhance security throughout the production networks.



Trend Will Take More than 3 Years to  
Reach Industrialization State

# Design Metaverse

## Overview

In industrial manufacturing, the concept of a design metaverse refers to a virtual environment where all aspects of product design and production are integrated and interconnected. Different tools and technologies, such as computer-aided manufacturing, product lifecycle management, IoT, and AI, are utilized to facilitate design iteration and optimization, simulation, and analysis, as well as collaborative workflows.

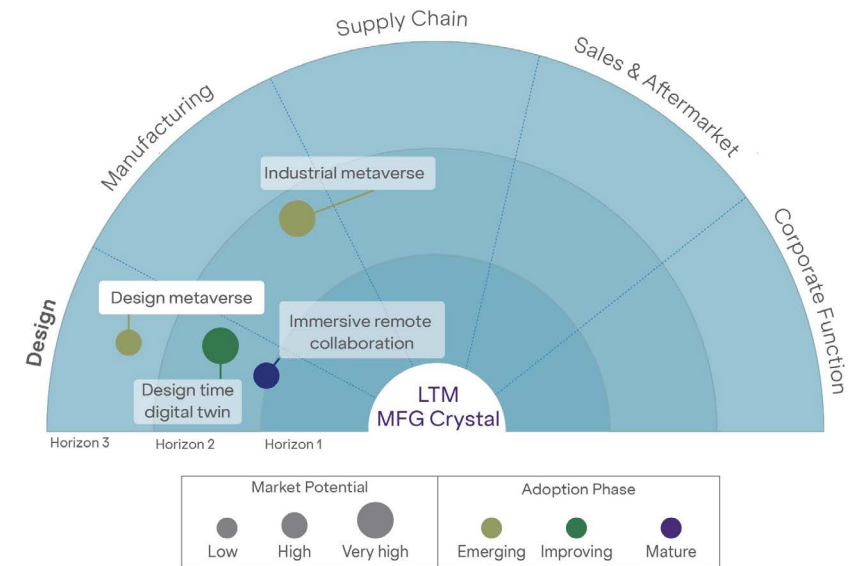
## Highlights

Metaverse has huge potential to enable businesses to interact with detailed virtual representations of products, machinery, and entire production facilities. It helps optimize product designs and make data-driven decisions. The industrial metaverse is being driven by advanced technologies such as digital twins, AI and ML, extended reality, blockchain, as well as cloud and edge computing. These innovations have progressed to the point where they can revolutionise the manufacturing sector by seamlessly merging the digital and physical realms. Virtual Reality (VR) is another technology that augments the capabilities of the metaverse. It gives design engineers the flexibility to create industrial designs with precise detailing. They can use virtual reality to see the product in a real-world setting, interact with it, and modify the design. This approach saves time and reduces the physical prototyping costs. Overall, the metaverse provides designers and engineers with new perspectives and ideas, allowing them to create more innovative and functional designs.

## Featured Story

A global EPC (Engineering, Procurement, and Construction) company faced the challenge of increased error possibility. They were viewing building information modeling (BIM) data on small PC monitors and mobile devices. To tackle this issue, they leveraged the design metaverse, which allowed them to use a VR device to gain immersive design viewing on a 1:1 scale. The implementation facilitated collaboration in VR design reviews among internal reviewers or customers across remote locations.

Radar View & Related Technologies



## Key Application Areas

**Facility design and engineering:** Before building anything, a virtual design of new equipment or a structure can be created.

**Supply chain integration:** Supply chain partners integrated into the design and production process can provide inputs on component design.

**Simulation and analysis:** Aerodynamic simulations and performance analysis can be performed without a physical prototype.

## Key Takeaway

The design metaverse has the potential to transform the entire product development lifecycle. It can enable manufacturers to achieve faster time to market, higher product quality, enhanced collaboration, and improved customer satisfaction.

# Industry 5.0

## Overview

Industry 5.0 is a new phase of industrialization that goes beyond mere efficiency and productivity. It prioritizes the well-being of workers and places them at the heart of the production process. By harnessing new technologies like AI and automation, it aims to create prosperity beyond employment and economic growth while transitioning towards a sustainable, human-centered, and resilient industry.

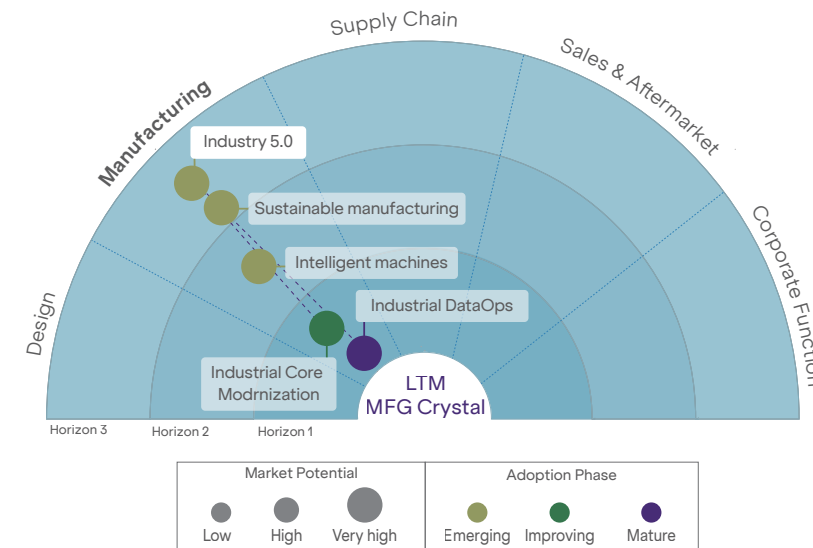
## Highlights

Industry 5.0 aims to harness the potential of cutting-edge digitalization, big data, and artificial intelligence (AI) to enhance production flexibility during periods of upheaval. The target is to fortify value chains, prioritize worker-centric technology, and promote circularity and sustainability. Industry 5.0 will augment the organization's journey with a sharp focus on areas like worker empowerment that would cover human-machine interaction, upskilling of workers, and enablement with digital devices and automation. Some notable examples of worker empowerment include FACTS4WORKERS, EVRYON, Human Manufacturing, etc. Ensuring security in Industry 5.0 will pose a significant challenge. The authentication methods utilized in the industry are essential for enabling seamless interaction with various devices and safeguarding against future quantum computing advancements in deploying IoT nodes. A unified namespace (UNS) is crucial for industrial digital transformation. It enables real-time data integration, improved decision-making, interoperability, and advanced technologies fostering efficiency, innovation, and agility for Industry 5.0.

## Featured Story

A UK-based technical injection molding company adopted the Matics platform to improve mold maintenance, control over mold usage, and overall production efficiency. The platform enabled real-time production monitoring, better productivity, and organization-wide communication. Matics increased the firm's process and production efficiency. This has helped to achieve Industry 4.0, which emphasizes human-machine collaboration to optimize production, operations, and boring activities.

Radar View & Related Technologies



## Key Application Areas

**Human-robot collaborative assembly:** The solution increased the robot's collaboration skills, such as load sharing and human touch recognition, to increase its adaptability.

**Remote monitoring:** Greater remote monitoring systems to enhance defect detection and prediction.

**Hyper-customization:** Increased cooperation between COBOTS and humans helps meet the hyper-personalization and hyper-customization needs.

## Key Takeaway

Robotics and analytics are expected to improve decision-making processes, optimize production, and promote circularity and sustainability initiatives, thus promoting Industry 5.0. How organizations manage human-robot collaborations and utilize data to generate insights and make timely decisions will determine the return on investments.

# Sustainable Manufacturing

## Overview

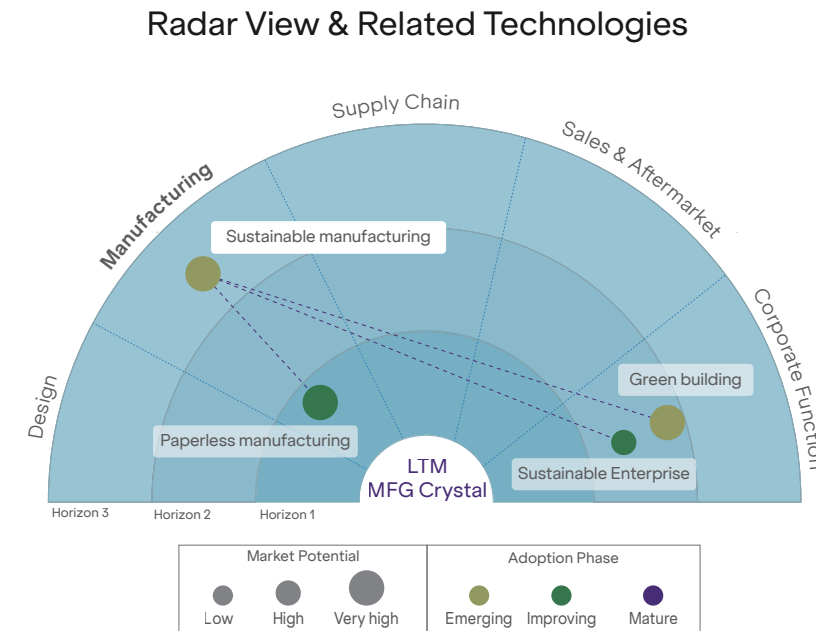
Industry 5.0 is a new phase of industrialization that goes beyond mere efficiency and productivity. It prioritizes the well-being of workers and places them at the heart of the production process. By harnessing new technologies like AI and automation, it aims to create prosperity beyond employment and economic growth while transitioning towards a sustainable, human-centered, and resilient industry.

## Highlights

Industrial manufacturing plants relying on energy can enhance sustainability by transitioning to renewable sources like solar, wind, and hydrogen. The shift bolsters companies' green credentials. Governments encourage manufacturing companies to deploy sustainable practices and invest in renewable energy sources. Following the Inflation Reduction Act of 2022 (IRA), the US invested USD 91 billion in over 200 manufacturing projects. They included 38 solar projects, 27 storage projects, 14 wind projects, and six hydrogen projects. The aim was to boost solar, wind, and storage deployment to 850 GW by 2030. In addition, automation aids in emission control through devices like Continuous Emissions Monitoring Systems (CEMS) and carbon capture systems. Smart automation, AI, and the IIoT can enhance sustainability. It reduces energy usage, cuts costs, and enables predictive analytics for resource efficiency, waste reduction, and maintenance optimization.

## Featured Story

A reputed Danish provider of insulation services and the highest-quality stone wool products integrated the IIoT platform with production machinery. This has enabled accurate identification and control of the production process, helping the company improve quality and operational efficiency. The company reduced its production waste by 20%, taking the first step towards its sustainability goals.



## Key Application Areas

**Cobots:** Reduce waste by performing complex tasks accurately and consistently.

**Remote monitoring:** Greater remote monitoring systems to enhance defect detection and prediction.

**AI:** Optimize performance, detect defects, and prevent machinery failure.

## Key Takeaway

Introducing sustainability initiatives entails mapping emissions, identifying priority areas, and transforming the industrial ecosystem. Embracing sustainable manufacturing prompts innovation, actionable goals, and a transformative journey toward a promising future.

# Factory in a Box

## Overview

A Factory in a Box (FIAB) is a modular manufacturing supply chain network that leverages industrial digital technologies. It enhances agility, modularity, mobility, and production without affecting quality and safety. FIAB units are generally located closer to the market and consumers to achieve just-in-time delivery. Its solution includes assembly robots, IoT sensors, and other automated machinery.

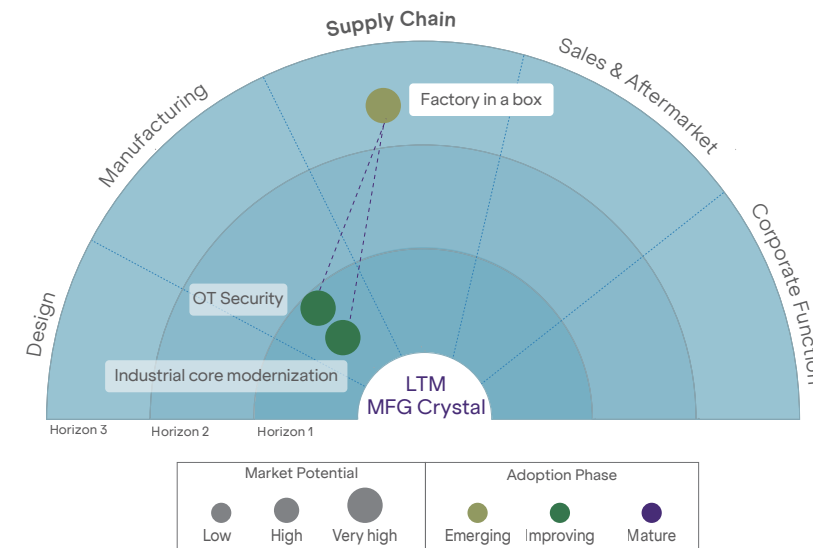
## Highlights

FIAB can reinvent the supply chain scenarios and may serve as the pioneer of Industry 4.0. A FIAB is expected to empower machines to work without human supervision. This can be achieved by deploying robotics and sensors connected to a network. FIAB systems can make automated decisions based on performance data through this network. Additionally, integrating technologies like AI and IIoT will enable FIAB to enhance process optimization, accuracy, and productivity. However, FIAB implementation comes with challenges. They include pacing the legacy system transformation to match the latest technologies and cybersecurity concerns stemming from digitalization, particularly to facilitate remote operations. A skill gap is also a significant challenge, especially in developing countries.

## Featured Story

A major Indian IT services provider implemented a test Factory in a Box for a global pharma company. The deployment involved standardizing processes. A metrics dashboard, including Live Defect and Test Metrics, was made available to the project and leadership team. Test Utilities RAT (Regulations Acceptance Testing) and RBT (Risk-based testing) helped with early defect detection and reduced report generation effort. Overall, the client achieved a 22% efficiency gain.

## Radar View & Related Technologies



## Key Application Areas

**Rapid new product introduction:** Movement of “Factory in a Box” to partners expedites prototyping.

**Training:** It provides hands-on experience in manufacturing processes and equipment.

**Micro-factory concept:** It is a small-scale production unit for niche products.

## Key Takeaway

FIAB, with its rapid deployment of manufacturing capabilities, can be considered a key to a globally decentralized supply chain. Although the adoption of FIAB is slow at present, it is expected to pick up gradually over the next few years.

# Touchless Finance

## Overview

Touchless Finance employs a machine-learning engine to continuously monitor and clean invoice records and make real-time predictions, allowing for more efficient operations. It can enhance accuracy and compliance in financial processes by eliminating manual data entry. Additionally, this technology provides real-time insights and analytics, offering decision-makers valuable information to support strategic initiatives.

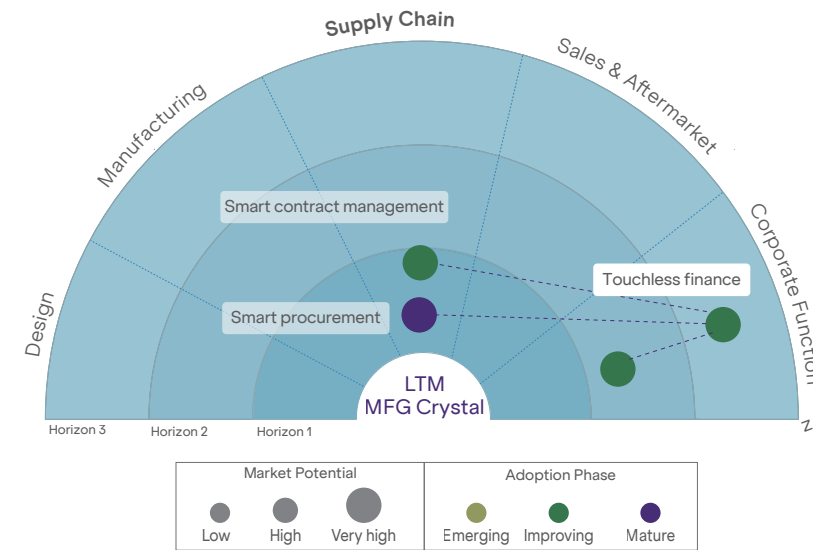
## Highlights

Touchless finance trends in industrial manufacturing improve efficiency and reduce costs in accounts payable processes. These developments rely on advanced automation systems, such as robotic process automation (RPA) and AI, to eliminate manual procedures and errors in financial transactions. This technology enhances financial processes by replicating offline operations, such as manual data entry, through automated systems. Additionally, it automatically notifies approvers, matches purchase orders (POs), and streamlines tasks to minimize errors. Furthermore, in procurement, touchless finance aids in reducing late payments to suppliers and establishing recurring expense payment schedules. The technology determines precise purchase volumes for discounts and facilitates the exchange of financial data and documents such as invoices, purchase orders (POs), and contracts.

## Featured Story

LTIMindtree automated financial operations for a high-end brokerage and wealth management customer. The client's difficulties included numerous modifications to the current ERP, which resulted in higher updates and maintenance costs. The ERP also lacked digital features and connected dashboards for real-time analytics. LTIMindtree presented a solution that provided a framework for successful remote working and touchless ERP experiences with a one-click data transfer tool and test automation platform.

Radar View & Related Technologies



## Key Application Areas

**Document data capture assistant with vision and voice:** The assistant is trained to read, extract, and learn from every document.

**Automate the account payable process:** PO-based invoices can be automatically approved and posted if the data matches the supporting documents.

**Improve invoice data quality:** Setting up KPIs to monitor and measure supplier invoice quality can make all the difference.

## Key Takeaway

The future of financial operations will involve touchless, data-driven, and intelligent finance factories digitizing large volumes of data, necessitating CFOs to understand how to generate value in this digital economy.

# AI-powered Digital Business Models

## Overview

In recent years, digital business models have surfaced as groundbreaking alternatives to conventional approaches. Characterized by their use of digital technologies and online platforms, these models unlock unparalleled opportunities for innovation, scalability, and global reach. Adopting digital transformation has become crucial for businesses aiming to succeed in today's economy. In our interconnected world, where technological advancements are happening at a rapid pace, AI Powered digital business models are propelling numerous manufacturers towards success.

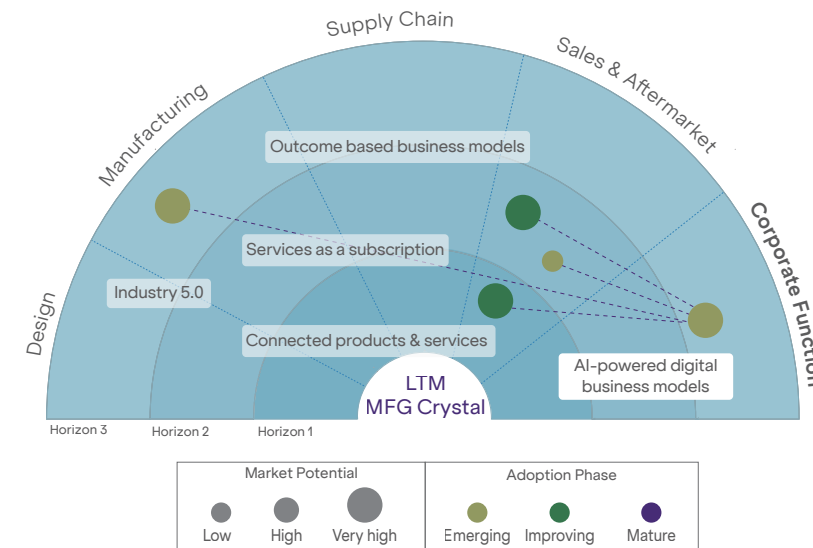
## Highlights

The advent of AI has profoundly transformed digital business models, presenting new opportunities for growth and operational efficiency. AI powered Digital business model innovation builds on the positive effects of digitalization; beyond efficiency improvements, manufacturers can explore new products and services, markets, and segments and internationalize operations. AI-driven analytics offer deep insights into customer behavior, facilitating personalized experiences and targeted marketing strategies. It automates routine tasks, boosting operational efficiency and cutting costs, and it enables the development of innovative products and services, thereby unlocking new revenue streams. Implementing AI-driven bots and systems to automate routine tasks results in significant cost reductions and operational efficiencies. AI-powered predictive maintenance can anticipate equipment failures and schedule timely interventions, thereby minimizing downtime and lowering maintenance expenses.

## Featured Story

A global industrial manufacturer enhanced its digital workplace experience by introducing a no-code chatbot to address sign-in problems within its corporate finance team. The solution autonomously consolidated and validated data from various sources across the company. This development resulted in higher employee satisfaction, a 30% reduction in login requests, and quicker workforce re-engagement. Consequently, IT costs decreased, enabling reinvestment into both external and internal innovations.

Radar View & Related Technologies



## Key Application Areas

**Improved Supply Chain:** Significant improvements in efficiency, accuracy, and cost-effectiveness.

**Cobort:** Increased productivity by navigating intricate areas and identifying objects.

**Assembly line optimization:** Reduce downtime & improve workflows by analyzing past metrics data.

## Key Takeaway

Conventional manufacturing methods frequently result in the exploitation of resources and labour. Advanced AI and digital technologies have the potential to create innovative product and service models that are not only commercially sustainable but also transformative. Digital business models powered by AI are driving many manufacturers to invest in new business models despite economic uncertainty.

## About LTM Crystal

LTM Crystal brings 'Beyond-The-Horizon' technologies to cross-industry enterprises. It presents exciting opportunities for future-ready businesses keen to make faster and smarter decisions on existing and emerging technology trends.

LTM Crystal is an output of rigorous research by our team of next-gen technology experts and meticulously rated by our Technology Council across a set of parameters.

For any queries and suggestions, please write to [crystal@ltm.com](mailto:crystal@ltm.com)

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### Technology Council

Technology Council is a formal body composed of experts and leaders, from various units.

|                              |                           |                        |                           |                        |                               |                      |
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|                          |                         |                      |                    |                          |                     |
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### Editorial, Design and Marketing

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# Glossary

|              |  |
|--------------|--|
| <b>3D</b>    | Three-dimensional                          |
| <b>5G</b>    | 5th Generation of mobile network           |
| <b>AGVs</b>  | Automated Guided Vehicles                  |
| <b>AI</b>    | Artificial Intelligence                    |
| <b>AMI</b>   | Advanced Manufacturing International       |
| <b>AMR</b>   | Autonomous Mobile Robots                   |
| <b>AR</b>    | Augmented Reality                          |
| <b>AS/RS</b> | Automated Storage and Retrieval Systems    |
| <b>AWS</b>   | Amazon Web Services                        |
| <b>BIM</b>   | Building Information Modelling             |
| <b>BYOD</b>  | Bring Your Own Device                      |
| <b>CAD</b>   | Computer-aided Design                      |
| <b>CEMS</b>  | Continuous Emissions Monitoring Systems    |
| <b>CFS</b>   | Connected Field Services                   |
| <b>DdoS</b>  | Distributed Denial-of-Service              |
| <b>EMS</b>   | Environmental Management System            |
| <b>EPC</b>   | Engineering, Procurement, and Construction |
| <b>ERP</b>   | Enterprise Resource Planning               |
| <b>FIAB</b>  | A Factory in a Box                         |
| <b>GenAI</b> | Generative AI                              |
| <b>HVAC</b>  | Heating, Ventilating, And Air Conditioning |
| <b>IoT</b>   | industrial Internet of Things              |

|                   |  |
|-------------------|--|
| <b>IRA</b>        | Inflation Reduction Act of 2022                          |
| <b>ISO</b>        | International Organization for Standardization           |
| <b>IT</b>         | Information Technology                                   |
| <b>IT -OT -IT</b> | (Information Technology) and OT (Operational Technology) |
| <b>KBE</b>        | Knowledge based Engineering                              |
| <b>KM</b>         | Knowledge Management                                     |
| <b>KPIs</b>       | Key Performance Indicators                               |
| <b>MDM</b>        | Manufacturing Device Management                          |
| <b>MEMS</b>       | Micro Electro Mechanical System                          |
| <b>ML</b>         | Machine Learning   |
| <b>MR</b>         | Mixed Reality  |
| <b>MTTR</b>       | Mean Time To Repair                                      |
| <b>NLG</b>        | Natural Language Generation                              |
| <b>OEE</b>        | Overall Equipment Efficiency                             |
| <b>OEM</b>        | Original Equipment Manufacturer                          |
| <b>OT</b>         | Operational Technology                                   |
| <b>PLC</b>        | Programmable Logic Controller's                          |
| <b>POs</b>        | Purchase Orders  |
| <b>RAT</b>        | Regulations Acceptance Testing                           |
| <b>RBT</b>        | Risk-based testing                                       |
| <b>RFID</b>       | Radio Frequency Identification                           |
| <b>RPA</b>        | Robotic Process Automation                               |
| <b>SaaS</b>       | Software as a Service                                    |
| <b>SAP</b>        | SAP SE is a German Multinational Software Company        |
| <b>SASE</b>       | Secure Access Service Edge                               |
| <b>TAC</b>        | Transport Access Control                                 |

|            |                              |
|------------|------------------------------|
| <b>USD</b> | US Dollar                    |
| <b>VR</b>  | Virtual Reality              |
| <b>WMS</b> | Warehouse Management Systems |
| <b>ZTE</b> | Zero Touch Enrolment         |

# References

- **The metaverse's impact on manufacturing: Applications and use cases**, Pooja Kumari, Softweb Solutions Inc, June 23, 2023: <https://www.softwebsolutions.com/resources/use-cases-of-industrial-metaverse.html>
- **How the Metaverse will influence the manufacturing sector**, Ramya Kannan, UST Global: <https://www.ust.com/en/insights/how-the-metaverse-will-influence-the-manufacturing-sector>
- **6 industrial metaverse use cases for manufacturing**, Mary K. Pratt, TechTarget, March 29, 2024: <https://www.techtarget.com/searcherp/feature/Industrial-metaverse-use-cases-for-manufacturing>
- **How Generative Design is Revolutionizing Manufacturing**, Nilesch More, March 22, 2024: <https://www.linkedin.com/pulse/how-generative-design-revolutionising-manufacturing-nilesch-more-ip9cf>
- **The time for the industrial metaverse could be right now**, Deloitte, November 13, 2023: <https://action.deloitte.com/insight/3630/the-time-for-the-industrial-metaverse-could-be-right-now>
- **Industrial metaverse and its impact in manufacturing**, PwC, 2023: <https://www.pwc.in/assets/pdfs/emerging-tech/metaverse/industrial-metaverse-and-its-impact-in-manufacturing.pdf>
- **Why industrial manufacturing will save the metaverse from extinction**, Susan Galer, Forbes, September 13, 2023: <https://www.forbes.com/sites/sap/2023/09/13/why-industrial-manufacturing-will-save-the-metaverse-from-extinction/?sh=5e8a0f324654>
- **Unlocking potential: the industrial metaverse and the rise of the digital twin**, XR LABS, May 25, 2023: <https://xrlabs.co/industrial-metaverse-rise-of-digital-twin/>
- **A global EPC company undertakes immersive design reviews with 3D models and VR**, Infosys: <https://www.infosys.com/industries/engineering-procurement-construction/case-studies/global-epc-company.html>
- **Digital twins: The key to smart product development**, Argolini, Federico Bonalumi, Johannes Deichmann, Stefania Pellegrinelli, McKinsey, July 31, 2023: <https://www.mckinsey.com/industries/industrials-and-electronics/our-insights/digital-twins-the-key-to-smart-product-development>
- **Digital Twin and Virtual Twin: How the technology paths can help enhance quality, efficiency, sustainability**, Kriti Saraiya, Economic Times, February 13, 2024: <https://auto.economictimes.indiatimes.com/news/auto-technology/digital-twin-and-virtual-twin-how-the-technology-paths-can-help-enhance-quality-efficiency-sustainability/107653305>
- **Digital twins: The next frontier of factory optimization**, McKinsey & Company, Sean Camarella, Michael P. Conway, Kevin Goering, Mark Huntington, January 10, 2024: <https://www.mckinsey.com/capabilities/operations/our-insights/digital-twins-the-next-frontier-of-factory-optimization>
- **Why will intelligent digital twins become an industrial manufacturing must-have?**, Deepak Singh, Plant Engineering, August 22, 2023: <https://www.plantengineering.com/articles/why-will-intelligent-digital-twins-become-an-industrial-manufacturing-must-have/>
- **Industry 4.0: Guide to Smart Manufacturing with Digital Twin Technology**, Matterport, March 7, 2024: <https://matterport.com/learn/digital-twin/manufacturing>
- **Digital twin in manufacturing Use-Cases Blog**, Andrey Koptelov, Itransition, April 5, 2022: <https://www.itransition.com/blog/digital-twin-manufacturing>
- **The Digital Twin Approach**, LTIMindtree Case studies, Dec 2018: <https://www.ltimindtree.com/wp-content/uploads/2018/12/Predictable-Future-The-Digital-Twin-Approach.pdf>
- **Connected Pump for Leading Pump Manufacturer in US**, LTIMindtree Case studies, December 2017: [https://www.ltimindtree.com/wp-content/uploads/2017/12/Connected-Pumps\\_Manufacturing.pdf](https://www.ltimindtree.com/wp-content/uploads/2017/12/Connected-Pumps_Manufacturing.pdf)
- **Generative AI in manufacturing: Use cases, benefits and development**, Akash Takyar, LeewayHertz: <https://www.leewayhertz.com/generative-ai-in-manufacturing/>
- **Generative AI for Virtual Prototyping: Accelerating Product Development Across Industries**, Nellaiappan L, MacroSoft™: <https://www.macrosoftinc.com/generative-ai-for-virtual-prototyping/>
- **Here's how designers are using AI in product design**, Oriol Banús, LogRocket, Jan 24, 2024: <https://blog.logrocket.com/ux-design/how-designers-use-ai-product-design/>
- **Immersive technology increases manufacturers' productivity by 20%**: Red-Fern, Sean Redfren, British Chambers of Commerce, July 11, 2022: <https://www.chamberelancs.co.uk/2022/07/4-benefits-of-being-a-sustainable-manufacturer-red-fern-member-news-2/>
- **How 360° remote collaboration is transforming the manufacturing space**, Devon Copley, Smart Industry, January 18, 2022: <https://www.smartindustry.com/examples-of-transformation/control-optimization/article/11288799/how-360-remote-collaboration-is-transforming-the-manufacturing-space>
- **ERGO Implements Virtual Reality Technology to Enhance Remote Collaboration & Training**, Arthur Technologies, March 29, 2023: <https://www.arthur.digital/blog/ergo-implements-virtual-reality-technology-to-enhance-remote-collaboration-training>
- **Logistics Execution in Industry 4.0**, Deloitte, 2023: [https://www2.deloitte.com/content/dam/Deloitte/de/Documents/technology/Deloitte\\_Logistics%20Execution%20in%20Industry%204.0.pdf](https://www2.deloitte.com/content/dam/Deloitte/de/Documents/technology/Deloitte_Logistics%20Execution%20in%20Industry%204.0.pdf)
- **Advanced Logistics in the Factory of the Future**, Daniel Küpper et al., BCG, November 08, 2022: <https://www.bcg.com/publications/2022/advanced-logistics-systems-in-factory-of-the-future>
- **Case Study: AGV Accelerates Efficiency at Toyota Motor Manufacturing**, MasterMover, 2024: <https://www.mastermover.com/case-studies/agv-accelerates-efficiency-at-toyota-case-study>
- **The Power of IT-OT Convergence in Manufacturing**, NC-Vision, December 15, 2023: <https://nc-vision.com/the-power-of-it-ot-convergence-in-manufacturing/#:~:text=IT%2FOT%20convergence%20is%20the,in%20enterprise%20and%20industrial%20operations.>
- **Boost productivity and sustainability with shop floor integration**, Siemens Digital Industries, March 2023: <https://static.sw.cdn.siemens.com/siemens-disw-assets/public/3dT5v3syZ0iuHlepHeMB7N/en-US/Boost%20productivity%20and%20sustainability%20with%20IT-OT%20integration.pdf>
- **Transforming manufacturing through IT/OT convergence**, Engineering.com, March 13, 2024: <https://www.engineering.com/story/transforming-manufacturing-through-it-ot-convergence>
- **Manufacturing Industry Expected to be Fundamentally Transformed by Industrial Metaverse**, Deloitte, September 14, 2023: <https://www2.deloitte.com/us/en/pages/about-deloitte/articles/press-releases/manufacturing-industry-expected-to-be-fundamentally-transformed-by-industrial-metaverse.html>
- **2024 manufacturing industry outlook**, Deloitte Research Center for Energy & Industrials, John Coykendall, Kate Hardin, John Morehouse, 30 October 2023, <https://www2.deloitte.com/us/en/insights/industry/manufacturing/manufacturing-industry-outlook.html>
- **6 industrial metaverse use cases for manufacturing**, Mary K. Pratt, TechTarget, March 29, 2024: <https://www.techtarget.com/searcherp/feature/Industrial-metaverse-use-cases-for-manufacturing#:~:text=The%20industrial%20metaverse%20can%20potentially,computing%20and%20wearables%2C%20like%20headsets>
- **Navigating the Industrial Metaverse**, World Economic Forum, Cathy Li, David Treat, March 2024: [https://www3.weforum.org/docs/WEF\\_Navigating\\_the\\_Industrial\\_Metaverse\\_A\\_Blueprint\\_2024.pdf](https://www3.weforum.org/docs/WEF_Navigating_the_Industrial_Metaverse_A_Blueprint_2024.pdf)
- **Generative AI, Industrial Metaverse to Change Manufacturing**, IoT World Today, Scarlett Evans, November 8, 2023: <https://www.iotworldtoday.com/iiot/generative-ai-industrial-metaverse-to-change-manufacturing>
- **Kawasaki DX Strategy Unveiled at Microsoft Build Conference**, Kawasaki Robotics, May 26, 2022: <https://kawasakirobotics.com/news/kawasaki-dx-strategy-unveiled-at-microsoft-build-conference/>
- **Boeing Prepares to Fly in the Metaverse Universe**, Turkish Airlines, Dec 17, 2021: <https://terminal.turkishairlines.com/en/boeing-prepares-to-fly-in-the-metaverse-universe/>
- **What Is Industry 5.0 And How It Will Radically Change Your Business Strategy**, Jeroen Kraaijenbrink, Forbes, May 24, 2022: <https://www.forbes.com/sites/jeroenkraaijenbrink/2022/05/24/what-is-industry-50-and-how-it-will-radically-change-your-business-strategy/?sh=6fce7d3e20bd>
- **Industry 5.0 Towards a sustainable, humancentric and resilient European industry**, Publications Office of the European Union, 2021: [https://msu.euramet.org/current\\_calls/documents/EC\\_Industry5.0.pdf](https://msu.euramet.org/current_calls/documents/EC_Industry5.0.pdf)
- **Industry 5.0: What this approach is focused on, how it will be achieved, and how it is already being implemented**, European Commission, 2023: [https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/industry-50\\_en](https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/industry-50_en)
- **Future of Industry 5.0 in society: human-centric solutions, challenges and prospectiveresearch areas**, Amr Adel, Journal of Cloud Computing, 08 September 2022: <https://journalofcloudcomputing.springeropen.com/articles/10.1186/s13677-022-00314-5#Sec9>
- **Modernizing Global Manufacturing Application Leads to Higher Productivity, Savings for Global Manufacturer**, LTM: <https://www.ltimindtree.com/wp-content/uploads/2021/04/Modernizing-Global-Manufacturing-Application.pdf?pdf=download>

- **Digitally Transforming Industries: What Sector Leads Tech Adoption, Whatfix, LinkedIn, March 22, 2024:**  
<https://www.linkedin.com/pulse/digitally-transforming-industries-what-sector-leads-tech-adoption-l65ic/>
- **The digital factory – gateway to the future, Ralf Schulze, HCLTech, April 4, 2023:**  
<https://www.hcltech.com/blogs/digital-factory-gateway-future>
- **Digitized Financial Operations for a Premium Broking & Wealth Management House, LTM:**  
<https://www.ltimindtree.com/wp-content/uploads/2022/01/Digitized-Financial-Operations-for-Premium-Broking-and-Wealth-Management-House-1.pdf>
- **6 ways to unleash the power of AI in manufacturing, World Economic Forum, Jasmeet Singh, January 4, 2024:**  
<https://www.weforum.org/agenda/2024/01/how-we-can-unleash-the-power-of-ai-in-manufacturing/>
- **What intelligent manufacturing is and how to introduce it into your plant, Yamato, 2024:**  
<https://www.yamatoscale.co.uk/what-intelligent-manufacturing-is-and-how-to-introduce-it-into-your-plant/#:~:text=Intelligent%20manufacturing%20also%20includes%20tracking,an%20OEE%20score%20as%20possible>
- **Microsoft Cloud for Manufacturing, Microsoft:**  
<https://www.microsoft.com/en-in/industry/manufacturing/microsoft-cloud-for-manufacturing>
- **Top 7 cloud manufacturing platforms in 2023, Shimpi Das, Fogwing Industrial Cloud, January 10, 2023:**  
<https://www.fogwing.io/blog/top-7-cloud-manufacturing-platforms-in-2023/>
- **2024's Manufacturing Makeover: Cloud-Powered Product Lifecycle Management Takes Center Stage. Six Reasons Why., Data Dynamics, December 19, 2023:**  
<https://www.datadynamicsinc.com/quick-bytes-2024s-manufacturing-makeover-cloud-powered-product-lifecycle-management-takes-center-stage-six-reasons-why/>
- **The Role of Cloud Computing in Modern Manufacturing, Aakash Sareen, Copper Digital, 2024:**  
<https://copperdigital.com/blog/the-role-of-cloud-computing-in-modern-manufacturing/>
- **How Manufacturing Industry Uses Cloud Technology: Bhagyashri Kambale, Three Case Studies, February 22, 2022:**  
<https://manufacturing.report/articles/how-manufacturing-industry-uses-cloud-technology-three-case-studies>
- **The Future of Mobile Device Management: What IT Professionals Need to Know, Alex Loughlin, LinkedIn, March 17, 2023:**  
<https://www.linkedin.com/pulse/future-mobile-device-management-what-professionals-need-alex-loughlin/>
- **MDM for Manufacturing Facilities, MOKI: https://moki.com/industries/manufacturing-2/ The Six Applications and Benefits of IoT in Manufacturing, Tata Tele Business Services, January 10, 2022:**  
<https://www.tatatelebusiness.com/articles/the-six-applications-and-benefits-of-iot-in-manufacturing/>
- **Apex Laboratories reduces service downtime and improves employee productivity with SureMDM, 42Gears:**  
<https://www.42gears.com/case-studies/apex-laboratories-reduces-service-downtime-and-improves-employee-productivity-with-suremdm/>
- **MEMS Incorporated in Industrial Automation Sensors, Eng. Simon Mugo, LinkedIn, April 28, 2023:**  
<https://www.linkedin.com/pulse/mems-incorporated-industrial-automation-sensors-simon-munyua-mugo/>
- **What recent trends in MEMS applications, SCISPACE:**  
<https://typeset.io/questions/what-recent-trends-in-mems-applications-1a5kdq6weh>
- **An introduction to MEMS, Engineering Product Design, December 6, 2023:**  
<https://engineeringproductdesign.com/mems-micro-electro-mechanical-system/>
- **Microelectromechanical Systems (MEMS) Industrial Uses, Electrical Control Systems, LinkedIn, July 10, 2023:**  
<https://www.linkedin.com/pulse/microelectromechanical-systems-mems-industrial/>
- **What is OT security, Nomios:**  
<https://www.nomios.com/resources/what-is-ot-security/#:~:text=OT%20security%20is%20commonly%20used,net-works%20and%20smart%20city%20appliances>
- **Ramping up cybersecurity on America's factory floors, PwC, October 09, 2023:**  
<https://www.pwc.com/us/en/industries/industrial-products/library/manufacturing-ot-cybersecurity.html#:~:text=Specifically%2C%20many%20manufacturers%20often%20struggle,and%20recovery%20initiatives%20and%20protocols>
- **Paperless Manufacturing: Boosting Productivity, Compliance & Sustainability, Gorkem Gencer, SCW.AI, March 13, 2024:**  
<https://scw.ai/blog/paperless-manufacturing/>
- **Paperless Manufacturing: Your Guide to Transitioning to a Paperless Factory, Augmentir Blogs, September 20, 2023:**  
<https://www.augmentir.com/blog/paperless-manufacturing-how-to-guide#what-are-the-benefits-of-going-paperless>
- **Complete Guide to Paperless Manufacturing, Rhema Hans, Deskera:**  
<https://www.deskera.com/blog/paperless-manufacturing/>
- **The road to paperless manufacturing in 2023 and what role IoT plays in it, Smartmakers, August 28, 2023:**  
<https://smartmakers.io/en/der-weg-zur-papierlosen-fertigung/>
- **Going Lean With Paperless Manufacturing: A Guide, Uphance:**  
<https://www.uphance.com/blog/paperless-manufacturing/>
- **Big Data in Manufacturing – Importance and Use Cases, Sudeep Srivastava, Appinventiv, March 14, 2024:**  
<https://appinventiv.com/blog/big-data-in-manufacturing/>
- **Benefits Of Big Data Analytics In The Manufacturing Industry, Intone, November 30, 2022:**  
<https://intone.com/benefits-of-big-data-analytics-in-the-manufacturing-industry/>
- **The Data-Driven Manufacturing Era: Big Data Analytics Takes Charge, Praxie:**  
<https://praxie.com/big-data-analytics-in-manufacturing/>
- **The Importance of Real-Time Manufacturing Analytics in Achieving OEE, Matics Manufacturing Analytics Ltd, 2024:**  
<https://matics.live/blog/the-importance-of-real-time-manufacturing-analytics-in-achieving-oeo/>
- **Sustainable Industrial Manufacturing: A Cleaner Future, BFW, 2024:**  
<https://bfwindia.com/blog/sustainable-industrial-manufacturing-a-cleaner-future/>
- **2024 renewable energy industry outlook, Marlene Motyka, Deloitte Research Center for Energy & Industrials, Marlene Motyka, Jim Thomson, Kate Hardin, Carolyn Amon, Deloitte Research Center for Energy & Industrials, December 4, 2023:**  
<https://www2.deloitte.com/us/en/insights/industry/renewable-energy/renewable-energy-industry-outlook.html>
- **20% waste reduction – how does a construction materials manufacturer take the first step toward sustainability? Transition Technologies PSC, Marcin Sztzec, TT PSC, 2024:**  
<https://ttpsc.com/en/success-stories/20-waste-reduction-how-does-a-construction-materials-manufacturer-take-the-first-step-toward-sustainability/>
- **The Role of Industrial Automation in Sustainable Manufacturing and Green Technology, PDF Supply, July 18, 2023:**  
<https://www.pdfsupply.com/blog/index.php/2023/07/18/the-role-of-industrial-automation-in-sustainable-manufacturing-and-green-technology/>
- **Advanced Applications of Computer Vision in Manufacturing Processes, Label your data, Yulia Kniazieva, September 21, 2023:**  
<https://labeyourdata.com/articles/computer-vision-in-manufacturing>
- **Achieving Manufacturing Excellence With Image Recognition Models for Surface Defect Detection, Debapriya Das, Subodh Rai, Unite.AI, August 24, 2023:**  
<https://www.unite.ai/achieving-manufacturing-excellence-with-image-recognition-models-for-surface-defect-detection/>
- **Manufacturing Excellence With Image Recognition Models, Debapriya Das, Subodh Rai, CDO Trends, August 28, 2023:**  
<https://www.cdotrends.com/story/18370/manufacturing-excellence-image-recognition-models>
- **Computer vision in manufacturing: 9 use cases, examples, and best practices, Aleksandr Ahramovich, Itransition, May 23, 2023:**  
<https://www.itransition.com/computer-vision/manufacturing>
- **Computer Vision Applications in Manufacturing, Encord Blog, January 11, 2024:**  
<https://encord.com/blog/computer-vision-manufacturing/>
- **Computer Vision-based Solution for Quality Control for Leading Automotive OEM, LTM:**  
<https://www.ltimindtree.com/wp-content/uploads/2021/09/Computer-Vision-based-Solution-for-Quality-Control-for-Leading-Automotive-OEM-CS.pdf?pdf=download>
- **How Is Connected Field Service Using the IoT?, PTC, Emily Himes, January 22, 2024:**  
<https://www.ptc.com/en/blogs/iiot/what-is-connected-field-service-using-iiot#:~:text=Connected%20field%20service%20offers%20proven,their%20equipment%20in%20the%20field>
- **Connected Field Service Solution Empowers Field Service and Manufacturing Companies, Business Wire, May 02, 2019:**  
<https://www.businesswire.com/news/home/20190502005225/en/Connected-Field-Service-Solution-Empowers-Field-Service-and-Manufacturing-Companies>
- **The Difference Between Field Service & Connected Field Service, Travis Pullen, MCA Connect, March 19, 2019:**  
<https://mcaconnect.com/difference-between-field-service-connected-field-service/>
- **Hyper-personalisation in manufacturing: ushering the next industrial revolution?, International Centre for Industrial Transformation Ltd, November 21, 2023:**  
<https://incit.org/en/thought-leadership/hyper-personalisation-in-manufacturing-usher-ing-the-next-industrial-revolution/#:~:text=When%20we%20throw%20hyper%2Dpersonalisation,of%20overproduction%20and%20excess%20inventory.>
- **How AI-driven hyper-personalisation is changing the manufacturing supply chain, International Centre for Industrial Transformation Ltd, November 20, 2023:**  
<https://incit.org/en/thought-leadership/how-ai-driven-hyper-personalisation-is-changing-the-manufacturing-supply-chain/>

- **Toyota taps IBM Watson for personalized Rav4 campaign, David Kirkpatrick, Marketing Dive, January 27, 2017:**  
<https://www.marketingdive.com/news/toyota-taps-ibm-watson-for-personalized-rav4-campaign/434874/>
- **Enhanced Warranty Management Systems for Manufacturers, Syncron, October 13, 2023:**  
<https://www.syncron.com/blog/revolutionizing-warranty-management-from-outdated-systems-to-enhanced-profitability/>
- **Designing a sustainable next-gen warranty business model, Prabhakar Ravishankar, Ankur Samaiyar TCS:**  
<https://www.tcs.com/what-we-do/industries/manufacturing/white-paper/intelligent-automation-warranty-claims-management#:~:text=Modern%20warranty%20management%20systems%20use,to%20effectively%20process%20warranty%20claims>
- **Innovation in Product Warranty Management, Dr. Albert Liao, Wareconn, July 31, 2023:**  
[https://www.wareconn.com/Insights/Innovationin-Product-Warranty-Management-Part-I-I/en\\_us](https://www.wareconn.com/Insights/Innovationin-Product-Warranty-Management-Part-I-I/en_us)
- **Industrial manufacturer reduces warranty claim fraud with timely insights, LTM, 2023:**  
[https://www.fosfor.com/wp-content/uploads/2024/02/Fosfor\\_industrial-manufacturer\\_Case\\_study\\_V001-3.pdf](https://www.fosfor.com/wp-content/uploads/2024/02/Fosfor_industrial-manufacturer_Case_study_V001-3.pdf)
- **How Manufacturers Can Make it a Profitable Business Model, LTM Whitepaper, Ali Shaan Haider, Venkat Agarwal & Nishant Srivastava, May 2020:**  
<https://www.ltimindtree.com/wp-content/uploads/2020/05/PaaS-How-Manufacturers-Can-Make-it-a-Profitable-Business-Model.pdf?pdf=download>
- **Manufacturers' Innovative Business Models: Service Customization, Servitization, and Outcome-based Business Models, LinkedIn Pulse article, Karyna Mihalevich, January 6, 2023:**  
<https://www.linkedin.com/pulse/manufacturers-innovative-business-models-service-karyna-mihalevich/>
- **These megatrends are revolutionizing manufacturing and service; but cross-functionality is key, ERP Today, Michael Bauer, November 3, 2023:**  
<https://erp.today/these-megatrends-are-revolutionizing-manufacturing-and-service-but-cross-functionality-is-key/>
- **Outcome-based business models are an opportunity for growth at ABB, Aalto University blogs, January 24, 2024:**  
<https://www.aalto.fi/en/news/outcome-based-business-models-are-an-opportunity-for-growth-at-abb#:~:text=Outcome%2Dbased%20business%20models%20are%20a%20form%20of%20business%20operations,September%20and%20December%20of%202023>
- **The Subscription Business Model: Does It Make Sense in the Manufacturing Industry?, Radiana Pit, Copperberg:**  
<https://www.copperberg.com/the-subscription-business-model-does-it-make-sense-in-the-manufacturing-industry/>
- **Subscription Services in Manufacturing, Sophie Conroy, January 21, 2021:**  
<https://www.dlapiper.com/en-us/insights/publications/2021/01/subscription-services-in-manufacturing>
- **The Subscription Business for Manufacturing is Here to Stay, Michael Brassea, Tacton, August 09, 2021:**  
<https://www.tacton.com/cpq-blog/the-subscription-economy-for-manufacturing-is-here-to-stay/>
- **Cat® Equipment Management, Caterpillar:**  
[https://www.cat.com/en\\_IN/support/technology/equipment-management.html](https://www.cat.com/en_IN/support/technology/equipment-management.html)
- **The Role of AI in Developing Resilient Supply Chains, Maxime C. Cohen & Christopher S. Tang, Georgetown Journal of International Affairs, February 5, 2024:**  
<https://gjia.georgetown.edu/2024/02/05/the-role-of-ai-in-developing-resilient-supply-chains/>
- **AI-driven operations forecasting in data-light environments, Jorge Amar, Sohrab Rahimi, Zachary Surak, and Nicolai von Bismarck, McKinsey & Company, February 15, 2022:**  
<https://www.mckinsey.com/capabilities/operations/our-insights/ai-driven-operations-forecasting-in-data-light-environments>
- **What is Demand Sensing?, Pluto7, 2024:**  
<https://pluto7.com/what-is-demand-sensing/#comparison>
- **How To Improve Demand Forecasting With Machine Learning And Real-Time Data, Vasudevan Sundarababu, Forbes, April 26, 2022:**  
<https://www.forbes.com/sites/forbestechcouncil/2022/04/26/how-to-improve-demand-forecasting-with-machine-learning-and-real-time-data/?sh=7a63fcc41fdd>
- **Auto Parts Manufacturer Recoups \$10M a Year with ML-Driven Demand Forecasting, Bristlecone, 2021:**  
[https://www.bristlecone.com/wp-content/uploads/css\\_auto-parts.pdf](https://www.bristlecone.com/wp-content/uploads/css_auto-parts.pdf)
- **Factory in a Box – A Potential Agile Supply Chain Disruptor, Aakash Sareen, Aranca, February 18, 2022:**  
<https://copperdigital.com/blog/the-role-of-cloud-computing-in-modern-manufacturing/>
- **The 'Factory in a Box' Concept, EIT Manufacturing, December 28, 2022:**  
<https://www.eitmanufacturing.eu/what-we-do/thought-leadership/signals/the-factory-in-a-box-concept/>
- **Factory in a box' concept provides business continuity advantages, Continuity Central.com, February 26, 2018:**  
<https://continuitycentral.com/index.php/news/business-continuity-news/2706-factory-in-a-box-concept-provides-business-continuity-advantages>
- **Test Factory in a Box™ Overview, HCLTech:**  
[https://www.hcltech.com/sites/default/files/documents/resources/brochure/files/test\\_factory\\_in\\_a\\_box\\_overview\\_brochure.pdf](https://www.hcltech.com/sites/default/files/documents/resources/brochure/files/test_factory_in_a_box_overview_brochure.pdf)
- **Enabling holistic decision-making to create a more intelligent network, Deloitte, February 22, 2022:**  
<https://www.deloitte.com/an/en/our-thinking/insights/industry/transportation-hospitality-services/intelligent-supply-chain-movement-of-goods.html>
- **From challenge to advantage: Supply network optimization, Deloitte, July 20, 2022:**  
<https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/consumer-business/deloitte-cn-cb-supply-network-optimization-en-220715.pdf>
- **Generative AI use cases in Supply chain management, Dontu Murali, LTIMindtree September 15, 2023:**  
<https://www.ltimindtree.com/blogs/generative-ai-use-cases-in-supply-chain-management/>
- **Top smart contract development trends in 2023, Antier Solutions, January 9, 2023:**  
<https://www.antiersolutions.com/top-smart-contract-development-trends-in-2023/#:~:text=Greater%20Use%20of%20Smart%20Contracts%20in%20Supply%20Chain%20Management&text=A%20smart%20contract%20development%20company%20can%20make%20it%20possible%20to,take%20place%20within%20a%20supply>
- **Smart Contracts for Innovative Supply Chain Management, Sanjeev Kapoor, ITeXchange, April 22, 2022:**  
<https://www.itexchangeweb.com/blog/smart-contracts-for-innovative-supply-chain-management/>
- **Best Smart Contract Use Cases Across Industries to Explore in 2024 and Beyond, Kira Belova, PixelPlex, December 26, 2023:**  
<https://pixelplex.io/blog/smart-contract-use-cases/>
- **Global Smart Contracts Market Size, Share and Growth Analysis, SkyQuest Consulting, March, 2024:**  
[https://www.skyquestt.com/report/smart-contracts-market#:~:text=Smart%20Contracts%20Market%20Insights,period%20\(2024%2D%202031\)](https://www.skyquestt.com/report/smart-contracts-market#:~:text=Smart%20Contracts%20Market%20Insights,period%20(2024%2D%202031))
- **Volody's Smart CLM helps Global automobile parts manufacturer do away with Manual Contracting Process, Volody:**  
[https://www.volody.com/docu/casestudy/pdf/Volody%E2%80%99s\\_Smart\\_CLM\\_helps\\_Global\\_automobile\\_parts\\_manufacturer\\_do\\_away\\_with\\_Manual\\_Contracting\\_Process.pdf](https://www.volody.com/docu/casestudy/pdf/Volody%E2%80%99s_Smart_CLM_helps_Global_automobile_parts_manufacturer_do_away_with_Manual_Contracting_Process.pdf)
- **How Generative AI will transform Sourcing and Procurement Operations, Vinay Rajani, Mike Deng, Deloitte, June 27, 2023:**  
<https://www2.deloitte.com/us/en/blog/business-operations-room-blog/2023/generative-ai-in-procurement.html>
- **Transforming digital procurement through Generative AI, Vinay Rajani, Mike Deng, Deloitte, January 04, 2024:**  
<https://www2.deloitte.com/us/en/blog/business-operations-room-blog/2023/digital-procurement-transformation-through-generative-ai.html>
- **Smart Procurement: Build More Agile and Efficient Processes, Julia Diniz, Pipefy, January 12, 2024:**  
<https://www.pipefy.com/blog/smart-procurement/>
- **Intelligence makes the difference, Intelligent Procurement Study 2024, Kadir Tekin, Dico van Dijk, Thomas Gannon, Capgemini, January 31, 2024:**  
[https://www.capgemini.com/wp-content/uploads/2024/02/Intelligent-Procurement-Study-2024-Invent\\_Brochure\\_Final\\_03042024.pdf](https://www.capgemini.com/wp-content/uploads/2024/02/Intelligent-Procurement-Study-2024-Invent_Brochure_Final_03042024.pdf)
- **Smart Procurement, Fairmarkit, 2024:**  
<https://www.fairmarkit.com/glossary/smart-procurement>
- **Consolidation of IT ordering process to streamline Procurement of IT Workplace, LTM:**  
<https://www.ltimindtree.com/wp-content/uploads/2023/07/Consolidation-of-IT-ordering-process-to-help-streamlining-procurement-of-IT-workplace-CS.pdf?pdf=download>
- **Harnessing generative AI in manufacturing and supply chains, Jacob Achenbach, Kevin Arbeiter, Nick Mellors, Rahul Shahani, McKinsey & Company, March 25, 2024:**  
<https://www.mckinsey.com/capabilities/operations/our-insights/operations-blog/harnessing-generative-ai-in-manufacturing-and-supply-chains>
- **How supply chains benefit from using generative AI, Glenn Steinberg, Mathew Burton, Ayoub Abielmona, E&Y, January 09, 2024:**  
[https://www.ey.com/en\\_gl/insights/supply-chain/how-generative-ai-in-supply-chain-can-drive-value](https://www.ey.com/en_gl/insights/supply-chain/how-generative-ai-in-supply-chain-can-drive-value)
- **Generative AI for Supply Chain Management, Dr. Jagreet Kaur Gill, Xenonstack, December 21, 2023:**  
<https://www.xenonstack.com/insights/generative-ai-supply-chain>
- **Five use cases for manufacturers to get started with generative AI, Charlie Sheridan, Matthias Breunig, Google, October 10, 2023:**  
<https://cloud.google.com/blog/topics/manufacturing/five-generative-ai-use-cases-for-manufacturing>
- **Gartner Survey Shows Half of Supply Chain Organizations Plan to Implement GenAI in the Next 12 Months, Gartner, January 10, 2024:**  
<https://www.gartner.com/en/newsroom/press-releases/2024-01-10-gartner-survey-shows-half-of-supply-chain-organizations-plan-to-implement-genai-in-the-next-twelve-months>

- **How generative AI is used in supply chains, Sumit Dutta, EY, February 01, 2024:**  
[https://www.ey.com/en\\_us/coo/how-generative-ai-is-used-in-supply-chains](https://www.ey.com/en_us/coo/how-generative-ai-is-used-in-supply-chains)
- **Case Study: Generative AI in Supply Chain: Building More Resilient Supply Chains, Alvarez & Marshall, August 8, 2024:**  
<https://www.alvarezandmarsal.com/sites/default/files/article/pdf/Generative%20AI%20in%20Supply%20Chain%20Re-port%20-%20Compressed%20version.pdf>
- **Supply Chain Transparency Defined: Why It Matters and Its Benefits, Mark Jackley, Oracle, November 21, 2023:**  
<https://www.oracle.com/in/scm/supply-chain-transparency/#:~:text=Supply%20chain%20transparency%20is%20the,%2C%20parts%2C%20and%20finished%20products>
- **What is supply chain transparency?, IBM Blogs, Amanda McGrath, Alexandra Jonker, December 5, 2023:**  
<https://www.ibm.com/topics/supply-chain-transparency>
- **The future of supply chain, KPMG, September 15, 2023:**  
<https://assets.kpmg.com/content/dam/kpmg/xx/pdf/2023/09/kpmg-future-of-supply-chain-report.pdf>
- **Blockchain in Supply Chain: Enhancing Transparency and Traceability in Manufacturing, University of Sri Jayewardenepura, January 27, 2024**  
<https://www.linkedin.com/pulse/blockchain-supply-chain-enhancing-transparency-pikgf/>
- **QIMA Blogs, January 30, 2024:**  
<https://blog.qima.com/csr/supply-chain-transparency-achieving-esg-goals>
- **Alcar Ruote rolls with changing car sector thanks to Oracle, Stefano Mariani, December 2020:**  
<https://www.oracle.com/in/customers/alcar-ruote/>
- **16 Warehouse Automation Trends for 2024, Erin Thompson, CYGN, April 22, 2024:**  
<https://www.cygn.com/blog/16-warehouse-automation-trends-for-2024>
- **North American Warehouse Automation Trends for 2024, Sean Wallingford, January 3, 2024:**  
<https://www.swisslog.com/en-us/case-studies-and-resources/blog/north-american-warehouse-automation-trends-for-2024>
- **Will robotic automation lead to lights-out warehousing? Benefits of automation and robotics in warehousing, Deloitte Consulting LLP, Wanda Johnson, January 12, 2023:**  
<https://www2.deloitte.com/us/en/blog/business-operations-room-blog/2023/lights-out-warehouse-automation.html>
- **Warehouse Automation using SAP EWM/MFS for World Leader in Insulation Services, LTM, August 8, 2022:**  
<https://www.ltimindtree.com/wp-content/uploads/2022/08/Warehouse-Automation-using-SAP-EWM-MFS.pdf?pdf=download>
- **What is an Environmental Management System?, Alex Walsh, Green Element, November 4, 2022:**  
<https://www.greenelement.co.uk/blog/what-is-an-environmental-management-system/>
- **The Complete Guide to Environmental Management: What It Is, how to do it like an expert, Alex Chamberlain, ERA Environmental Management Solutions, August 07, 2019:**  
<https://www.era-environmental.com/blog/environmental-management#:~:text=Generally%20speaking%2C%20this%20means%20monitoring,process%20and%20what%20comes%20out>
- **Environmental Management System Case Studies You Can Learn, Agus Agung Pribadi, Octobits, January 15, 2024:**  
<https://blog.octobits.io/it-strategy/environmental-management-system-case-studies/>
- **Achieving sustainable manufacturing with IoT technology, Max Pilats, November 2023:**  
<https://www.manufacturingtomorrow.com/story/2023/11/achieving-sustainable-manufacturing-with-iot-technology/21676/#:~:text=IoT%20enables%20emission%20monitoring%20in,and%20address%20any%20environmental%20concerns>
- **Top 5 benefits of green building, Galia Shtang, Inogen, August 17, 2022:**  
<https://www.inogenalliance.com/blog-post/benefits-green-building>
- **Green Building Material Market Size and Share - Growth Potential and Forecasted outlook for 2032, Market Research News Publication, LinkedIn March 6, 2024:**  
<https://www.linkedin.com/pulse/green-building-material-market-size-share-w4a4f/>
- **The Role of Green Building in Creating More Sustainable Economies, Patrick Murphy, Maket:**  
<https://www.maket.ai/post/the-role-of-green-building-in-creating-more-sustainable-economies>
- **Are green buildings expensive alternatives to traditional structures, Ashish Pandey, The Economic Times, August 2, 2023:**  
<https://economictimes.indiatimes.com/small-biz/sustainability/are-green-buildings-expensive-alternatives-to-traditional-structures/articleshow/102340836.cms?from=mdr>
- **The Future of Green Buildings: Predictions and Trends, Damon John S., LinkedIn, January 6, 2023:**  
<https://www.linkedin.com/pulse/future-green-buildings-predictions-trends-damon-samuria/>
- **Daikin's Office Retrofit: Pushing Forward the Drive for Sustainability, Daikin UAE:**  
[https://www.daikinuae.com/en\\_us/about/case-studies/Green%20Buildings:%20Best%20Practice%20Case%20Studies%20in%20Retrofitting.html](https://www.daikinuae.com/en_us/about/case-studies/Green%20Buildings:%20Best%20Practice%20Case%20Studies%20in%20Retrofitting.html)
- **Immersive Technologies in Manufacturing Industry, LTM:**  
<https://www.ltimindtree.com/wp-content/uploads/2022/09/ar-vr-manufacture-industry-pov.pdf?pdf=download>
- **The Case for Immersive Training, Motive.io, 2020:**  
<https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RW1iJOj>
- **20 Ways How AR and VR are Transforming Training in Manufacturing, Proven Reality, November 25, 2023:**  
<https://provneality.com/manufacturing/how-ar-and-vr-are-transforming-training-in-manufacturing/>
- **9 Applications of Virtual Reality in Manufacturing: Changing the Way We Make Things, Vivian M, Vection Technologies, February 27, 2023:**  
<https://vection-technologies.com/blog/9-Applications-of-Virtual-Reality-in-Manufacturing-Changing-the-Way-We-Make-Things/>
- **Virtual reality training tours Purina pet food facility, Tim Wall, PetfoodIndustry®, October 14, 2020:**  
<https://www.petfoodindustry.com/pet-food-market/article/15467221/virtual-reality-training-tours-purina-pet-food-facility>
- **Using knowledge management systems in manufacturing organizations, Bloomfire, August 11, 2022:**  
<https://bloomfire.com/blog/knowledge-management-systems-in-manufacturing/>
- **Knowledge management in manufacturing – why is it so important?, NSFLOW, February 22, 2022:**  
<https://nsflow.com/blog/knowledge-management-in-manufacturing-why-is-it-so-important>
- **How knowledge management streamlines manufacturing process, Sheebha Austin, LinkedIn, June 23, 2023:**  
<https://www.linkedin.com/pulse/how-knowledge-management-streamlines-manufacturing-process-austin/>
- **Knowledge management in the era of Industry 4.0., Haitao Luo, RealKM, January 03, 2024:**  
<https://realkm.com/2024/01/03/knowledge-management-in-the-era-of-industry-4-0/>
- **Knowledge-based Engineering (KBE), Infosys, 2018:**  
<https://www.infosys.com/engineering-services/service-offerings/documents/key-product-development.pdf>
- **The Future of Finance Automation: Emerging Technologies and Trends, Akhil Malik, Signity Solutions, November 3, 2023:** <https://www.signitysolutions.com/blog/finance-automation-emerging-technologies-and-trends>
- **Payslip Harnesses AI to Revolutionize Global Payroll Management, Payslip, July 19, 2023:**  
<https://payslip.com/resources/blog/payslip-harnesses-ai-to-revolutionize-global-payroll-management>
- **Five tactics for peace-of-mind, touchless accounts payable, MEDIUS, June 23, 2023:**  
<https://www.medius.com/blog/five-tactics-for-peace-of-mind-touchless-accounts-payable/>
- **Digitized Financial Operations for a Premium Broking & Wealth Management House, LTM:**  
<https://www.ltimindtree.com/wp-content/uploads/2022/01/Digitized-Financial-Operations-for-Premium-Broking-and-Wealth-Management-House-1.pdf>
- **Zero Trust Blueprint: Safeguarding Manufacturing Operations from Cyber Threats, Jordon Hargrove, Carlos Rojas, Cisco, July 26, 2023:**  
<https://blogs.cisco.com/manufacturing/zero-trust-blueprint-safeguarding-manufacturing-operations-from-cyber-threats>
- **Theory and Application of Zero Trust Security: A Brief Survey, Hongzhaoning Kang, MDPI, November 28, 2023:**  
<https://www.mdpi.com/1099-4300/25/12/1595>
- **Securing manufacturing operations: Why zero trust at the PLC level is critical, Jay Smilyk, October 17, 2023:**  
<https://www.smartindustry.com/examples-of-transformation/industry-perspectives/article/33013185/securing-manufacturing-operations-why-zero-trust-at-the-plc-level-is-critical>
- **Zero-Trust Model for Smart Manufacturing Industry, Biplob Paul and Muzaffar Rao, MDPI, December 24, 2022:**  
<https://www.mdpi.com/2076-3417/13/1/221#sec2-applsci-13-00221>
- **Empowering Small and Medium-Sized Enterprises through Digital Business Model Innovation, World Economic Forum, Kiva Allgood, Liedi Bernucci, May 2024:**  
[https://www3.weforum.org/docs/WEF\\_Empowering\\_Small\\_and\\_Medium\\_Sized\\_Enterprises\\_through\\_Digital\\_Business\\_Model\\_Innovation\\_2024.pdf](https://www3.weforum.org/docs/WEF_Empowering_Small_and_Medium_Sized_Enterprises_through_Digital_Business_Model_Innovation_2024.pdf)
- **Comparing Traditional & Digital Business Models, 2Stallions blog, Razy Shah, October 26, 2023:**  
<https://2stallions.com/blog/comparing-traditional-and-digital-business-models/>
- **The Evolution of Digital Business Models in the Age of AI, LinkedIn Blogs Tyrone M. Robinson, July 11, 2024:**  
<https://www.linkedin.com/pulse/evolution-digital-business-models-age-ai-tyrone-m-robinson-iii-manzf/>
- **The Evolution of Digital Business Models Driven by AI and Its Impact, Illuminar Digital Digest, June 2024:**  
<https://www.avaali.com/illuminar-digitalenterprise/the-evolution-of-digital-business-models-driven-by-ai-and-its-impact/>
- **Siemens AG's "Holmes" chatbot helps solve employee login issues, Avanade Case Studies:**  
<https://www.avanade.com/en/clients/siemens-ag-ai-chatbot>



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