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Smart Factory

A Frost & Sullivan White Paper

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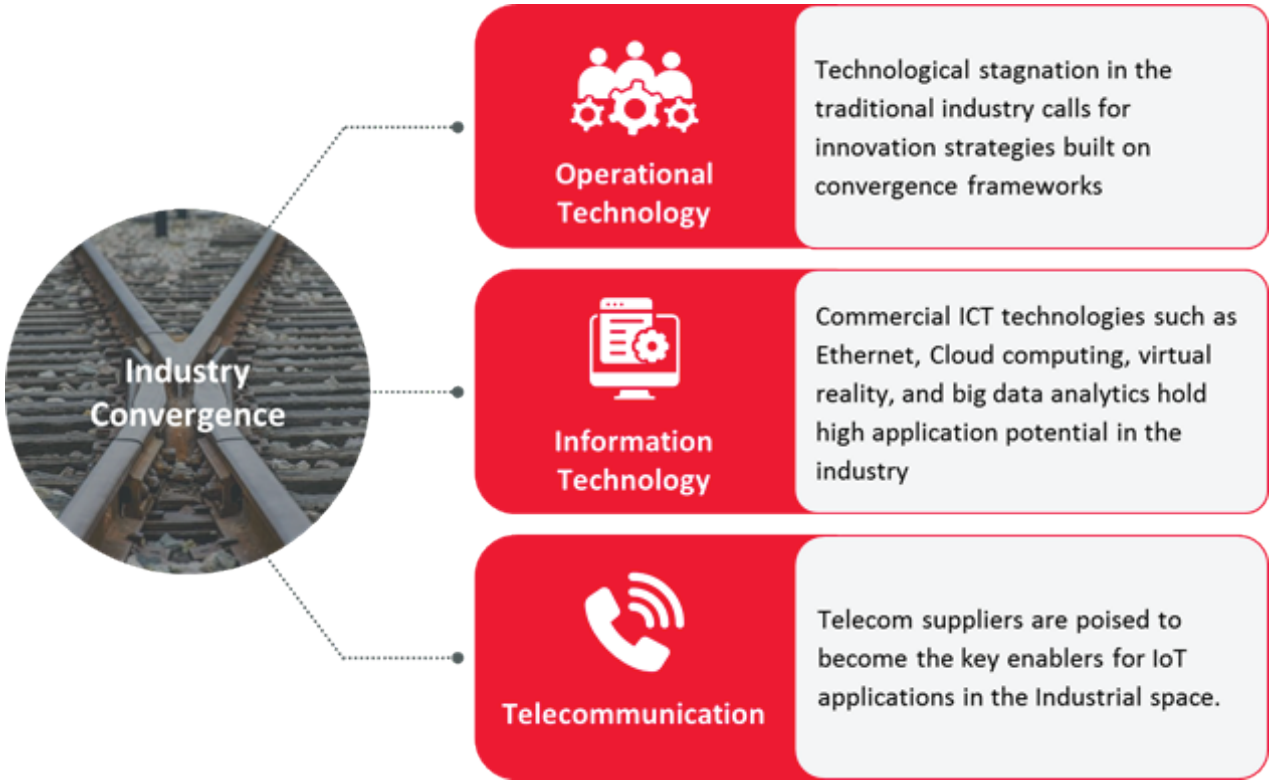
Overview of Smart Factory

Automation vendors and end-user industries have been investing in Industrial Internet of Things (IIoT), across their diverse applications, convinced with the view that IIoT is going to be the key driver for digital transformation.

Industry Convergence: A cross-pollination of OT, IT and Telecommunication



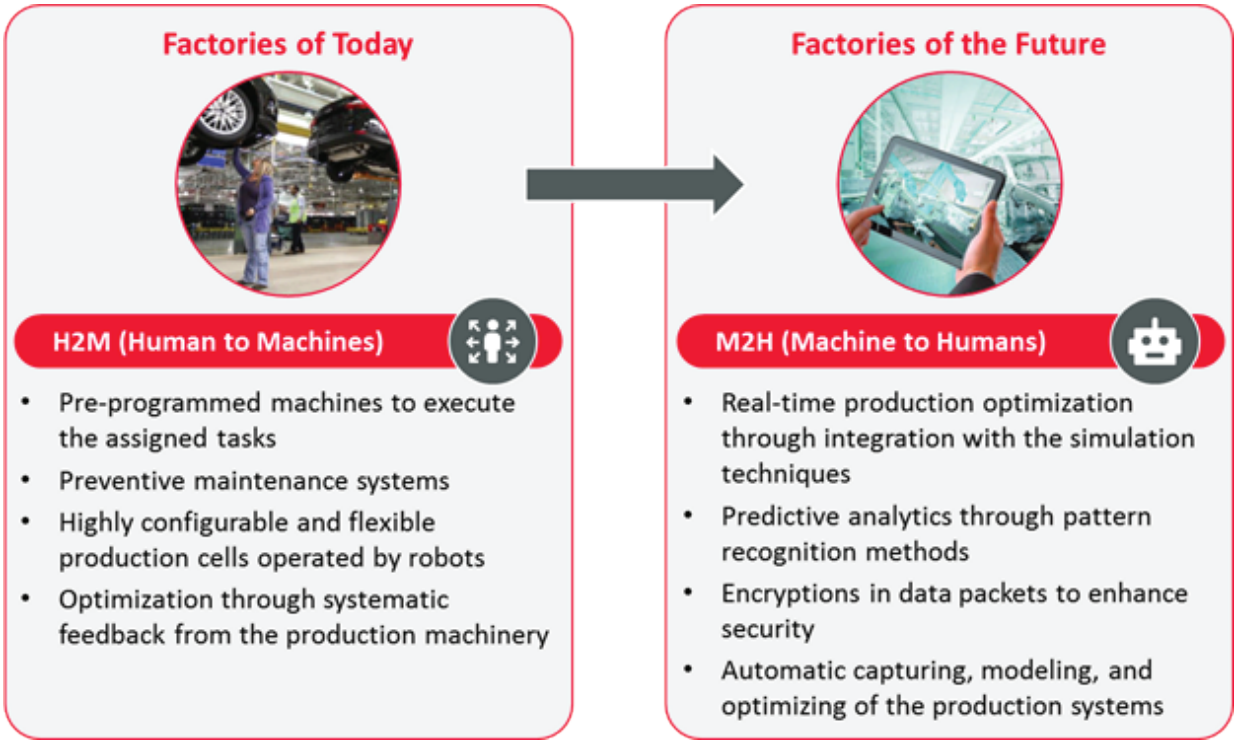
Source : Frost & Sullivan

The advent of advanced ICT technologies in the traditional manufacturing sector is creating a new factory ecosystem of the future, called the “Smart Factory”. One of the key mega trends that define a smart city is ‘Smart Factory’ in the manufacturing sector, the aim of which is to get products connected through sensors, use of technologies such as AI, Edge computing, etc. to facilitate data collection and delivery of services to customers.

The cross pollination of technologies, systems, people and processes between the ICT industry and manufacturing sector will form the crux of the fourth Industrial Revolution or Industry 4.0.

Definition:
Smart Factory

Smart Factory is a highly digitized and connected production facility that employs IoT enabled sensors, predictive analytics, modeling, big data and other advanced automation technologies to improve manufacturing efficiencies. It is also commonly known as “Industry 4.0”.

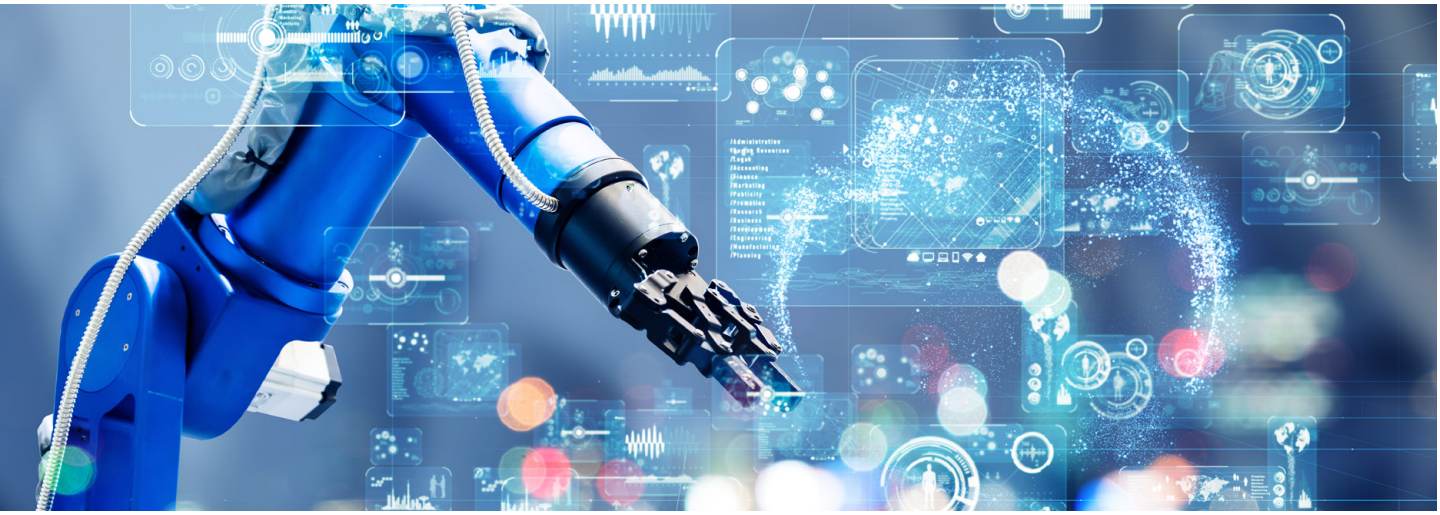


A ‘smart factory’ has the potential -

- To aggregate diverse set of data from equipment and systems
- To analyze the data that can be leveraged to undertake key business decisions and
- To facilitate actionable strategies that include reduction of operating costs and inefficiencies, acceleration of productivity, automation of processes, expansion

Smart factory facilitates integration of shop floor decisions and real-time data captured therein is synchronized with the rest of the supply chain through an interconnected ecosystem of information technology (IT) and operational technology (OT).

Key Applications



Production Automation

The main objectives of production automation are to improve the efficiency of labour and quality of manufactured products, and to create suitable conditions for optimum utilization of existing resources. Degree of automation in a factory can vary from partial, integrated to total automation.

Predictive Maintenance

It is one of the maintenance strategies where application of predictive analytical algorithms against real-time data is used to proactively identify areas of potential concerns and to provide suitable solutions to address the issue. One of the key reasons for interest in predictive maintenance application in a smart factory will be the cost savings it enables, which can be significant over a period of time. However, factories have to deal with issues such as data protection and significant capital expenditure.

Integrated IT systems

Integrated IT Systems facilitates end-to-end system visibility between business systems and operational systems. In a smart factory, this facilitates integration of shop floor decision with the rest of the supply chain processes such as R&D, Engineering & Design to Customer service.

Resource Efficiency

Resource efficiency refers to maximizing inputs such as materials, people, other assets (such as smart meters, smart lighting, etc.) to minimize cost and waste. Globally, manufacturing companies continue to face pressure from governments and investors to improve energy efficiency, reduce emissions, and comply with regulations. Machines that are fitted with integrated sensors and factories that leverage big data and AI would be able to optimize resources and better manage costs.

Key Sectors

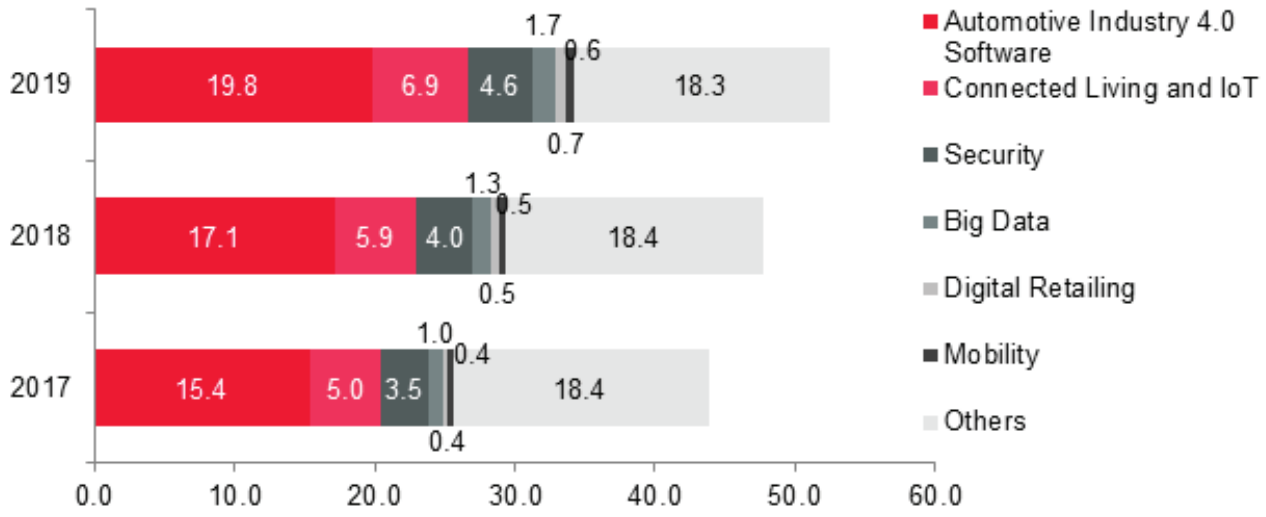
Smart Factory is well suited for discrete industrial sectors such as automotive and manufacturing which includes machinery, aerospace & defense, and electronics and semiconductors.

Automotive

This sector comprises of original equipment manufacturers (OEMs) involved in the design, development, and manufacturing of automobiles.

Automotive industry has always been at the forefront of technology adoption, with the adoption of various smart manufacturing technologies.

IT / IoT Spending ($Billion) in the Automotive Sector, Global, 2017-2019



Source: Frost & Sullivan Analysis

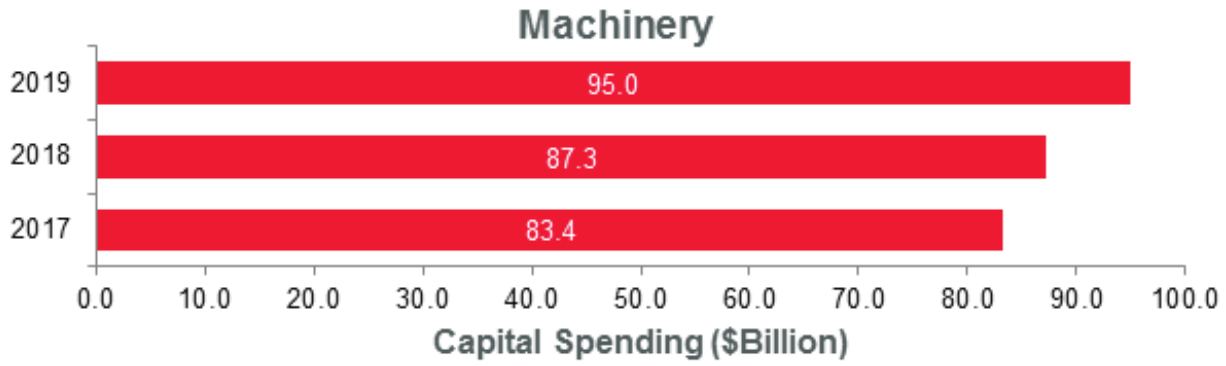
Others include technologies and software such as communication services, over-the-air (OTA) updates, infotainment content, cloud computing, data center systems, legacy system transformation, and autonomous and self-driving technologies.

• In 2019, automotive industry investments in IT/ IoT areas totaled USD 52.5 Billion and this is expected to reach USD80.0 Billion by 2025.

• New technologies and processes have led to various synergies among automation vendors and automotive OEMs to improve manufacturing efficiencies, ROIs, and new revenue opportunities.

Manufacturing

IoT Capital Spending in Discrete Manufacturing Sector, Global, 2017-2019



Notes:

IoT Capital spending in electronics and semiconductor industry is not available.

Under machinery sector, figures include metal cutting and metal forming categories of machinery.

Source: Association for Manufacturing Technology, Frost & Sullivan

Machinery: This includes the segments involved in the manufacturing and servicing of industrial tools and machinery. With advances in hardware and software technology, machine tool manufacturers are developing machines that are faster, smarter, and highly versatile. Key trends observed in this sector include 3D Printing, flexible manufacturing, augmented reality, advanced computer-aided-manufacturing and data analytics. The top 5 markets dominating this sector include China, the United States, Japan, Germany and South Korea. In 2019, machine tool manufacturers focused on platforms and software solutions to drive digital connectivity in the manufacturing sector.

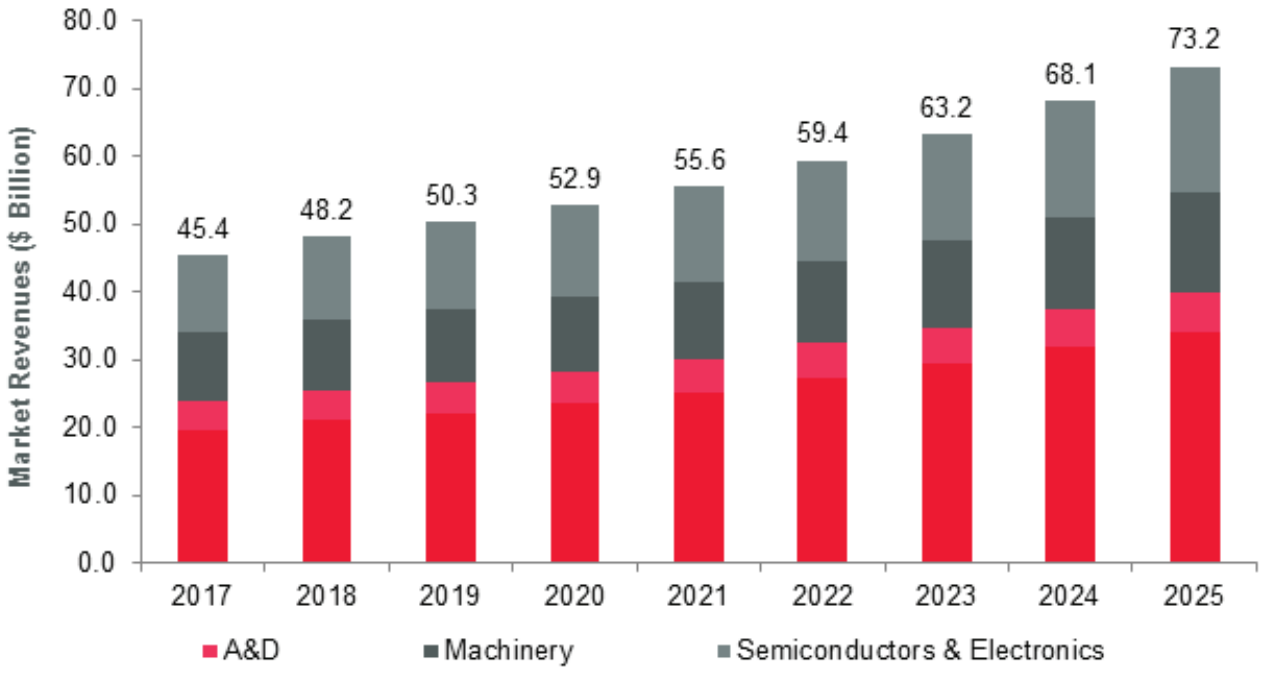
Electronics and Semiconductors: This includes businesses involved in the design and fabrication of semiconductors and electronics. Rising investments in the semiconductors industry is due to growing demand for mobile devices, LED displays, and smartphones. Automation plays a crucial part in the production process as there remains a high requirement to maintain the quality of finished products. With access to a new level of industrial intelligence, manufacturers would be able to improve quality, increase throughput, have better insights into the root cause of issues, reduce downtime, and optimize the day-to-day maintenance of manufacturing equipment. The US and Europe are expected to be the major adopter of IIoT and drive investments in semiconductors. However, China will continue to dominate in the case of new facilities and equipment CAPEX.

Market Forecasts

The automotive sector continues on its growth trajectory despite challenges, and will be the prime driver for the smart factory automation market, especially in North America and Asia Pacific (APAC) regions.

Strong order booking in the A&D sector ensures growth for automation in the long term. However, short-term growth for automation opportunities in the A&D sector is likely to remain modest.

Chart I: Smart Factory Market: Revenues by Key Sectors, Global, 2017-2025



Source: Base year is 2018; Frost & Sullivan Analysis

Smart Factory Market: **Key Drivers, Global, 2020–2025F**

Key Drivers	Impact		
	1-2 years	3-4 years	5 years
Smart manufacturing technologies offer immense benefits to manufacturers	●	●	●
Growing Collaboration Among Industry Stakeholders Indicates Potential that Will Yield Long-Term Gains	●	●	●
Connected Supply Chain Enables Customization, Flexibility, and Conformance to Regulations	●	●	●

Key: ● High ● Medium ● Low

Source: Frost & Sullivan, 2019

Drivers

Smart manufacturing technologies offer immense benefits to manufacturers

Digital manufacturing technologies are expected to profoundly impact the growth of various industries and serve as the key for industries to implement sweeping changes, resulting in smart factories. Being a disruptive technology, digital manufacturing provides advanced computing abilities that will alter the traditional manufacturing processes

The ability to virtualize and simulate data will allow manufacturers to tackle engineering and production challenges, enable better planning in production schedules and equip them with critical information on machinery and assets.

Growing Collaboration Among Industry Stakeholders Indicates Potential that will Yield Long-Term Gains

There have been many strategic partnerships aimed at jointly developing innovative solutions, techniques, and platforms for advancing digital manufacturing according to the increasing demand of growing industries.

Large conglomerates in the manufacturing sector are signing MOUs/acquiring small companies for expanding their portfolio and expertise in providing digital manufacturing solutions and achieve better plant visibility. Such visibility ensures a constant flow of data and, hence, managers and engineers can react immediately to shifting production needs and operational issues.

Connected Supply Chain Enables Customization, Flexibility, and Conformance to Regulations

Smart factory initiatives help manufacturers to plan and optimize the product lifecycle management (PLM) process, thereby resulting in improved productivity. Some of the key benefits for manufacturers in the industrial automation domain include:

- Energy Management and Resource Optimization: Energy is among the highest contributors to cost overheads for manufacturing facilities. Currently, several initiatives are underway to control and reduce energy consumption, some of which includes the use of alternate energy sources. Besides, IoT systems and automation of environmental controls such as HVAC can bring additional cost savings for manufacturers.

- Conformance to Regulations: The need for factory-wide adoption and implementation of intelligent and integrated processes for manufacturing products using sustainable and environment-friendly production techniques with zero-emission of hazardous substances is one of the key drivers for the adoption of digital manufacturing techniques.

- Proactive Maintenance: Manufacturers have widely accepted the concept of preventive and condition-based monitoring, but this is yet to gain widespread acceptance across industries. Digitalization empowers better control by identifying malfunctioning equipment and alerting the concerned personnel when events go out of permissible limits.

Smart Factory Market: **Key Restraints, Global, 2020–2025F**

Key Restraints	Impact		
	1-2 years	3-4 years	5 years
Problems in Data Communications Technologies Hinder Data Analytics in Smart Factories			
Design Challenges and Interoperability Result in Slower Adoption			
Problems Caused by Cybersecurity Could Negate the Benefits from Digitalization			

Key: High Medium Low

Source: Frost & Sullivan, 2019

Restraints

Problems in Data Communications Technologies Hinder Data Analytics in Smart Factories

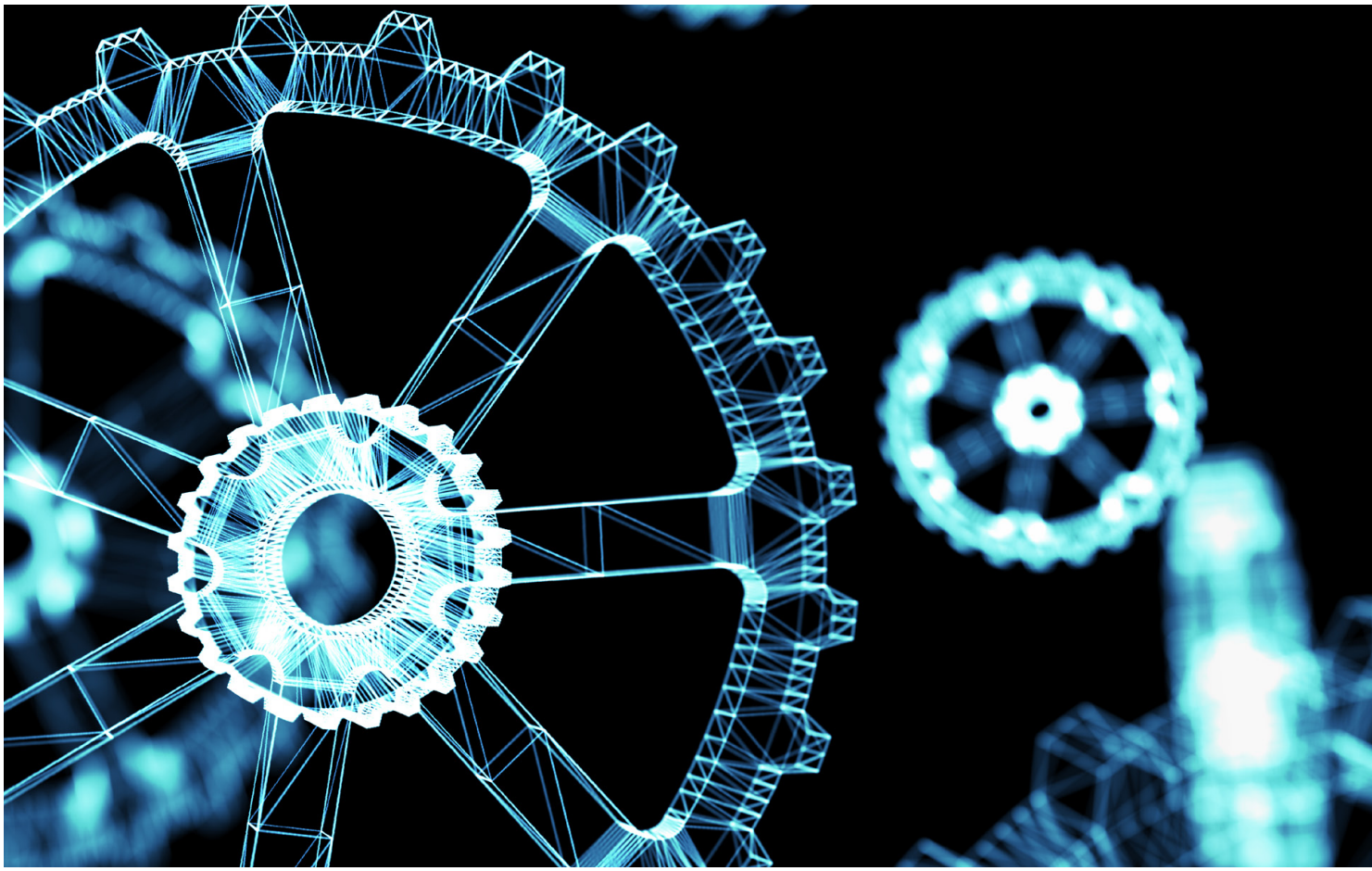
A key part of digitalization is the ability to effectively use data from diverse touch points. Achieving robust data connectivity remains a challenge given the issues with design, deployment, and maintenance. Many manufacturing plants rely on the expertise of operators and their ability to react and communicate real-time issues.

Focus on retraining those operators to the data-centric environment is likely to reduce the impact of this restraint during the forecast period.

2Design Challenges and Interoperability Result in Slower Adoption

IIoT requires that manufacturing plants upgrade their systems regularly, creating feasibility issues for some factories. Also, companies investing in IIoT encounter multiple issues during operation because numerous networks operate as individual units serving different purposes.

With automation systems, interoperability is necessary to enable smooth and efficient production. However, when the individual units operate in silos, it is not possible to achieve synchronization and obtain the desired results.



Problems Caused by Cybersecurity Could Negate the Benefits from Digitalization

Ensuring cybersecurity is one of the major challenges with IIoT managed systems. The threat to confidential data being hacked or misused is a major concern, which can restrain companies from pursuing IIoT and digitalization.

Most IIoT-enabled devices and sensors are not designed to operate in a connected ecosystem as such consequences were not anticipated until IoT gained acceptance. Some of the basic security controls/checks involving device authentication and encryption controls are not found at a device level. IoT is likely to throw up challenges and its success will be tied to how effectively data is managed, transmitted, stored and protected. Data, which will be an asset for a lot of companies, is also highly confidential. Protecting them will be a huge challenge given the enormity of the data that will be generated and handled.

Overview of Key Industry Stakeholders

Given the competition between stakeholders, the manufacturing industry faces no dearth of funding with regard to IIoT as most major suppliers—Siemens A.G., Honeywell, Schneider Electric, etc —are all active in this domain.

Company Name	Overview in 'Smart Factory' Automation
Siemens	Sharpening focus on electrification, automation, and digitization businesses and pushing Software-as-a-Service (SaaS) to capture the SMEs market segment.
ABB	In 2017, the company launched 'ABB Ability', divesting of non-core businesses, and a change in engineering, procurement, and construction (EPC) business models. ABB's recent acquisition of B&R Automation and GE Industrial Solutions is set to drive the company's growth from 2020 and beyond.
Emerson	Post the launch of its IIoT platform, Plantweb Digital Ecosystem, Emerson has positioned its products and business strategies to complement the platform and drive tangible business benefits out of it. Recent acquisitions of Mynah and ProSys are set to unlock new value for Emerson's clients.
Schneider Electric	The company's main priority has been to grow its partner network (distributors, system integrators and technology solution providers) and widening its services and software portfolio. The company has its IIoT-ready architecture and platform, EcoStruxture platform, which is embedded with end-to-end cyber security, positioned for all key end user sectors.
Honeywell	Driving the expansion of industry-specific IIoT solutions with the connected enterprise platform, Honeywell is approaching new routes to the market through third-party service providers and software application developers. Acquisition of Nextnine has strengthened Honeywell's portfolio of industrial cyber security technologies.
Yokogawa Corporation	The co-innovation strategy of Yokogawa will help it to establish a collaborative approach with its clients in developing solutions and creating additional value.

Industry stakeholders are either keen to acquire or partner with companies that have strong business portfolio in cloud technology, networking capabilities, industrial robotics, AI and the like to strengthen their market position over the next 10 years. Strategic partnership with pure-play IIoT vendors will enable traditional manufacturing companies to understand and integrate IIoT technologies into their existing production process and product line, thereby offering greater value to end users. There are key existing partnerships in Industry 4.0 between automation companies with domain knowledge and ICT companies with strong expertise in IIoT technologies as listed below:

Siemens (Mindsphere) + Amazon Web Services (AWS) + SAP	AWS and SAP enable Siemens to host MindSphere, an IIoT operating systems, on their cloud, providing a robust platform for industrial customers to develop IIoT solutions within a shorter time frame.
Emerson + Dell + Intel	Traditionally, Emerson control systems have been using Dell EMC servers with Intel Xeon processors. In 2017, Emerson collaborated with Dell to develop an advanced wireless valve-monitoring solution, which gathers data from digital valve controllers and transmits it through the Dell Gateway onto the cloud.
Schneider Electric + Cylance	In 2018, Schneider Electric partnered with Cylance, a cyber security company that provides AI-based security against malware, file-less attacks, and other cyber threats. This partnership will provide secure industrial software platform for engineering, planning, operations, asset performance, monitoring, and control.
ABB (Ability) + Hewlett Packard Enterprise (HPE) + IBM (Watson)	**Partnership with HPE** enables ABB to run Ability, a digital solution offering, on both cloud and hybrid platforms. Furthermore, a new edge data center has been developed to operate in harsh industrial environments. **ABB and IBM** will take advantage of Watson's AI capabilities to identify defects through real-time production images recorded using an ABB system.
Honeywell + Flowserve	This collaboration is a part of the Honeywell INspire program that brings together customers, equipment vendors, process licensors and Honeywell experts to jointly develop solutions for diverse operational challenges ranging from supply chain efficiency, safety risks, production, unplanned outages, etc.

Technologies Driving Smart Factory

There are various technologies that drive ‘smart factory’ adoption. However, in particular, technologies such as 5G - Connectivity, sensors, big data and artificial intelligence (AI) and cloud or edge computing are the four main influential technologies that will drive automation in factories of the future.

5G - Connectivity

5G Connectivity is at the heart of Industry 4.0, which focuses on creating versatile, scalable and highly efficient smart factories. The success of Industry 4.0 is highly dependent on the technical performance of 5G.

The integration of 5G ultra-reliable low latency communication (URLLC) in the manufacturing process will make smart factories more efficient and productive. URLLC with ultra-high availability and resilience can best be leveraged using a dedicated local network deployment.

The number of connected devices within the smart factory is expected to increase, generating thousands of petabytes of data. The current 4G networks can support needs until some point in time where its capabilities will no longer be sufficient to provide the speed and capacity needed to capture, analyze and transmit these enormous streams of data, especially in smart factories. Local 5G Networks are deployed by enterprises to optimize or enable business processes.

Benefits of 5G in Manufacturing

- Network slicing: 5G network has the ability to create multiple virtual networks for specific service and traffic.
- Control: Local 5G network are deployed in-house, the owner of the network will have complete control over every aspect of the network.
- Bandwidth: 5G will allow large quantities of data to be transmitted over the network.
- Security: The network will be able to set up its own security policies.
- Wireless: Local private network will replace the need for wired technologies like Ethernet in factories, as they are unsuitable for connecting large number of small devices.

Smart factories are reliant on data-intensive machine application. The higher speeds and low latency of 5G is required for effective use of applications, such as automated vehicles, virtual reality and augmented reality applications, which will shape the future of smart factories.

While some connected devices are able to utilize 4G networks using unlicensed spectrum, 5G will enable smart factory applications to expand in scope and to scale to an unprecedented level taking the smart factory concept to the next level.

Key Smart Factory Applications with Local 5G

Applications that can be supported on local-area private 5G network include the following:

Ultra-HD Cameras and Machine Vision

5G can support the large volume of data generated by dense ultra-HD cameras and the low cycle times needed. It will enable predicative maintenance, to recognize manufacturing faults in the production line and address the issue quickly.

Virtual and Augmented Reality (VR/AR)

Augmented reality can improve training and operation maintenance on factory floors. 5G networks have the capacity to support the weight of more connect devices and shared AR experiences. On top of that, 5G's low latency can enable for real-time responsiveness.

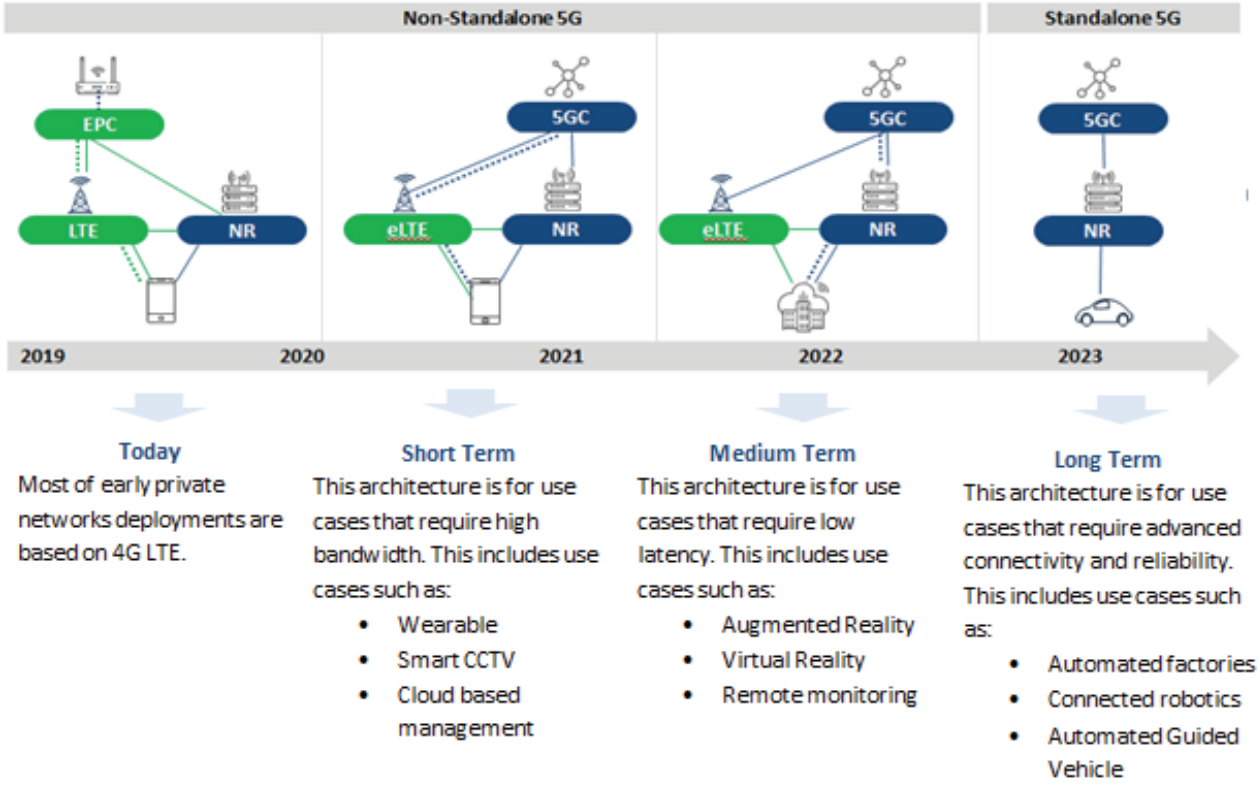
Automated Guided Vehicle (AGVs)

5G will support greater numbers of AGVs per service area. In fact, 5G will enable one million connected units per square kilometers. It will enable AGVs to uptake advanced applications such as video remote control for risky loads such as fuel and chemical tankers.

Robotics with Artificial Intelligence (AI)

5G low latency will enable the use of robotics with artificial intelligence. Robotics will automate certain processes and create new forms of worker-robot interaction. AI will enable robots to make better decisions, minimize errors and delays and work alongside humans in dynamic environments.

Evolution of Private 5G Network Architecture



Today

Most of early private networks deployments are based on 4G LTE.

Short Term

This architecture is for use cases that require high bandwidth. This includes use cases such as:

- Wearable
- Smart CCTV
- Cloud based management

Medium Term

This architecture is for use cases that require low latency. This includes use cases such as:

- Augmented Reality
- Virtual Reality
- Remote monitoring

Long Term

This architecture is for use cases that require advanced connectivity and reliability. This includes use cases such as:

- Automated factories
- Connected robotics
- Automated Guided Vehicle

5G

LTE

Control Anchor on 5G Core

Control Anchor on

Key: EPC – Evolved Packet Core
eLTE – Enhanced Long Term Evolution
5GC – 5G Core
LTE – Long Term Evolution
NR – New Radio

The Need for Private 5G Network in a Smart Factory

As each application within a smart factory will have different requirements, with private 5G network, manufacturing enterprises can set up secure and dedicated networks within limited areas that can be tailored for specific smart factory applications.

The table below summarizes the varying levels of need in respect to communication for different use cases within smart factory. The table below shows that smart factory applications require a high level security requirements and place high importance on heterogeneity, both requirements can be met within private 5G networks.

Smart Factory Applications	Latency	Reliability	Band-width	Coverage Availability	Security	Hetero-geneity	Autonomy
Time-critical optimization	Ultra-low	Ultra-High	Low to high	Indoor	Critical	Important	Less critical
Non-time critical control	Less critical	High	Low to high	Indoor On-site Outdoor	Critical	Important	Critical for location tracking
Remote Control	Less critical	High	Low to high	Wide Area	Critical	Important	Less critical
Intra-/Inter-enterprise communi-cation	Ultra-low to less critical	High	Low to high	Wire Area On- Site Outdoor	Critical	Important	Less critical
Connected Goods	Less critical	Low	Low	Wide Area	Important	Important	Critical

Source: White Paper on 5G and the Factories of the Future by 5G-PPP Europe, 2015

Case Studies: Private 5G Network to Address Market and Industry Needs

	Case Study #1	Case Study #2
Description	A company became the first automobile manufacturer to enable full 5G wireless coverage in all its production plants in China.	Private 5G network in a factory in Japan to leverage 5G connectivity to enable automation and stable connectivity between IoT devices.
Market needs it addresses	• Increasing demand for autonomous vehicle • Large quantity of data in factories	• Rising demand for automation in factories • Declining workforce in factories • Rise in connected devices
Application Requirements	• High reliability • Ultra-low latency • 5G NR	• High Reliability • Ultra-low latency • High Availability • 5G NR
Impact	• Increase efficiency, quality and flexibility in production • The 5G data rate increased from an initial 600 megabytes per second to one gigabit per second.	• Improve efficiency and productivity • Reduced interference
Companies Involved	BMW Brilliance Automotive, China Unicom & China Mobile	Nokia, NTT Docomo & Omron Factory
Key Takeaway	Enterprises within the manufacturing industry are deploying private 5G networks to improve their factory plants, to improve internal operations in terms of efficiency and productivity.	Enterprises are opting to collaborate with mobile operators and system integrators to develop their private 5G network due to their expertise in the private network market.

Requirement Considerations for Private 5G Network

Spectrum Bands
Spectrum is the key to unlocking the private network market. One of the most significant challenges in the market is deciding which spectrum band private 5G networks should be deployed on. At present, there are three spectrum band options available: Licensed, Unlicensed and Shared.

For smart factories, it is observed that the majority of enterprises within the manufacturing sector are collaborating with mobile operators to deploy private networks. Therefore, it is likely that private 5G network will run under a licensed spectrum band within such scenarios.

Besides that, operating the private 5G network within a licensed spectrum band will mitigate the risk of interference, which is particularly important for smart factory applications.

Deployment Scenarios
The emergence of the shared, unlicensed spectrum access approach is expected to drive the deployment private networks going forward. One of the main discussions today revolves around which enterprises will pocket that investment. That is because enterprises that want to benefit from private 5G network will have a number of deployment options, either in-house deployments or mobile operator deployment.

Advantages & Disadvantages of Private 5G Network Deployment Scenarios

	Advantages	Disadvantages
In-House Deployments	• Better security • Improve privacy • Reduce dependency • Better control	• Deployment cost • Lack of operational personnel
Mobile Operator Deployments	• Faster time to deployments • Access to spectrum • Access to technical skills	• Less control • Lower security levels

As it is favorable to use a licensed spectrum band for smart factory, acquiring exclusive access to radio spectrum bands will require high investments by enterprises. Therefore, most enterprises in the manufacturing sector will likely opt for partnerships with a mobile operator for the deployment of private 5G network. This deployment model will require collaboration between enterprise and mobile operators.

The mobile operator will build and operate the private 5G network at the enterprise premises and utilize either parts of its own spectrum or spectrum acquired by the enterprise or non-service provider. Some potential benefits of utilizing mobile operator spectrum include roaming between the dedicated private and public networks, which can ensure service continuity.

Architecture Transformation

5G Non-Standalone (NSA) and Standalone (SA)

With 5G, the first wave of networks and devices will be classified as Non-Standalone (NSA), where the 5G network will be supported by existing 4G core infrastructures. However, as 5G use cases in smart factories become more complex and require capabilities, such as ultra-low latency and higher capacity, it will require operation on a 5G standalone (SA) network. With 5G SA, the mobile operator transitions to both 5G New Radio (NR) and 5G Core, enabling new use cases and business models that require Massive Machine Type Communications (mMTC) capabilities.

The 5G SA network and device standards are expected to take off from 2020 onwards, as mobile operators migrate from 5G NSA to SA. Some of the key countries where we can expect some 5G SA launches within 2020 include China, Japan, South Korea and the United States.

Today, mobile operators have different vendors to run RAN, Transport and Core. With 5G, there is the rising importance for end-to-end capabilities that work seamlessly. As such, this will become a key criterion for all enterprise solutions in the near future, especially private networks in smart factories.

As a result, cooperation with system integrator (SI) vendors is crucial for the end-to-end implementation of private 5G network. Mobile operators that want to drive private network rollout can jointly collaborate with SIs with the necessary skills as they are able to support end-to-end billing and work with multiple vendors.

Business Models and Pricing Schemes

It is critical that mobile operators identify adequate pricing schemes to leverage on and grow the revenue opportunity with smart factories. With the previous 4G networks, pricing schemes were focused on data bundles; however, this approach may not suffice for 5G, especially implementations with mMTC solutions. With 5G, there will be a lot of new parameters to consider and new charging mechanisms to take into account in pricing schemes.

Mobile operators can build on past experience with Internet of Things (IoT) pricing models to come up with pricing schemes for private 5G network in smart factories. This round, however, the consideration is more than just connectivity of sensors through a common gateway as was the case with early M2M implementations. As we start to get into new innovative end to end solutions, it becomes apparent that there is still little development in the area of business models and pricing schemes for private 5G networks.

The reason for this is the inherent complexity as some of these new solutions will include advanced edge computing based on a mixture of local and cloud processing of data, multiple solution providers and advanced analytics that are starting to include video recognition capabilities.

What is clear is that we are at the early stages of developments in business models and pricing schemes for private 5G networks. Some of early basic models include a variety of cost-and benefit-sharing revenue models such as:

- Right to Use
- Permanent License
- Subscription
- Connectivity-as-a-Service

However, we know that these models alone will not suffice in the 5G era. The best innovation in business models and pricing schemes for private 5G networks has yet to come.

Sensors

Sensors enabled with IoT technology empowers the sensors to collect and communicate high volume of data from multiple points in the manufacturing facility that can relay to a cloud, which in turn will be used for decision-making and analytics. Sensors are one of the most important elements in the IIoT structure.

Most industrial systems depend on sensors for reliable and consistent data for automation purposes. IIoT can be implemented successfully only when sensors are able to accurately track parameters such as temperature, strain, position, and pressure, among other variables.

Benefits of Sensors in Manufacturing

- Facilitates seamless interoperability of instruments & devices
- Pushes up product & system efficiency
- Ability to provide corrective action
- Minimizes wastage and reduces downtime
- Brings Ease of communication with other devices inside and outside the factory.
- Common standards facilitates easier adoption

Big Data and AI

Big Data and AI is an attempt to create machines that can sense, process and act like humans including undertaking complex tasks such as natural language processing, planning, image, object and sound recognition, and making objective business decisions.

For instance, using big data, manufacturers can undertake predictive maintenance in the smart factory to identify patterns or predict events that can bring significant cost savings and improve margins.

Benefits of AI can be obtained across products, business processes and at various levels of manufacturing as given below:

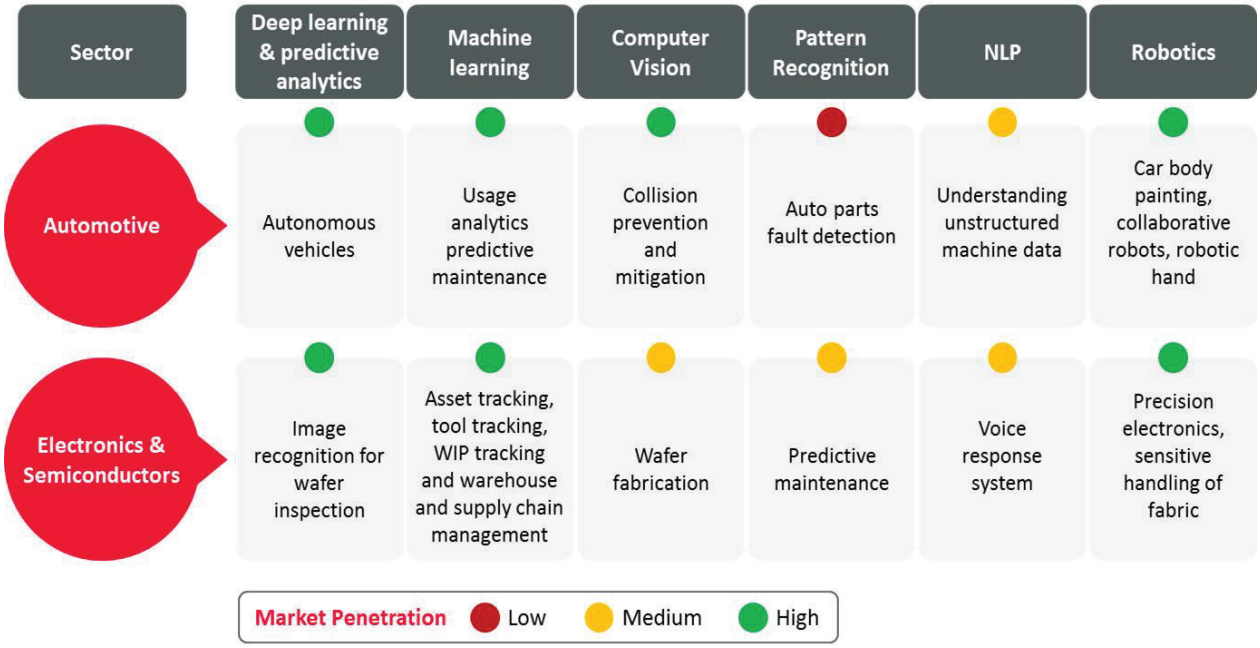
Benefits of AI in Manufacturing

- Immediacy and efficiency: AI facilitates real-time processing of data that can lead to faster and more efficient production of goods and services at the shop floor.
- Handling complexity: AI is a proven tool to solve complex issues with minimal or zero human interference.
- Performing diverse tasks: AI, when introduced into industrial assets can resolve varied set of tasks concurrently. This will make these assets capable of multitasking.
- Ensuring plant safety: AI can enhance shop floor safety by accessing production areas that are otherwise dangerous to human life.
- Reliability and accuracy: Cognitive robots can work alongside humans, delivering the required output without taking a break or getting exhausted.

Manufacturers evaluating AI for adoption will need to strike a fine balance between human and machines on the factory shop floor to optimize the production value chain.

Cutting-edge AI technologies such as machine learning, computer vision, Natural Language Processing (NLP), cognitive computing, etc., can considerably revolutionize the future of smart factory.

Artificial Intelligence in Manufacturing: Market Penetration Analysis



Source: Frost & Sullivan

Cloud/ Edge Computing

Manufacturers use either private or public cloud where voluminous data that is generated, is sent and retrieved from the cloud. However, this process is time consuming, expensive and at times, highly unviable for many companies. To address these challenges, edge or fog computing is emerging as a promising technology that bridges the gap between the cloud and connected equipment in the factory. However, both cloud (where data is at a centralized location) and edge computing (data is located at the edge of a connected device) are required in a smart factory to leverage the data effectively as they are complementing technologies.

In a typical smart factory, data that is generated in the manufacturing ecosystem may be distributed between the edge and the cloud, as required to save time and facilitate faster decision making. Market positioning of the manufacturers will depend on how effectively they combine and adopt both cloud and edge computing technologies in the smart factory set up.

Benefits of Edge Computing in Manufacturing

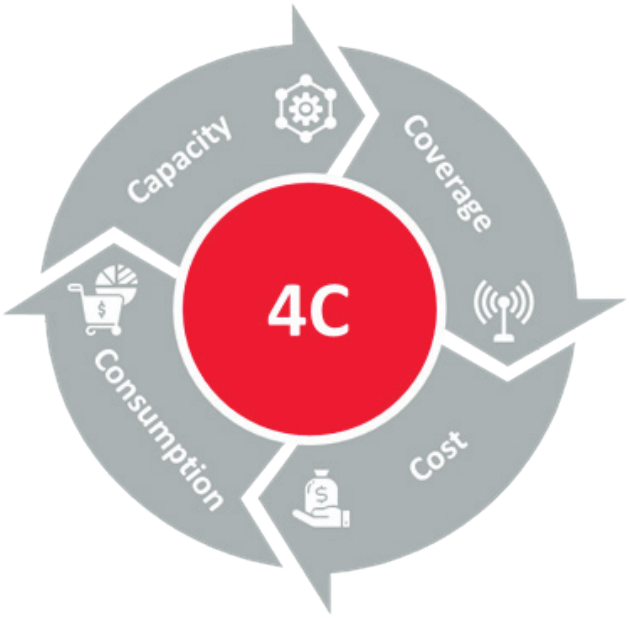
- Real-time data analysis: Data analysis is much quicker at the local device level when compared to the cloud level.
- Enhanced data security: Edge computing assures manufacturers higher data security as the connected products or systems can be secured easily through door access controls, video surveillance cameras, and physical security methods. Besides, data security remains a lesser concern as it is restricted physically within the precincts of the shop floor.
- Reduced operational costs: As the data generated is stored within the device itself, operational or data management cost is very low which in turn, translates to nominal infrastructure costs for network transmission.
- Offloading computing tasks: Edge computing, being very location-centric enables servers on the edge to reduce the load from connected devices by storing information on the edge. It can also function as a private cloud that can be accessed from remote locations.

Cloud vs. Edge Computing

Functionalities	Cloud	Edge
Location	Centralised Location	Distributed Structure
Location awareness	No	Yes
Mobility	Restricted	Supported
Distance between client and server	Multiple hops	Single hop
Real-time interaction	Yes, Possible	Yes, Possible
Scalability	Low	High
Response time	High	Very Low
Point of service	Typically anywhere within the internet	Mainly at the edge of local network
Security	Ambiguous; prone to attacks	Definable; safe from attacks

Smart Factory:
Case Studies

Murata Manufacturing Leading the Way in Smart Factories



Connectivity and convergence is one of the global mega trends impacting business models and creating alternate monetization. Within the manufacturing sector, an important convergence is that of Operations Technology (OT) and Information Technology (IT). Manufacturing today is no longer labor intensive but it is intelligent, super-fast, IT-inclined and devoid of defects. Industries and business are being disrupted by digital technologies. Smart factories will be hyper-connected, self-healing, self-optimizing and self-learning. Many manufacturing companies also follow 'Poka Yoke' technique, known as mistake-proofing to avoid simple human errors that can cause defective products.

An increasing number of manufacturing companies realize the need for coordination as the value of IoT can be achieved only when devices are connected to the cloud and collectively analyzed. IIoT's benefits extend to all aspects of manufacturing from reducing costs, increasing storage capabilities, facilitating high level of automation, creating better agility in computing techniques and increasing the focus on innovative methods.

Murata Manufacturing is a leading global electronic device manufacturer with a proven track record with wireless communication modules, such as smart-phones and other communication devices. As a key vendor of LPWAN technologies, Murata is committed to fostering innovation to consistently address the 4Cs (Coverage, Capacity, Cost, Consumption) of LPWAN application suitability for its wide-reaching end-users.

To respond to customers' diverse needs, Murata has formed strategic partnerships with market leaders to accelerate the development of products using LPWA technology. Murata recently partnered with Semtech and STMicroelectronics, for developing a Module solution which could leverage the strengths of all three partners for this technology.

While the main focus for Murata's development of this Module solution was to support the LoRaWAN market, the hardware would also support other protocols based on FSK technology and to switch between the two – if required.

The Open MCU Module from Murata continues to support could also support use with Sigfox function throug the software release from ST Micro in early 2018 and the development of a dedicated Firmware release for the Murata Module, which is in the final stages of development – expected to be released in 2018.

Furthermore, Murata's high quality RF design, RF performance and RF components have earned itself several pre-certified radio regulatory approvals. Both software and hardware modules are available on Murata's LoRa Platform, producing the industry's smallest module size (also known as the compact LPWAN wireless module) with an option that covers the frequency band for North America, Europe, and the most of AsianASEAN countries .

These capabilities clearly position Murata among the industry leaders, providing the most efficient LPWAN technology that nurtures an ever-expanding ecosystem of low-power IoT applications, enhancing the connectivity and convenience for users around the world.

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ABOUT MURATA

Murata Manufacturing Co., Ltd. is a worldwide leader in the design, manufacture and sale of ceramic-based passive electronic components & solutions, communication modules and power supply modules. Murata is committed to the development of advanced electronic materials and leading edge, multi-functional, high-density modules. The company has employees and manufacturing facilities throughout the world.

For more information, visit Murata's website at www.murata.com