

Mobile Edge in Focus - Manufacturing

Exploring Edge Computing Benefits for the Manufacturing Industry

RESEARCH BRIEF

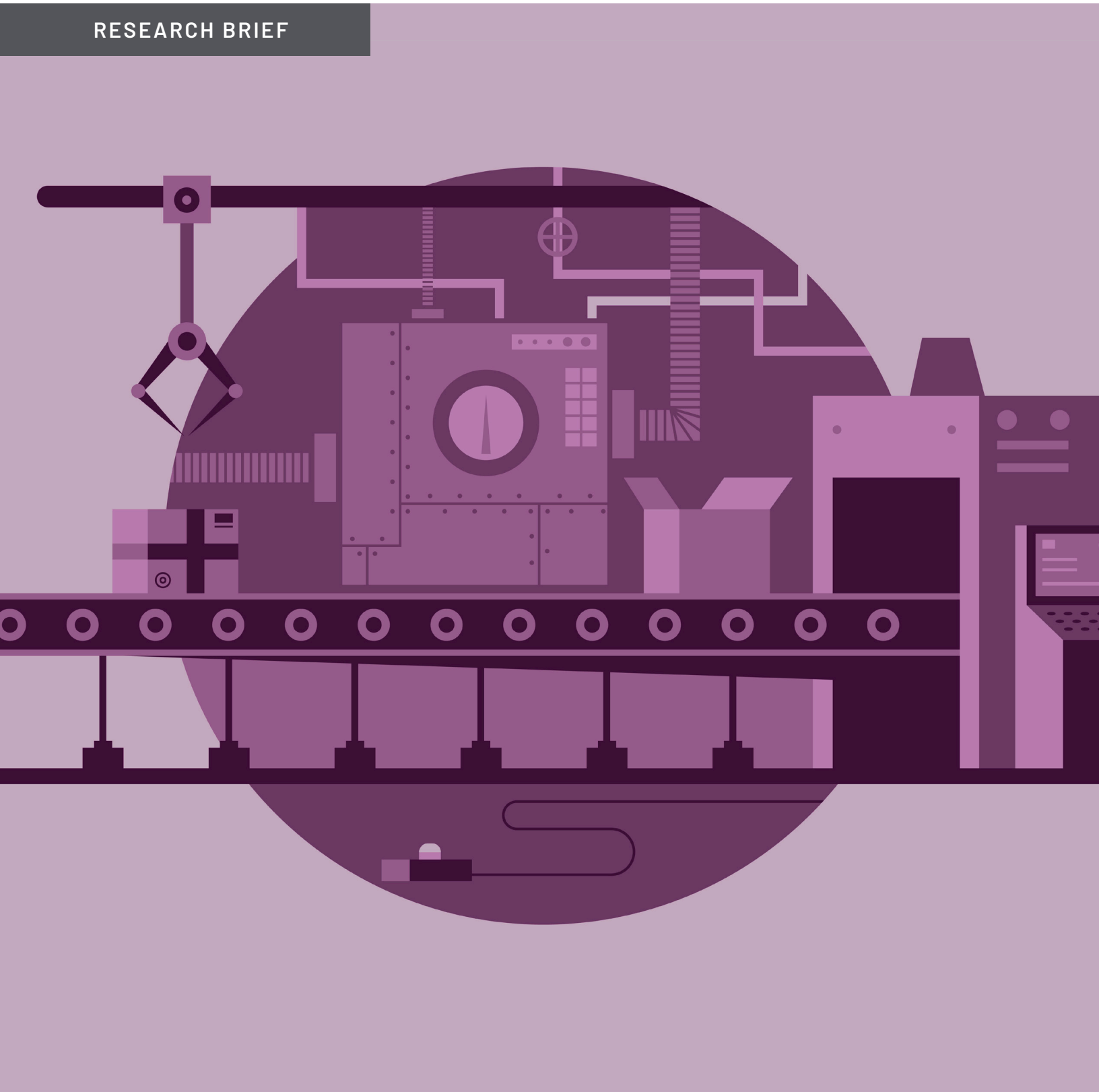


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Overview

This brief is part of our series of research reports examining mobile edge computing opportunities in select enterprise verticals. As we laid out in our **2020 Edge and Beyond report**, edge computing spans multiple locations with different tradeoffs at each. While the benefits provided by the edge for each industry vertical will differ, manufacturing is a vertical that's recognized as a primary beneficiary of 5G and edge computing.

Ongoing geopolitical events and health crises are validating the importance of agile and scalable manufacturing practices partnered with a fluid yet robust supply chain. It has shone a light on the difficulty of operating production lines when capacity is capped by government health restrictions, increased regional tensions, or inability to access raw material.

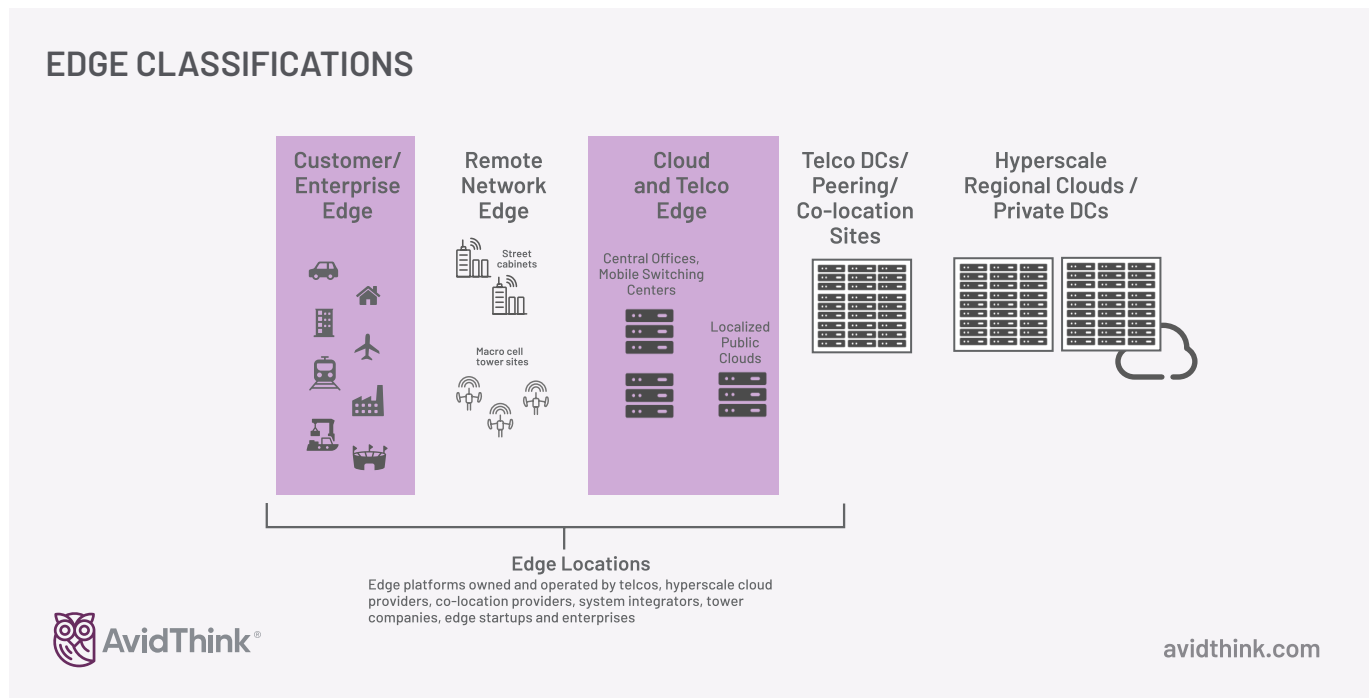
Traditional practices like lean operations, just-in-time (JIT) manufacturing and Six Sigma have previously been employed, but companies are always looking to disruptive technologies to power their next wave of performance improvements. Here is where Industry 4.0 enters and ushers with it Industrial Internet of Things, or IIoT, digital twins, artificial intelligence (AI) and machine learning (ML), advanced automation and robotics, and additive and distributed manufacturing including 3D printing. Additional technologies of interest in the Industry 4.0 movement include augmented reality (AR) and virtual reality (VR). Coincidentally, public and private 5G with mobile edge computing intersects with and enables many of these disruptive technologies.

This research brief is aimed at CIOs, technologists, developers, and business executives in the manufacturing sector. In this brief, we will provide an overview of mobile edge computing, explain its benefits, and discuss how manufacturing trends align with what the edge can offer. We will discuss promising use cases and then wrap up with a concrete set of steps to get started.

What is Mobile Edge Computing?

Let's start by examining edge computing. Today's public and private enterprise clouds are hosted within large data centers that benefit from economies of scale and provide application developers with a rich set of supporting services. However, there are use cases where it is beneficial, or even necessary, to host computing resources closer to users and enterprises – the edge. The exact location of the edge depends on one's vantage point. In this brief, we'll use the high-level classification of edge locations as depicted in the diagram.

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From the diagram, edge locations relevant to our discussion include:

- **Enterprise or customer edge** – This refers to computing, storage, and networking resources located on-premises at customer locations. These locations could be factories, office buildings, mines, oilfields, or semipublic venues like airports, stadiums, theme parks, and shipping ports.
- **Cloud or telco edge** – These are off-premises locations hosted by either public cloud providers or telecom operators. Topologically close to enterprise locations, they include mobile switching centers (MSCs), wireline central offices (COs), and mobile cell sites. They may also be localized public cloud edges placed near high-density metropolitan areas such as London, Tokyo, Los Angeles, or New York.

With the shift towards 5G-powered mobility, the telecommunications industry has been looking into embedding computing resources within the mobile radio network to improve user experience and application performance. Originally called mobile edge computing, the MEC acronym has been redefined as multiple-access edge compute to broaden its applicability, and the European Telecommunications Standards Institute (ETSI) has led efforts to promote this.

MEC embedded deep within the radio access network (RAN) is in early trials. However, edge computing resources located upstream in the MSCs or mobile service access points (SAP), where traffic from multiple RANs are aggregated, are now available for public access. Hyperscale cloud providers such as Amazon Web Services (AWS), Google Cloud Platform (GCP), and Microsoft Azure are partnering with mobile network operators (MNOs) globally to extend their cloud computing platforms into the mobile network. At the time of this research brief’s publication, AWS Wavelength is the only available public cloud service embedded in a telco network. Launched in August 2020, AWS Wavelength is now in production in thirteen cities across the U.S. on Verizon’s network, in South Korea with SK Telecom, in Japan with KDDI, and in the U.K. and Germany with Vodafone. Other sites in partnership with Bell Canada, Singtel and Telstra have been hinted at with no launch dates.

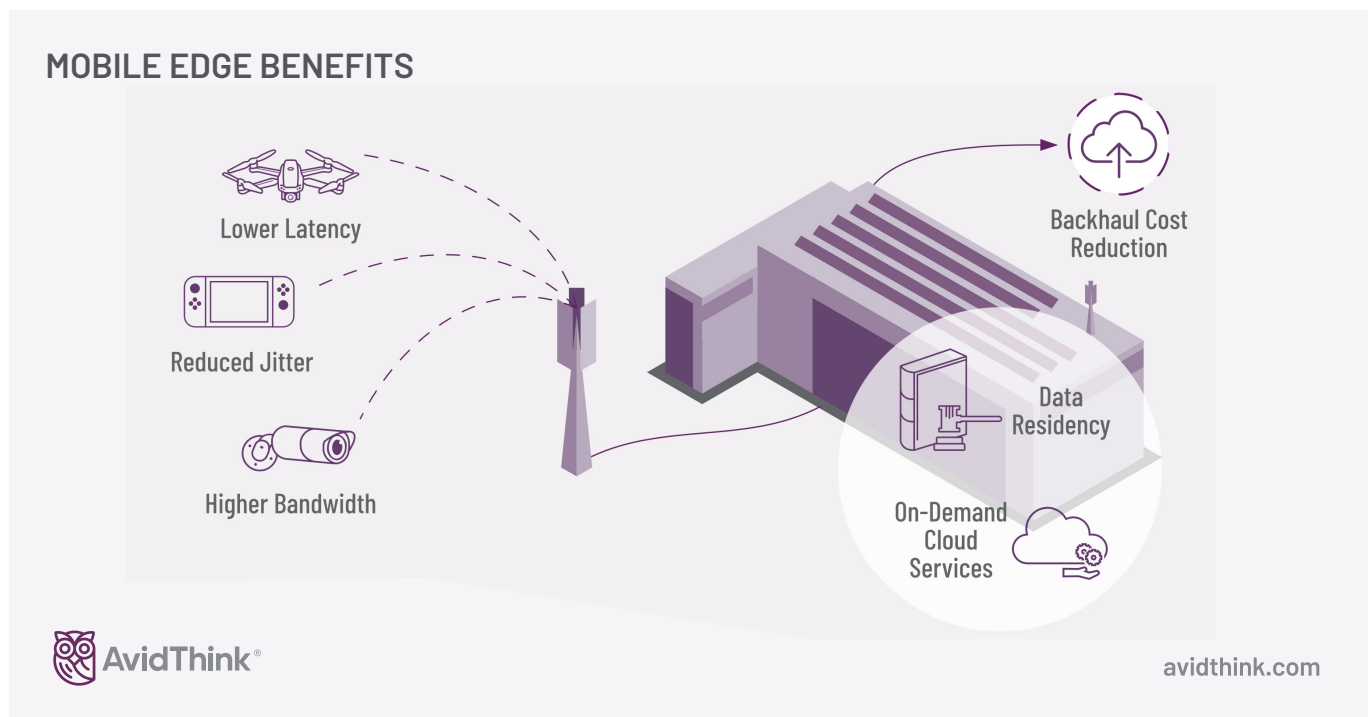
For the manufacturing sector, private MEC coupled with private 5G onsite in factories can provide a unique joint platform that unlocks new enterprise use cases. Carriers, hyperscalers, system integrators, and server OEMs are all engaging the market, offering their own flavors of private MEC alone or in partnership with each other. For example, AWS has AWS Outposts,

Microsoft Azure offers Azure Stack Edge. Meanwhile, Dell, HPE, and Lenovo all have their own versions of an on-premises edge (often in concert with a virtualization software vendor like VMware or IBM/RedHat), but also partner with hyperscalers.

Benefits of Mobile Edge Computing

For most of this brief, when we discuss mobile edge computing, we'll focus on the class of solutions represented by AWS Wavelength and similar potential offerings from other hyperscale cloud providers. However, because of the value of private on-premises MEC and metro edge locations to manufacturers, we'll also discuss the relevance of those edge options.

Regardless of which form of edge computing manufacturers employ, the benefits include:



- **Lower latency** – Compared to computing services located in regional clouds, edge computing serves devices on public or private mobile networks without incurring additional transmission latency or the vagaries of internet routing.
- **Reduced jitter with increased reliability** – Due to the reduction in hops and devices that the packets must traverse, connectivity to edge sites is more reliable and suffers less jitter.
- **Higher bandwidth** – Depending on the uplink capacity from the MSCs to the rest of the network, heavy mobile traffic can bottleneck in backhaul network connections. But data stored and generated at the mobile edge then transmitted to mobile devices does not. In this way, the mobile edge could act as an intermediary, caching data both ways, optimizing backhaul links, and scheduling transfers at off-peak times. For on-premises edge computing, applications would only need to contend with local area networks which have more bandwidth available than wide area links.
- **Backhaul cost reduction** – As a corollary to the previous benefit, if data is generated and processed at the edge, then backhaul links can be sized appropriately, resulting in cost savings. For use cases involving preprocessing and filtering of data before uploading to a central location, the bandwidth reduction can lower costs.

- **Adherence to data residency regulations** – In situations where the closest public cloud is in a foreign country, an in-country mobile edge could be used to process sensitive or regulated data. On-premises mobile edge options avoid data leaving enterprise locations altogether.
- **Convenience of on-demand cloud services** – One of the more holistic benefits of mobile edge clouds is the ability to spin up nearby cloud computing resources on demand. Enterprises could build their own edges by purchasing racks of equipment and placing them in data centers near- or on-premises. However, that approach lacks the on-demand and elastic nature of edge clouds hosted by carriers or cloud providers. It also necessitates upfront capital expenditure instead of a pay-as-you-go billing model.

Enterprises gain an additional advantage if the edge is an extension of an existing cloud service or presents the same interfaces. Consistency of application programming interfaces (APIs), development tools and pipelines play a role in saving development cycles, increasing productivity, reducing errors, and speeding up time to market.

Use cases that benefit from these mobile edges include video analytics, AI and ML, location services, IoT applications, augmented reality and virtual reality, content distribution, and caching. For manufacturing, early use cases include powering production control systems, processing IIoT sensor data, controlling autonomous guided vehicles (AGVs) and autonomous mobile robots (AMRs), as well as conducting video surveillance of manufacturing sites for security and safety.

Key Trends in Manufacturing

Recent global health crises have demonstrated how a few key events can dramatically impact global manufacturing. In a flash, supply chains for consumer and durable goods, including food, automobiles, computing and electronics equipment can experience massive volatility and fall victim to cancellations, delays, shortages and oversupply. Producers have learned that lean manufacturing practices like just-in-time (JIT), while beneficial to reducing operational costs and wastage, can result in production halts when streamlined inventories run out. Manufacturers are more aware of contingency planning and balancing leanness versus resiliency as they continue to reinvent their supply chains.

The Industry 4.0 Umbrella

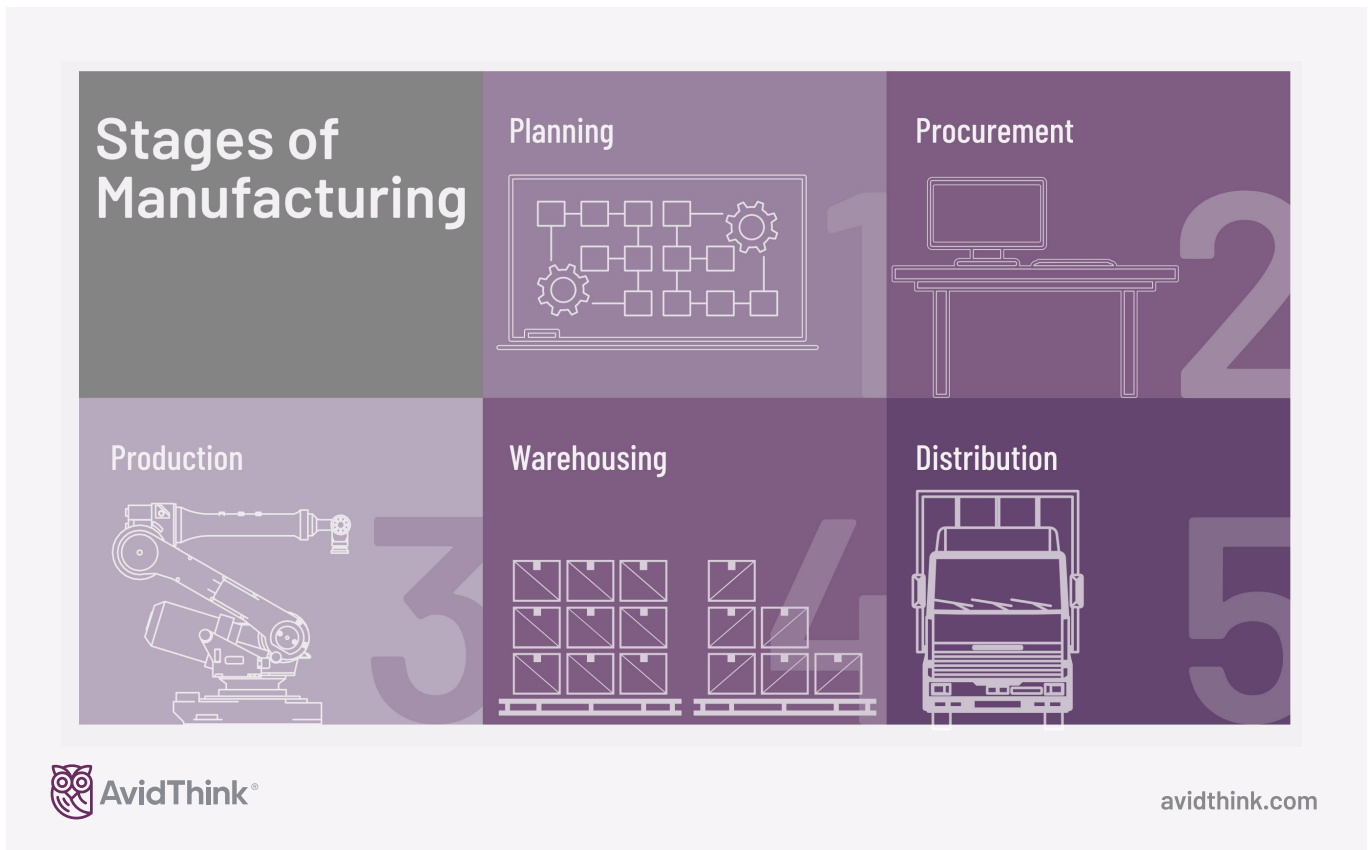
The term "Industrie 4.0" originated in 2011 from a German government strategy project promoting the use of digital technologies in manufacturing. Adopted by the world as representative of the next wave, or fourth wave, of industrial revolution, Industry 4.0 is now the major catchphrase for the digital transformation of producers everywhere. In 2018, the World Economic Forum (WEF) estimated that Industry 4.0 would create **USD 3.7 trillion of worldwide economic value by 2025**. Industry 4.0 is viewed as a key priority in the **WEF's Great Reset** efforts to rebuild a sustainable global economy.

Therefore, digital transformation, automation, robotics, IoT and use of AI/ML remain critical technology initiatives for manufacturers everywhere. Along with these digital initiatives come parallel efforts to upskill workers. A combination of technology and humans is required to unlock the full value of digital capabilities and employees will need to be trained. In the same way, processes will have to be adapted to take advantage of the insights, speed and scale that Industry 4.0 innovations bring.

We'll now look at key digital and related initiatives throughout the manufacturing value chain, across planning, procurement, production, warehousing and distribution.



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Planning

Global health scares and recent geopolitical tensions have made forecasting and planning harder. Ongoing dynamism in global trade and supply chain disruptions are further complicated by restrictions on IP exports and continuing strained relationships between the West, Russia and China. On top of demand volatility, manufacturers must deal with supply chain volatility. All of which make accurate forecasting and real-time visibility critical elements for manufacturers to stay operational and profitable.

To help with planning and forecasting, manufacturers strive to improve visibility across the supply chain: from their suppliers to distributors and beyond. Real-time information, coupled with assistance of data analytics and predictive models can help improve planning and might mitigate future shocks to the supply chain.

Procurement

Intelligent procurement and sourcing are part of a manufacturer's competitiveness, and investments in supply chain tracking and traceability can help reduce loss and manage volatility. For regulated and high-value source material, digital tagging technologies can reduce counterfeiting and ensure regulatory compliance.

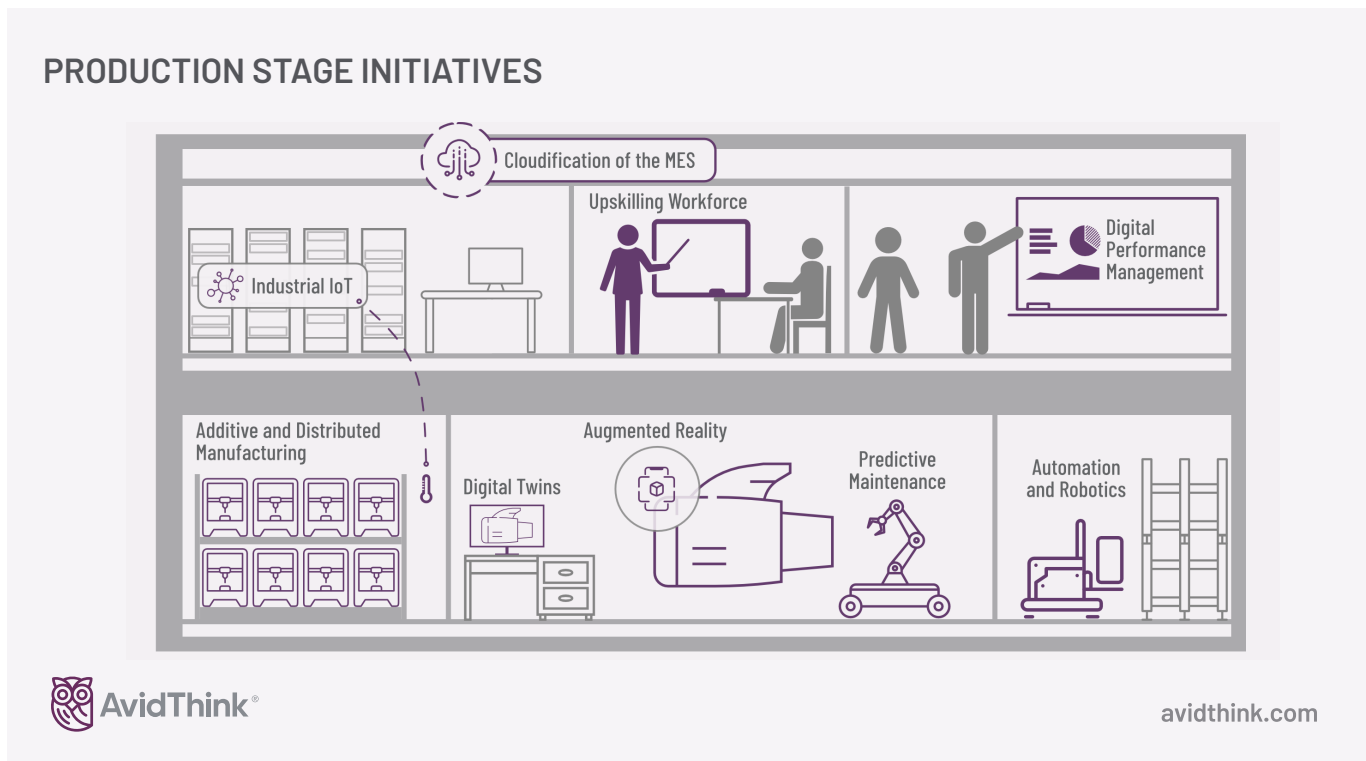
Tracking parts across supplier networks and ensuring that supplies and parts in transit provide real-time data can improve production planning and minimize inventory held. IoT can play a big role in this monitoring, especially where temperature-sensitive goods are being transported. Manufacturers that invest in digital technologies can improve procurement productivity and benefit from greater on-time delivery.

Production

The production processes in manufacturing are where the bulk of digital efficiencies will be extracted. Whether the manufacturer is focused on small lots (custom parts for aerospace or rail), mass customization (auto parts, contribution equipment) or high-volume manufacturing (durable consumer goods, toys, electronics, automobiles), digital transformation can bring significant value.

Digital production techniques can add agility by enabling efficiency and increasing production while maintaining quality. Manufacturing is an area that has seen ongoing evolution, from simple programmable logic controllers (PLC) to more sophisticated programmable automation controllers (PACs) for process control. On the machining front, moving from manual setups to numerical control (NC) or computer numerical control (CNC) has brought about increased flexibility. As manufacturers continue to look for increased efficiencies, driving towards an agile state where small batches can be profitably manufactured, digital enablement will be critical. And regardless of technology, manufacturers are looking to increase overall equipment effectiveness (OEE), achieving full utilization of the equipment with no stoppage and no flawed rejects.

From a process perspective, tighter factory floor integration with engineering and design software (CAD/CAM) allows faster flow of information during design changes, reducing manufacturing and assembly errors. Use of simulation and other verification techniques as part of a new more dynamic and agile flow – mirroring the continuous integration/continuous deployment practices of cloud software development – can speed up implementation of design changes.



Cloudification of the MES

The manufacturing execution systems (MES) that manage the top-level production process are undergoing an evolution. As they migrate to a SaaS footprint, they are becoming more cloud native, data driven and analytics enabled. Although this transformation is moving at pace, not every element will be suited to cloud. We expect the more performance-sensitive

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components to remain on-premises or be hosted at nearby edge computing locations.

Industrial IIoT

One of the fundamental initiatives that continues to receive heavy investment is IIoT – application of IoT principles to manufacturing and industrial operations. Through the use of smart and connected devices in factories or by retrofitting sensors and interfaces to existing equipment, IIoT provides the ability to capture and generate data for analysis along with the means to exert digital control and facilitate automation. IIoT is the foundation for the digital transformation of the factory.

Digital Twins

A key concept that marries well with IIoT is the digital twin. The digital twin is a virtual proxy of a physical system that only exists in the digital space. It provides a close representation – or twin – of the structure, behavior, and

state of the physical asset it mirrors. By interacting with the twin, a program can examine the past and present state then analyze what the future state might be. Digital twins can also be virtual aggregates of multiple physical elements – e.g., multiple jet engines can be combined to represent an aggregate on a plane. Likewise, digital twins can represent a production process, allowing manufacturers to virtually recreate a product and predict its real-world performance through simulation. Through digital twins, the entire digital lifecycle of a product, from design to build to operation to servicing and decommissioning, can be simulated and examined as part of a concept called Digital Thread.

Predictive Maintenance

By using digital twins, in concert with sensors and IIoT, AI and machine learning can predict, prevent and fix problems before they occur. This form of predictive maintenance helps reduce potential downtime, contains costs, and can drive higher OEEs.

Digital Performance Management

Digital twins and threads tend to focus on the factory floor and the products. Broadening the idea results in digital performance management: the establishment of a single system that covers performance management reporting for senior leadership, supply chain reporting and in-factory performance metrics used by key frontline workers. With a single integrated system that can show financial and operational results, the hope is that corrective action can be taken rapidly when performance gaps are observed. For example, by looking more deeply at the operational results within a digital performance management system, manufacturers hope to find the levers that eke out a few more points of OEE, thereby increasing production without further investment.

Additive and Distributed Manufacturing

Additive manufacturing, aka 3D printing, allows manufacturers to create objects by layers, providing improved design, production freedom and less waste. By taking advantage of and driving innovations in material technology, even complex objects can be constructed with little added cost. It can create lighter, better performing, greener and potentially cheaper products, while improving operational flexibility and reducing time to market. Additive manufacturing allows for greater agility by limiting the retooling needed for products and helps create flexibility to customize manufactured objects. This technology enables manufacturing to be flexibly distributed across multiple sites, building products closer to point of consumption and helping re-establish manufacturing in countries like the U.S.

Automation and Robotics

Automation and robots have been used in industrial manufacturing for some time. However, new technologies like AI/ML are bringing a fresh breed of robots to the frontline. Whether in product assembly, warehouse operations or logistics, new AGVs, AMRs and collaborative robots (cobots) can provide an expanded range of assistive functions at lower costs than before. AGVs and AMRs can be used on the factory floor during production to ferry materials and in warehouses and distribution centers to move finished products.

Using automation in the product assembly process from material handling to quality testing and packaging can reduce direct and indirect labor costs. Like additive manufacturing, automation allows manufacturing to be established in higher labor-cost markets by reducing transportation costs and time-to-market.

Augmented Reality

AR smart glasses, in conjunction with assistive techniques through automation and robots, can deliver further efficiencies for manufacturing. For workers on the factory floor, the glasses can provide instructions on standard operating procedures and enable quick lookup of product and parts information. Early indications suggest that AR can also reduce error rates in tasks that involve complex assemblies. There are benefits too for maintenance of manufacturing equipment. AR smart glasses can provide staff with guidance on regular preventive maintenance and access to online documentation for fixing less common problems, enabling faster time-to-recovery and shorter maintenance windows.

Upskilling

With the increased digitization of the manufacturing floor and the value chain, the credentials and skills required of employees are no longer the same. As AGVs, AMRs, cobots, and other forms of automation are adopted, the workforce will need to interact with and manage these technologies. The technical skills for much of the workforce will need to be upgraded.

Warehousing

Beyond production, manufacturers are extending digitization into the warehousing of produced inventory (as well as to raw material, parts and other inputs), finding ways to improve asset tracking, reduce warehousing costs and streamline inventory management. Digitization, use of IIoT and precision location can provide improved visibility into the state of stock in the warehouse, and manufacturers can eliminate or reduce material handling labor by using automated vehicles for material delivery and robots for palletizing.

Distribution

Manufacturers don't always get involved in distribution, but if they do, technologies like IIoT and GPS can provide real-time delivery tracking and accurate delivery windows. Gathering detailed delivery data, or even cost data, along with other KPIs such as shrinkage and on-time performance from different distributors can be fed into a data analytics engine to help reduce transportation costs.

Candidate MEC Use Cases

For the manufacturing vertical, certain use cases are best served by a private MEC instance tied to a local private 5G or 4G LTE network, while others can be addressed from a public MEC over a public 5G network. As we discuss the candidate use cases that can leverage MEC below, we'll call out which might be served from a public MEC:

- **Onsite process controls** – For PLCs/NC/CNCs used in production, private MEC can host the control applications while a private 5G network is used to tie the controls to equipment on the factory floor. The reliability, consistency, security and low latency of the private 5G/MEC combination, coupled with network QoS works as an effective control platform. By centralizing

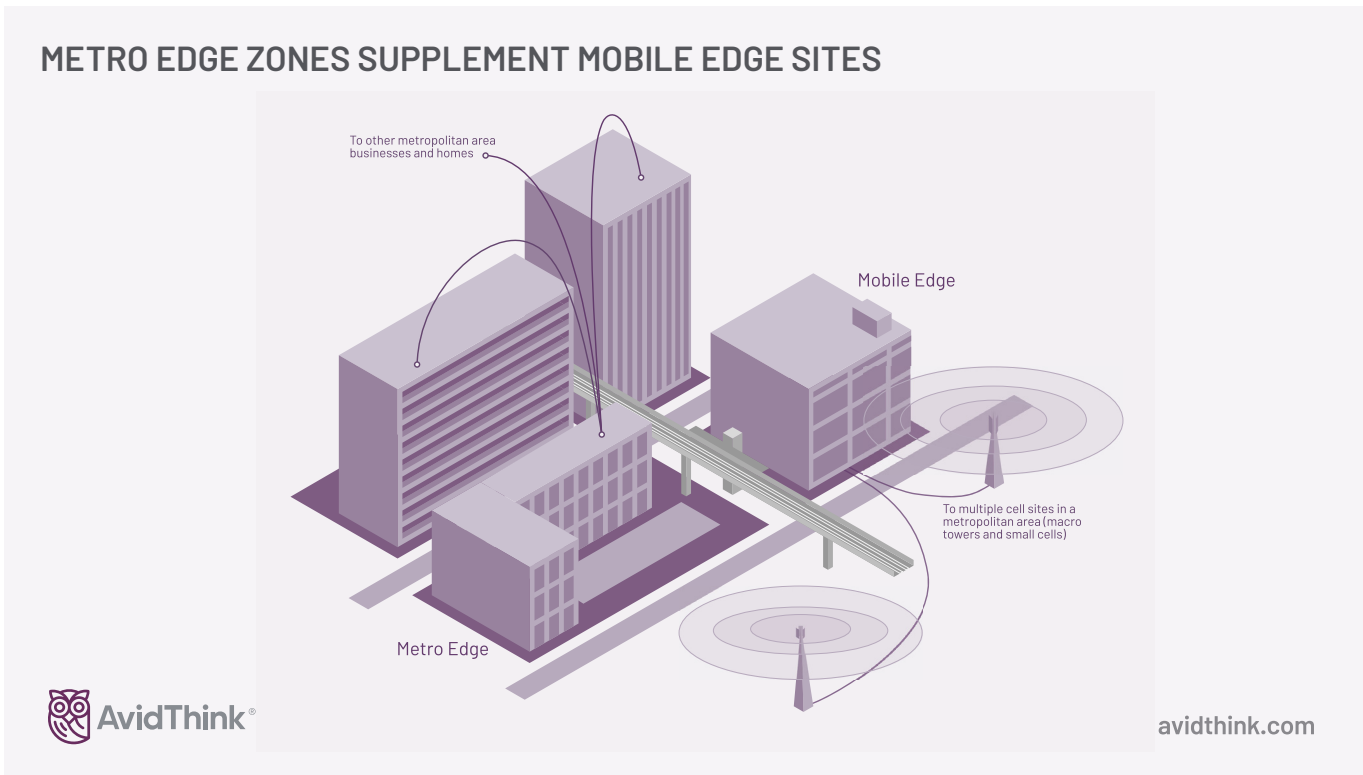
controls within the factory, manufacturers benefit from a simplified infrastructure, lower operational expenses, and greater innovation. Private MEC can host compute-heavy AI/ML engines that take real-time input from the sensors and provide automation assistance to the control systems.

- **AGV and AMR controls** – Private MEC-hosted computer vision applications combined with real-time sensor information can assist with AGV and AMR controls. AI/ML can provide autonomous and safe operations of robots traversing the factory floor. By running the bulk of the logic on centralized systems, robots can be lighter and run longer.
- **AR app hosting** – Private or public MEC can be used to host augmented reality applications that pop-up overlaid information as needed to assist in troubleshooting, maintenance or just to decrease error rates in normal guided operations.
- **Predictive maintenance** – Private and public MEC can crunch the information from equipment sensors – temperature, vibration, humidity and audio – to determine if equipment components are at risk of failure and suggest early maintenance to prevent more expensive failures downstream.
- **Digital twin hosting** – Private and public MEC can host the simulation environments that contain digital twins for on-premises equipment, updating their state in real-time from connected sensors. Likewise, control signals on these digital twins can be conveyed into physical counterparts in a timely manner because of the low latency provided by the 5G network, ensuring a tight control loop. And by having the digital twins hosted at the edge, the amount of data traversing backhaul links to regional data centers can be reduced.
- **Real-time inventory tracking** – Private and public MEC can be used to track parts and finished goods across multiple locations and facilities. As product is moved between manufacturing and warehousing facilities spread out over a city, or neighboring cities, 5G-enabled IIoT devices (or trackers attached to products/pallets) can be tracked across locations and as they are transported. This should reduce theft and improve management of warehouse space.
- **Health and safety** – Private or public MEC-hosted computer vision applications, powered by AI/ML, can help track staff compliance with healthcare mandates or safety violations. For instance, MEC-hosted control systems can detect humans entering unsafe areas on the factory floor and immediately halt production.
- **Private 5G hosting** – Private MEC onsite can host the components of a private 5G or 4G LTE core network – or even radio network software functions in a disaggregated RAN solution – the low-latency provided by onsite MEC meets the requirements of such mobile stacks. Further, co-locating the network core functions on the same private MEC stack as onsite manufacturing control (e.g. real-time components of the MES, AGV/AMR controls) can provide cost savings and simplify IT management.

The reliability, consistency, security and low latency of the private 5G/MEC combination, coupled with network QoS works as an effective control platform.

Metro Edge Zones – Alternative and Supplement to MEC

As we've depicted thus far, both private and public MEC with 5G networks are compelling platforms for manufacturers to host applications, process data and power their Industry 4.0 initiatives. Onsite private MEC provides the lowest latency for performance-sensitive use cases, while leveraging public MEC can provide an on-demand, low-latency platform for less latency-sensitive use cases.



There is a third commercial alternative: metro-area edge computing centers located in dense urban and suburban areas. These locations may add a few milliseconds of round-trip latency compared to the mobile edge, but they have the advantage of being able to serve multiple wireless carrier subscribers as well as wireline subscribers. In addition, they may provide a richer set of cloud computing services and have more scale than the mobile edge. While metro edges tend to be dwarfed by regional public cloud data centers in scale and scope of services, they represent another compelling alternative to balancing latency and performance needs versus costs and scale.

For manufacturers, metro edges can provide an option to host what would normally be hosted in a private MEC, with slight added latency. However, metro zones can eliminate the need to find a secure onsite location with the space, power and cooling that computing equipment requires. They may be a good choice for existing factories that are connected via performant wireline connections today and, hopefully, low-cost 5G fixed-wireless access in the near future. The choice of what edges to use, including on-premises computing, can be complex.

Cloud providers that are able to provide a similar experience and interface across multiple cloud and edge options, including on-premises computing, will find themselves in a strong position when pitching their platforms to retailers looking to embrace the edge. Likewise, virtualization vendors that can offer a seamless abstraction platform and consistent workflow across all hosting locations — edge and cloud — will have a stronger play.

Mobile Edge Benefits Summary – for Manufacturing

Key themes across many of the use cases discussed above is the use of MEC to host real-time functions for manufacturing control processes, MES, and to perform local processing for sensor or IIoT data, reducing backhaul bandwidth consumption.

Likewise, leveraging advanced AI/ML at the edge can also keep computing localized and reduces the upstream data load. The end result is improved automation and intelligence while streamlining IT operations.

Attributes of mobile edge that benefit the manufacturing sector directly include:

- **Lower latency** – With sub-20ms for latency-critical use cases on the public mobile network and sub-10ms to sub-5ms for private MEC, edge computing can be used to drive AR applications for factory workers and technicians. This low latency also enables real-time diagnostics, fast IIoT sensor response, low-latency computer vision use cases like tracking inventory, guiding AGVs/AMRs, safety controls on production lines, and more in-facility health and safety capabilities.
- **Reliable and consistent network** – The reduced number of network elements between the mobile device, application servers, and data cuts down on variability and packet loss. The increased reliability makes the mobile edge a solid candidate to host critical functions like automation and robotic controls, where safety is paramount. Private and public MEC provide an advantage versus regional clouds, which can suffer from higher packet loss rates or routing inconsistencies. Likewise, the network's reliability ensures a consistent video feed, guaranteeing that use cases like video surveillance for health and safety continue to operate with high uptime.
- **Backhaul traffic reduction** – IIoT devices, sensors and video analytics can generate a considerable amount of data. To the extent that a significant portion of this data is localized, using the private or mobile edge can reduce the amount of traffic that has to go to regional clouds, keeping the backhaul network available for other traffic.
- **Reduced learning curve** – For a private MEC or public MEC paired with a public cloud, one of the most underestimated attributes is the frictionless developer experience in extending their application to the edge. Many manufacturing applications built on cloud infrastructure – think MES as SaaS – can be extended to the edge without going through another learning curve. Application developers can reuse their development methodology, application monitoring constructs, and infrastructure. This silo-free approach speeds up innovation at the edge.
- **Edge intelligence** – Edge clouds have AI and GPU acceleration that can be used to offload onboard processors on AMR/AGVs. By leveraging edge systems, robots can operate with greater intelligence without consuming more weight or power on-device.
- **Improved data jurisdiction compliance** – Mobile edge clouds will tend to be located in-country and private edges sit on-premises. For regions such as the EU, where regional clouds might be in a different country, utilizing edge clouds for processing of sensitive data could aid compliance with privacy and data processing regulations.

Fundamentally, the mobile edge provides manufacturers with the reliability, agility, and consistency needed to move forward with Industry 4.0 initiatives.

Mobile Edge Considerations for Manufacturing

While the mobile edge comes with a host of potential benefits, there are considerations that adopters should be aware of. These include:

- **Edge platforms are evolving** – The mobile edge is an early technology. While most mobile edges will use mature and trusted cloud platforms, the specific placement of these resources is new, as is the tighter coupling with mobile networks – both private and public mobile. Nevertheless, those who take advantage of mobile edge by trialing new use cases that aren't possible with regional clouds will come out ahead.
- **Financial tradeoffs exist** – Some workloads do not need the low-latency or reliable connections at the edge. For instance, regional clouds may make better sense for many components of a MES or for AI/ML training of models using IIoT sensor data. Regional clouds usually cost 20-30% less than the edge for compute and storage resources. Likewise, for non-time-critical data analytics, using regional clouds may be the best option.
- **Mobile edge coverage is early** – Publicly-available mobile edge services are starting to roll out. The number of regions served is limited today but multiplying. As we discussed earlier, many workloads will work well in regional clouds, and metro edges can act as a multicarrier alternative if the latency constraints allow the application to still perform adequately.

- **Application orchestration across edges will add complexity** – There is complexity in the orchestration of application components across multiple locations, and optimizing to maximize performance and user experience while minimizing costs and adhering to business constraints presents its own challenges. While the hyperscale clouds may provide underlying infrastructure management across regional clouds, metro edge locations, and mobile edge zones, application developers will need to carefully consider workload placement logic and leverage automation provided by the underlying cloud platforms.

As with any promising new technology, there will be bumps in the road in early deployments. However, there's undoubtedly a significant opportunity in this arena, and manufacturers can benefit from the use of private and public MEC.

Getting Started with the Mobile Edge

For manufacturers who have yet to invest in an edge computing strategy, the mobile edge can be a place to trial new initiatives. For example, there's a desire and willingness to test out AI/ML technologies for improved production controls and use MEC to power and manage IIoT devices across warehouses.

Beyond these use cases, video surveillance for safety and security are popular starting points for MEC, with packaged solutions available from vendors that can be leveraged.

In addition to these concrete starting use cases, AvidThink recommends that manufacturers adopt the following strategies in their IT roadmap:

- **Complete the cloud transition** – The edge is an extension of the cloud. So, those undergoing digital and cloud transformation should accelerate the process to get to the edge.
- **Architect for agility** – Manufacturers with significant legacy applications and assets, will want to re-architect their IT systems to be agile and easily distributed across centralized clouds and the edge. Likewise, the same framework of disaggregation and modularity should be applied to their processes and culture. By taking a leaner approach, manufacturers can adapt more rapidly to customer needs. MEC allows manufacturers to create a compute footprint that is location independent, can be deployed globally, and is backed by a computing stack that provides real-time responses.
- **Innovate early** – The edge represents a significant technology move, and when coupled with 5G, it is even more impactful. While analysts might be overly bullish on the immediate impact of both, the longer-term impact is undeniable. The early entrants in this, if they make moderate investments, can find new ways to drive advanced manufacturing techniques to market more rapidly, putting them in a better position to weather future uncertainties.

Manufacturing IT leaders can choose from commercial offerings available today across private and public mobile edge, as well as the metro edge, across worldwide locations. We advocate getting on the path to understand the possibilities these edge platforms offer. This new wave of innovation offers manufacturers the opportunity to derive competitive advantage and capture new strategic business value throughout the value chain – from raw input to final delivery.

Edge clouds have AI and GPU acceleration that can be used to offload onboard processors on AMR/AGVs. By leveraging edge systems, robots can operate with greater intelligence without consuming more weight or power on-device.



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