Hype Cycle for Manufacturing Operations Strategy, 2020

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A dynamic and volatile market environment is changing the face of manufacturing operations. This Hype Cycle will help manufacturing operations leaders shape future strategies, create roadmaps, align investments and educate peers.

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What You Need to Know

It is not business as usual in 2020. Market volatility, the impact of COVID-19, and sweeping shifts in how factories are located, staffed, managed and digitized are placing pressure on manufacturing operations leaders. They must move fast and cultivate balanced strategies where manufacturing operations continue to make bottom-line improvements — but also is a contributor to top-line growth. This Hype Cycle describes a broad portfolio of enabling capabilities, their maturity and business impacts. The goal is to provide a holistic view of key concepts that can guide them when defining current and long-term strategies.

The Hype Cycle

Manufacturing operations is profoundly changing. COVID-19 has introduced a new set of challenges and risks to managing resources on a global basis. This is atop preexisting executive expectations for manufacturing operations to be a partner to the business and directly support corporate growth initiatives. Balancing innovation, digital transformation and agility with resiliency, cost optimization and efficiency initiatives is a paradoxical challenge for manufacturing operations leaders.

This year's Hype Cycle reflects that challenge by laying out mature and emerging technologies, management disciplines, describing their level of maturity, risks, expected business impact and market penetration. A few trends to highlight for this year's Hype Cycle:

Manufacturing operations has a strong innovation pipeline:

- Cyber-physical systems (CPS) and 5G represent new ways to access and control production. Both are reliant on Internet of Things (IoT) and will impact smart factories and network design.
- New operating models require agile manufacturing capabilities: COVID-19 and other disruptive events have illustrated the time to respond to unforeseen events or how production capacities are rapidly scaled up (or down) are serious challenges to manufacturing operations. Modular operating models enable an organization to break its activities into composable, "plug-and-play" process agility designed to meet changing market and customer needs.
- Circular economy's focus on recovering resources and new efficiencies for raw materials will be enhanced by synchronized BOMs, which improve efficiency of using content throughout the

product/service life cycle. Both are boosted by traceability, provenance and decision management enablement of the digital thread.

Management disciplines for core competencies are also evolving:

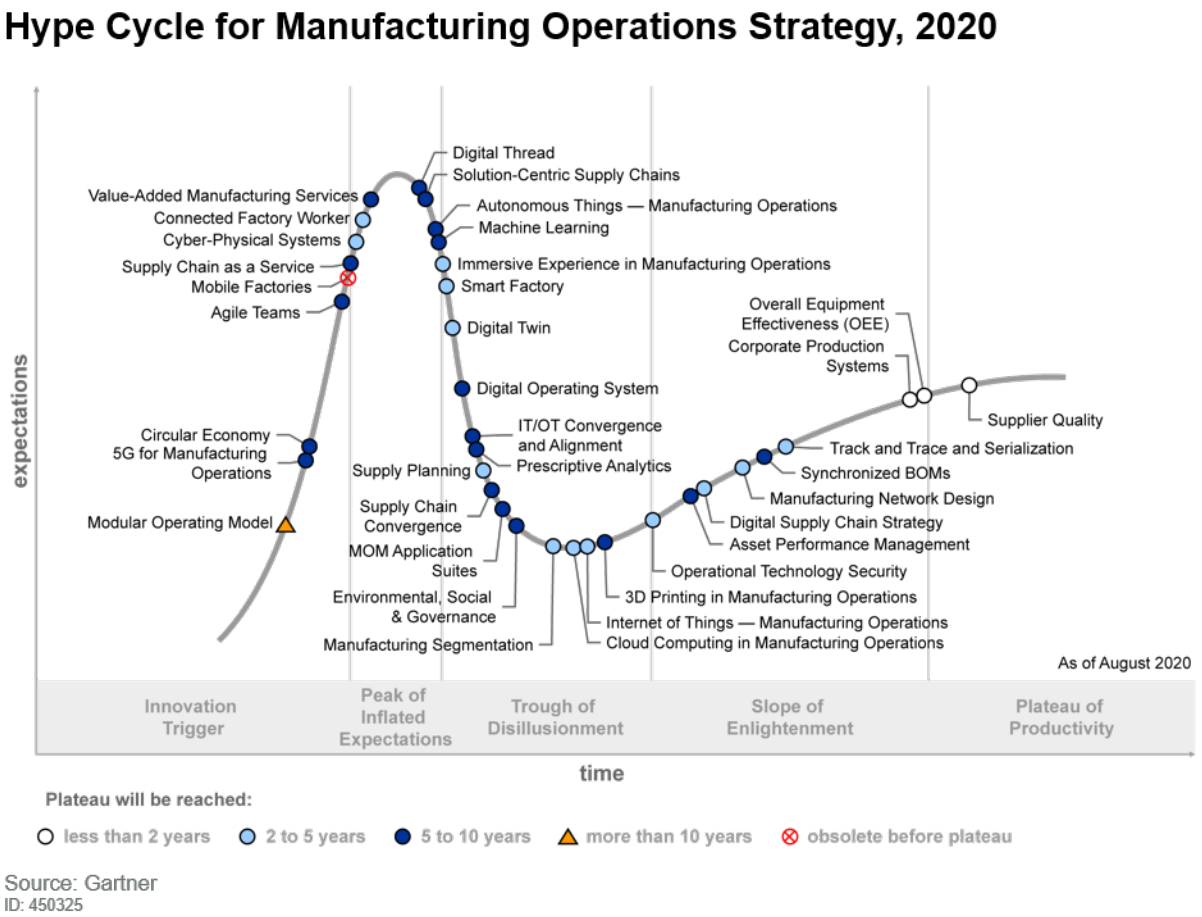
- Digital operating systems build upon the lean and continuous improvement focuses of corporate production systems to incorporate new harmonized best practices, standard work and metrics for technology leverage and scale.
- The strong forward movement of autonomous things and connected factory worker, the introduction of agile teams and the focus on IT/OT (operational technology) alignment reflects the shifts in organizational designs and factory staffing models for day-to-day execution in factories.

Not to be overlooked are the profiles that are foundational to enabling the transformation of manufacturing operations strategy:

- Supply planning and supply chain convergence and manufacturing segmentation require focus to integrate and orchestrate production activities as part of supply chain's designed to deliver stakeholder value. The forward progress of digital supply chain strategy should help design the roadmaps to facilitate this.
- COVID-19 elevated the importance of cloud computing, which is slowly exiting the trough. IoT has entered the trough. Additionally, the aggressive movement of digital twins only accelerates the movement toward the trough. While the hyped vision of a digital twin is appealing, only 10% of the respondents in a Gartner's 2019 Realization of Industry 4.0 Survey consider it among the top five technologies impacting manufacturing operations.
- OT security continues to progress and will need attention and investment as innovation continues.

To shorten any tenure in the trough and accelerate movement toward the plateau, lowering the threshold and cost of entry is essential. Investments need to take a broad view and account for new skills and behaviors and refactoring of core processes, and leveraging external partnerships are essential. Internally clarifying manufacturing's role and alignment — and for manufacturing operations leaders to work with key stakeholders in business and cross-functionally (including IT and HR) to attentively lead and manage change — are necessities. This way, new and innovative capabilities cultivated in manufacturing operations truly contribute to growth and do not create constraints for other supply chain functions.

Figure 1. Hype Cycle for Manufacturing Operations Strategy, 2020



Source: Gartner
ID: 450325

The Priority Matrix

The Priority Matrix illustrates the immediate and future opportunities to build new competencies and adopt new technologies, based on their potential impact and maturity. The selection of “most important” should always be done in the context of your own business goals and objectives and how they influence manufacturing strategy. Keep an eye toward which will enable manufacturing operations to drive future competitiveness and customer value.

Although a large number of innovation profiles will take five to 10 years to reach the plateau, they are more mature than that time scale suggests. There is value to be captured now and successful pilots are inevitable. Their lasting effects will be temporary. Although cost and quality are suitable minimum viable outcomes to summon support and investment, it is the next level of — and more disruptive — benefits that be diffused across other parts of the business that matters (see “Apply Bimodal to Achieve the Next-Level Benefits of Smart Manufacturing”).

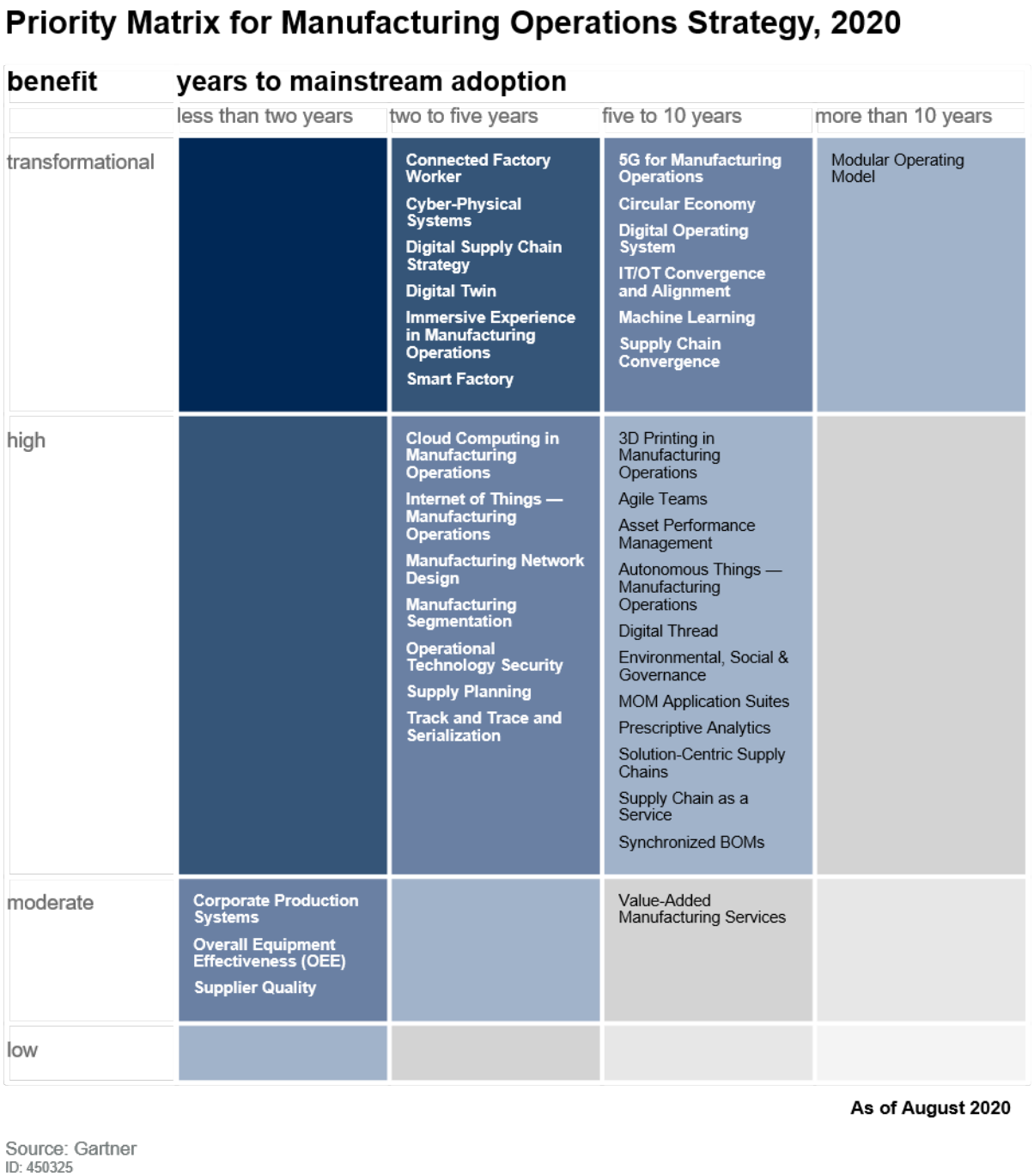
In a time of significant uncertainty, prepare to put your organization's risk appetite and innovation capability to the test. Organizations with a lesser appetite for risk and first-mover rewards should plan to be "fast followers." Falling too far behind the curve could be damaging to the business in the long term.

Pay attention to the key themes and their interdependencies between profiles when evaluating focus and investment:

- People: The changes in factory operating models and talent availability have shifted focus toward the "associate experience." Immersive experiences, connected factory worker and autonomous things all stand to alter how day-to-day activities are performed. This will be done through guided work or experiential training and learning. Agile teams are small, cross-functional groups with defined decision authority to deliver new innovations (see "Supply Chain Brief: Successful Return-to-Work Strategies for Factories").
- Agility and flexibility: The next level of capability will be enabled by IoT, cloud computing and 5G. However, a smart factory strategy that looks beyond technology projects in isolation is necessitated (see "4 Tactics for CSCOs to Shift Manufacturing From a Cost of Doing Business to a Competitive Weapon"). This elevates the importance of manufacturing network design (see "A Simple Framework to Understanding Supply Chain Network Design") to rightsize and realign global manufacturing networks to optimize capacity and minimize risk in consciously planned fashion.
- Modular operating models, supply chain as a service and mobile factories will enable new levels of agility by supporting different capacity orientations, such as asset light or new lines at a fraction of traditional capital expenditure. The planned obsolescence of mobile factories is only reflective of the profile becoming subsumed by smart factories in the future.
- Inside the factory, autonomous things and cyber-physical systems will change the speed and flexibility of some production processes.
- Corporate commitment: Environmental, social and governance (ESG) and circular economy reflect the organization's impact on resource usage, fair business practices and how climate change is responded to. The eventual maturation of machine learning (ML) will impact targeted raw materials reuse or efforts to bring sites to zero-carbon or renewable energy capability.

The challenges and strategy opportunities facing manufacturing operations strategy in 2020 will continue into 2021. This is a fluid, ever-changing environment. The linchpin to any scalable, lasting success will be the connection of future endeavors with ongoing continuous improvement so that adaptation and leverage is continual and not episodic.

Figure 2. Priority Matrix for Manufacturing Operations Strategy, 2020



Source: Gartner
ID: 450325

Off the Hype Cycle

The following are off the Hype Cycle this year:

- Industrial operational intelligence is off the Hype Cycle as analytics are near ubiquitous across near every technology on the continuum.
- External Manufacturing is a mature concept and passes the plateau. Meanwhile, its successor, value-added manufacturing services, reflects the wider range of services than “making products” is near the peak.

The following profile names have been changed:

- Corporate social responsibility (CSR) is now ESG, to reflect expanding organizational focuses into other areas, such as responding to climate change, how they treat their workers, building trust, fostering innovation and other ethical business practices.
- Digital business is now digital supply chain strategy. With this change, we refocus on the supply chain-specific priority of defining a strategy to support an enterprisewide digital strategy. A digital supply chain strategy prepares the supply chain to create a short- and long-term vision that aligns stakeholders behind an integrated set of principles, digital-enabled capabilities and investments.
- Connected worker is now connected factory worker to reflect the more targeted manufacturing operations focus versus how the concept is managed and executed in other industries, such as utilities or oil and Gas or functions such as field services.

On the Rise

Modular Operating Model

Analysis By: Jennifer Loveland

Definition: Modular operating models (MoM) break organization activities into composable chunks to enable plug-and-play process agility in meeting changing business and customer needs. MoM are an advanced process segmentation enabling quick delivery of new infrastructure and outcomes.

Position and Adoption Speed Justification: In MoM, all organizational activities tie to a service portfolio of around 30 services independent of organizational structure or asset ownership. These services are a basis for resource alignment, cost alignment, investments, day-to-day operational governance and metrics. Independent service building blocks can be pieced together to create different outcomes, increasing the speed for the organization to shift capability, resource, governance and value stream components. MoM is a more flexible form of process design, governance and operation than static one-size-fits all segmented operating modal design.

Increasingly, functional strategies require design agility to support a rapidly changing company or industry environment. Increased focus on the speed at which new capabilities, processes and partners can become operational is due to:

- Hypercompetitive industries.
- Product proliferation and a shift toward fulfilling solutions rather than products.

- Increasingly diverse customer expectations.
- Emerging digital technologies changing how processes are done.
- Evolving business models to support digital business.
- Large partner ecosystems and service providers offering new models and technologies.
- Accelerated merger, acquisition and divestiture activity.

MoM builds on many years of service architecture development in IT but is embryonic in application to other more physical oriented functions such as supply chain where the earliest examples have emerged in the high-tech industry and migrated toward food, consumer goods and healthcare. As the above digitally driven trends continue to intensify, MoM is expected to continue to expand across all industries, reaching mainstream adoption in more than 10 years. Adoption has increased recently as factory-in-a box, pop-up warehouses, pop-up hospitals have increased in search of resilience to disruptions and agility to support growth. These examples represent making portions but not all the operating model composable.

User Advice: Functional leaders should assess the need for operating model design agility on a five- to 15-year time horizon based on business dynamics. At the first sign of increasing importance of design agility, begin developing the talent and infrastructure required to support a MoM. Indications are that implementing a full MoM requires a two- to three-year transformation of design and governance, and organization maturity.

As a complex form of process segmentation, MoM impacts the customer outcomes that organization delivers; also, it will change behavior for a significant percentage of organization-controlled resources and will require influencing and incentivizing resources the organization does not directly control. Due to this large scope of change, MoM requires direct C-Suite sponsorship. The multiyear transformation is often coordinated by a small number of resources from a strategy team with an extended team of resources representing all activities within the organization's span of control. Together, they define and launch the following:

- **Modular service portfolio:** To provide a common taxonomy or language focused on value to internal or external customers.
- **Process life cycles:** To map interdependencies between services.
- **Management operating system:** To govern day-to-day operations by defining for each service the accountability, standard measures, resources used, costs, and mechanisms for reviewing performance, addressing issues and using service interdependencies to generate desired outcomes.
- **Design operating system:** To govern strategy development, investments and change projects by services rather than ad hoc projects and programs. Each service should have a multiyear plan to support strategic goals, continuous improvement and innovation.

Business Impact: Dynamic process architectures enabled by the service building blocks of a MoM counter long periods of disruption in the external environment, creating a competitive advantage with speed to adapt and innovate in:

- Bringing new solutions (physical, digital, services) to market.
- Changing operational and go-to-market models and entering new markets.
- Leveraging new technologies (advanced analytics, 3D printing and Internet of Things, smart machines, etc.).
- Capitalizing on new market entrants/innovation from startups.

A MoM increases the value organizations provide to the business and customers. Value exists in aligning to expectations, meeting execution needs and focusing on revenue as well as cost. For example, an early supply chain adopter saw an 11% improvement in scheduled to lead time requested, a 15% to 25% improvement in customer escalations and a 14% reduction in nonmaterial spend.

You often offer differentiated order-level experience on prices, lead time, availability, delivery precision, and solution and delivery options. You may enable new outcomes as well as optimize how outcomes are delivered, leading to double-digit improvements across multiple metrics — both improving efficiency and supporting growth.

By improving the ability to innovate, MoM enables organizations to support changing business models, handle increasing complexity and make the organization a strategic partner in supporting profitable growth, rather than just a cost of doing business.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Recommended Reading: “Case Study, Part 1: Cisco’s Supply-Chain-as-a-Service Architecture Enables Subscription Solutions in a Digital Business Transformation”

“Supply Chain Brief: ‘Factory in a Box’ Concept Challenges Traditional Factory Setup”

“Maverick* Research: Operate Your Business Like a Lego Set to Win in Disruptive Times”

“How to Choose the Right Type of Supply Chain Segmentation for Your Objectives”

“Guide to Aligning Digital Business and the Digital Supply Chain”

5G for Manufacturing Operations

Analysis By: Andrew Stevens; Simon Jacobson

Definition: 5G for manufacturing operations are tailored, next-generation mobile broadband and cellular standard data services. 5G delivers across a spectrum of 3 mm wave bands (low, mid and high frequency). 5G service capabilities for manufacturing will initially be provided through brand new targeted supply chain data and communications services available via communication service providers (CSPs), commonly referred to as Telcos.

Position and Adoption Speed Justification: 5G for manufacturing operations is in the very early phases of evolution. The speed of CSPs' ability to provide specific data services will be dependent on their prioritization and allocation of resources for managing both private/campus 5G networks and larger-scale mobile networks. Early cadence for accelerated adoption in manufacturing operations will be dependent on objective evaluation of 5G's ability to empower and augment across a new spectrum of technology use case applications for manufacturing. These include network slicing, Internet of Things (IoT) with edge, edge computing and analytics, low-latency and mixed reality spectrum applications. Early piloting 5G in manufacturing has been observed across industries such as automotive and aerospace and engineering. Further momentum for discovery and broader applications in the manufacturing environment is expected to increase in parallel with global rollouts of 5G networks, ongoing country bandwidth auctions of networks spectrums and increases in successful early applications across manufacturing operations.

User Advice: Manufacturing operations leaders must objectively assess 5G's potential to complement, enhance and upgrade existing services through new generations of data communications services. Early applications will favor process-intensive, hazardous and time-critical operations, given 5G's ability to significantly increase data speed (projected to be least 10 times faster) and capacity. New generations of 5G data services offer manufacturing environments tools for increased data speed and capacity optimization, accelerated processing times and richer distribution, and visualization tools for real-time decision making. Manufacturing operations leaders should extend their strategic technology planning responsibilities to facilitate more direct working relationships with CSPs for collaboration and to sponsor immersion learning opportunities for CSP delegates to foster accelerated early value propositions. Manufacturing operations leaders (working in conjunction with CSPs) must map early use-case pilots and service propositions to the correct spectrum applicability. An example is high-frequency millimeter wave (mmWave) that will likely support new 5G applications, especially across critical processing streams systems that encounter heavy data traffic and require very low-latency responsiveness and agility low- to mid-frequency spectrums. They will support improved data mobilization, will enhance user experiences and will be best-positioned to meet the increasing capacity demand for mobile services. 5G has the potential to be transformational to manufacturing operations if planned and phased correctly across networks of devices, machines, systems and enterprise applications. 5G's impact is both broad and ubiquitous for manufacturing operations domains. Collaboration and collective learning from within manufacturing will generate maximum benefits for applying 5G against minimum disruption to ensure business continuity. It will also serve to continually reinforce the supply chain 5G value service proposition.

Business Impact: Business criteria will be shaped through evolution of larger numbers of targeted use cases in manufacturing operations. These opportunities might include:

- Predictive/preventive plant, machine and device maintenance — real-time data collection and analytics across distributed networks of devices, machines and service-based field assets.
- Continuous quality automation/in-process perception artificial intelligence (AI). In addition, learning and feedback loops for process optimization, yield, capacity utilization and product development.
- Next-generation agile self-learning and automated robotics networks.
- Untethered virtualized operations panels, video feeds for remote management and processing synchronization across critical or hazardous processing phases.
- Integration accelerator for data mining, real-time data capture and cleansing across disparate manufacturing networks for richer business information for decision making.
- A new era of remote working and operations through reliability and integrity of data feeds — a migration to virtualized operations and transactions and new opportunities for e-learning and remote training through mixed reality, augmented reality (AR)/virtual reality (VR) applications.
- Engineering collaboration/simulation of correlations between product designs and factory layouts leveraging 3D models, digital twin technology and mixed reality (AR and VR)

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Embryonic

Sample Vendors: AT&T; China Mobile; Ericsson; Korea Telecom; Nokia; SKF; Swisscom; Telia; ZTE

Recommended Reading: "The 2020 Strategic Supply Chain Technology Trends"

"Starting Now, Supply Chain Leaders Should Assess the Potential for 5G Mobile Communications Networks"

"Innovation Opportunities Will Be Enabled as 5G Evolves Through 2025"

"Top 10 Strategic Technology Trends for Manufacturing Industries: Smart Factory"

"What 5G Requirements Do Manufacturing Industries Have"

Circular Economy

Analysis By: Sarah Watt

Definition: "Circular economy" is an economic model that separates the ability to achieve economic growth from the consumption of primary natural resources. The circular economy is based on three principles. Firstly, designing out waste, toxicity and pollution from products to ease materials recycling, remanufacturing and reuse. Secondly, materials are kept in use for as long as possible, which may lead to adjustments in business models. Lastly, when materials are returned to the environment, this is done in a way that has a positive impact.

Position and Adoption Speed Justification: Gartner identified the circular economy as an emerging concept in 2017 and a leadership trend in 2018. Its position on the 2020 Hype Cycle is based on our understanding of companies' priorities over the next two years, also considering the impact of the European Green Deal. In a 4Q19 Gartner survey, 70% of respondents stated that they are investing in the circular economy. However, only 27% of respondents have integrated the circular economy into existing business unit and growth strategies. Although some companies are pursuing this strategy, it is by no means at scale; although for Europe-based organizations the Circular Economy Action Plan under the Green Deal may act as an accelerator. The circular economy has the potential to provide improved raw material availability and a hedge against material price volatility, but these benefits are achieved only through systemic change.

User Advice: Now is the time to investigate how applying the circular economy may provide a potential competitive advantage to your organization. First movers are already advancing, but there are plenty of opportunities to innovate, disrupt your market and engage your customers.

CSCOs are advised to:

- Become familiar with fundamental circular economy concepts, such as the design principles that underpin the models and the various types of business or product/service models that become possible through the application of circular design.
- Engage the supply chain to lead your company's circular economy strategic planning by setting up a program office. Give the team the goal of becoming the company's experts in circular economy concepts and models. Ask them to deliver a series of options to advance the circular economy. Define measures of success for the circular economy strategy (see "Metrics for the Circular Economy: If You Can't Measure It, You Can't Manage It").
- Organize a cross-functional strategy team to explore opportunities, business cases and good practices. Initiate conversations around analyzing customer pain points and defining new customer experiences.
- Identify collaborators and partners that can develop, deliver and scale the capabilities required to execute your circular economy model. For example, suppliers may be able to reprocess or remanufacture product of materials (see "4 Practical Steps to Engage Suppliers in Circular Economy Models to Improve Raw Material Availability").
- Extend the benefits of your digital investments by pinpointing the potential intersections between your company's digital business strategy and circular economy strategy (see "Employ Digital Technology to Enable a Circular Economy").

Business Impact: The business impact depends on how a company chooses to apply circular economy principles to its operating model. Some companies first create a closed-loop system to support material recovery for a single product while continuing to deliver other products conventionally. In other instances, the company's entire business model is based on the circulation of a single asset between multiple users.

Any transition will require systems thinking, collaboration and learning agility. Teams from across the enterprise must work together to identify and design the outcomes that customers really want, while reducing waste and the dependency on additional natural resource inputs to deliver them

However, the circular economy may happen sooner than we think, as economic stimulus during and following the COVID-19 crisis may be tied to “green” low-carbon options.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Recommended Reading: “Driving Value Through the Circular Economy”

“Circular Business Models Position Supply Chain as a Growth Partner”

“Retail Supply Chains Embrace the Circular Economy”

“Preparing for 2029, When Consumer Product Supply Chains Cannot Produce Waste”

“Video: Johnson & Johnson’s Circular Economy Partnership Supports Growth in Emerging Markets”

“Future of Supply Chain: Reshaping the Profession”

Agile Teams

Analysis By: Ken Chadwick

Definition: Agile teams are small, cross-functional groups with defined decision authority to deliver fast-cycle solutions for supply chain projects, innovations or challenges. They work in iterative cycles to design and implement minimum viable solutions. With a high tolerance for ambiguity and risk, they test assumptions as solutions are applied to real-world operations, redirecting actions quickly as they learn. As a self-directed team, they target specific outcomes and are guided by design principles/criteria given to them by the business.

Position and Adoption Speed Justification: While “agile” is often seen in the press, we do not currently see significant application of true agile methods to team-based work in supply chains. Perhaps this is because the industry is conflating agility (speed of decision making) with more formal agile approaches. The application of agile methodology, closer to that of the IT construct, can have significant benefits to supply chains in mobilizing teams to action in many situations. There are limited examples emerging of companies applying agile methodology (a descendant of IT agile) to supply chain environments. Those limited examples are picking up on agile team constructs, agile mindsets, sprint methodology and the concept of minimum viable product to accelerate time to development of innovations, projects or solutions to disruptions. While there is a lot of hype around agility, we see few instances where the hype defines an agile team beyond one that is nonhierarchical and fast moving.

User Advice: Supply chain leaders can use agile teams today, but first should develop a clear definition of agile teams and how they operate differently. Agile teams must be small and have the staff representation and skills needed to design the solution with the customer in mind. To move quickly, the team must have accountability for decision making, access to enough information to make decisions and a clear understanding of the goals and design parameters of the project. They must also have the agile development process defined for them so they are able to break down their work into the sprints necessary to develop each group of work (defined as the minimum viable product). In addition to the structure of the team and process, leadership and the team need to reorient their mindset to be agile. This means reorienting leaders to empower the team to make decisions and to accept the risks of failure that come with each sprint and minimum viable product (MVP). For its part, the team must embrace its decision-making role, be willing to make decisions with less than perfect information, be willing to take risks and deliver the MVP while learning from each success and failure. Where parallel agile teams are designing components of the same project, the teams must synchronize their work to provide an integrated solution for users/customers. As agile scales, additional investment in agile coaches and product leaders are required to ensure teams follow the process and stay in sync.

Business Impact: Agile teams can benefit supply chain leaders across their global business. We have seen successful application of agile teams to speed solution development in disruptions (trade and tariff network realignment), as well as in supply chain operations (manufacturing planning). Companies can use agile to increase the pace and adoption of innovations (digital technology), engage in better user design for supply chain processes (sales and operations planning [S&OP]) or to get better outcomes from supply chain technology (planning systems). Agile teams and methodologies can be used in any function and in any situation where a team is required to develop a solution, focusing the solution on customer/user outcomes. Agile teams can reduce the cycle time for solution delivery (faster time to market), deliver better user-defined outcomes (usability), as well as deliver on business-defined outcomes (reduced inventory, improved network capacity, etc.).

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Recommended Reading: “Adaptive Decision Process (Schneider Electric)”

“The Agile Supply Chain Imperative: Empowering Agile and Self-Forming Teams”

“Survey Analysis: How Decision Making Can Drive an Agile Supply Chain Culture”

Mobile Factories

Analysis By: Simon Jacobson; Kamala Raman

Definition: Mobile factories are self-contained production units constructed of ready-for-use modules that can be deployed into markets and assembled at a fraction of the traditional time, cost and risk of a conventional plant.

Position and Adoption Speed Justification: Mobile factories are an innovative approach to deploying highly flexible, simple and cost-effective production capacities at far less than 50% of traditional cost. It is still a nascent concept in a post-pandemic world that deems operational resilience an essential capability (even as pressures for cost efficiency continue and flexibility is very attractive) This creates slightly higher hype and pushes mobile factories ahead in 2020. However, the concept will be obsolete before the plateau.

Although adoption rates have not been as robust as expected, the obsolescence should not be a deterrent for organizations seeking to develop a strategy for mobile, fit-for-purpose, capacity. Those early adopters that have operationalized this strategy are able to understand demand, develop pricing strategies and, should the market be profitable, establish a larger footprint. Should markets not be capitalized upon, these factories can be disassembled, packaged up and transferred to another market.

Instead, obsolescence is a factor of absorption into other facets of an organization's manufacturing strategy. First, the broad promise of mobile factories will eventually become a component of an organization's smart factory strategy. Second, this blend of technology and concept is enabled by the usage of techniques such as manufacturing segmentation. Not to be overlooked is how this concept will be enabled by a broader maturation of network design strategies.

User Advice: In order to maximize the potential of mobile factories, supply chain leaders responsible for network design and/or manufacturing operations strategy should:

- Connect the cultivation of mobile factories with an overall smart manufacturing and smart factory strategy.
- Be clear on success measures by looking at more than plant efficiencies. For example, cost efficiency and speed to market should trump efficiency metrics as success measures.
- Target SKUs with less complex BOMs and conversion requirements while retaining flexibility in the range of SKUs based on local needs.
- Limit scale-up costs by collaborating with machine builders and developing standard configurations for accelerated ramp-up.
- Develop a transfer or wind down strategy using global orchestration and local execution. Not all mobile factory deployments will be successful. This requires firm time frames on when to see results by running cost models to evaluate total costs to serve against commercial price points.
- Master local infrastructure (e.g., energy reliability, supplier proximity), tax laws, government subsidies and talent availability. Even though processes are simplified, people are still needed.

Business Impact: Manufacturers will grow in new markets or expand, differentiate or offer new products and services in existing markets. Mobile factories will not only reduce production scale-up costs but can also boost competitiveness, enable flexibility, maintain compliance (e.g., country of origin) and create resiliency in the network.

Consider the following impact areas:

- **Risk: Low —** When tied to a structured innovation strategy to feed smart factories, the risk can be lower. This is in addition to significantly lower capital expenditures, which should not overshadow an understanding of the target market's dynamics and in-market policies or cultivation of ecosystem partners to support this new production model.
- **Technology intensity: High —** Preconfigured solutions and capacity that utilize combinations of new manufacturing techniques and automated systems must be reliable and maintain performance standards. Newer technologies such as 5G can accelerate standing up of capacity across manufacturing networks. This can take time to prove out and require R&D investment. Once a solution is configured, it can be deployed in standard configurations, leading to consistent and accelerated startup projects.
- **Organization change: Low —** Core values remain stable, as global standards should be used for sourcing, planning and operations.
- **Process change: Medium —** Mobile factories emphasize long-term planning, network design, procurement, logistics and segmentation. They also require significant orchestration of machine builders, OEMs and design partners. Broad changes in network design processes to ensure resiliency on a broader scale require attention too.
- **Competitive value: High —** Correctly executing can mean early market access and better long-term market growth and/or lower cost to serve.

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Embryonic

Recommended Reading: "Supply Chain Brief: 'Factory in a Box' Concept Challenges Traditional Factory Setup"

"Video: Diageo — Delivering Innovative Solutions Through Capital Investment"

"Enabling a Manufacturing Ecosystem Needs a Long-Term View"

Supply Chain as a Service

Analysis By: Michael Dominy

Definition: Supply chain as a service (SCaaS) is an externally focused commercial digital service that delivers ongoing management of one or more supply chain functions to other enterprises. These business process services leverage technologies and supply chain professionals. Processes are standardized, configurable and exploit cloud technologies.

We have combined supply chain (SC) business process as a service (BPaaS), business process outsourcing (BPO) and digital SC services into SCaaS to better align with how the market describes the innovation.

Position and Adoption Speed Justification: Cost-effective availability of cloud computing infrastructure services, multitenant SaaS applications, open-source software and analytics tools have enabled service providers and some enterprises to create, launch and sustain SCaaS offerings. Adoption will vary by maturity and current application portfolio. Organizations with limited or outdated supply chain applications will be more open to using SCaaS. Access to master data and transaction systems, such as ERP, will be critical enablers for the service.

Adoption varies by process area:

- Transportation management, customs clearance process and tracking are mature examples. In the area of tracking, basic tracking is not charged separately.
- Postsale or postdelivery services are less mature.
- Supply chain planning and analytics as a service are less mature, but are being offered and hyped by many providers.
- Sourcing and procurement, like logistics, is mature overall with differences between direct and indirect categories. Indirect sourcing and procurement is very mature, while direct materials or parts is immature.

User Advice: If you are considering launching your own SCaaS, evaluate your ability to compete. Use, "Take Four Steps to Develop Your Supply-Chain-as-a-Service Strategy" to help assess your capabilities, the competitive landscape and solution requirements.

If you are considering using SCaaS, prioritize processes and functions with lagging capabilities or those spanning multiple organizations. For example, if you have poor supply chain planning capabilities and constrained budgets or insufficient planning professionals, you should consider a SCaaS offering for supply chain planning. An example SCaaS targeting processes spanning multiple organizations would be those enabling a digital business model for a product company that requires integration and coordination of forward fulfillment and aftermarket or delivery services.

Continually monitor the market for new SCaaS offerings. As software functionality becomes more advanced, and as integration capabilities utilizing cloud services improve and expand, service providers will bring new and broader services to the market. Digital tools, such as artificial intelligence, robotic process automation and machine learning, are enabling providers to create, deploy and scale services faster than traditional license, design and implementation approaches using packaged applications.

Business Impact: SCaaS will continue to impact the logistics function, especially as logistics service providers look to leverage technology to offer more differentiated services to shippers. Aftermarket services, such as returns and reverse logistics, will be impacted as companies expand digital offerings or embrace circular business models. SCaaS will also impact planning and optimization, including demand forecasting, supply planning and inventory optimization. Manufacturing operations processes that involve regulatory and compliance activities, such as environmental, health and safety (EH&S) reporting, material safety data sheet (MSDS) processing and reporting, will be impacted. The demand-sensing and demand-shaping functions within supply chain management (SCM) will also be impacted as existing and new service providers capture and

analyze consumer data from social networks and combine it with other sources of demand data, such as POS scan data.

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Arrow Electronics; Celestica; DHL; Entercoms; Genpact; Jabil; KPMG; Mayo Clinic; Tata Consultancy Services; UPS Supply Chain Solutions

Recommended Reading: "Take Four Steps to Develop Your Supply-Chain-as-a-Service Strategy"

"Market Guide for Supply Chain Strategy and Operations Consulting"

"Market Guide for Supply Chain Planning BPO or BPaaS"

"Magic Quadrant for Third-Party Logistics, North America"

"Market Guide for Electronics Manufacturing Services"

At the Peak

Cyber-Physical Systems

Analysis By: Katell Thielemann

Definition: Cyber-physical systems (CPS) are engineered systems that orchestrate sensing, computation, control, networking and analytics to interact with the physical world (including humans). They enable safe, real-time, secure, reliable, resilient and adaptable performance.

Position and Adoption Speed Justification: Already deploying in smart grids, smart buildings or autonomous vehicles, CPS are also core to future visions of smart manufacturing and Industrie 4.0. They represent the confluence of physical and virtual systems to connect people, products, data and processes within the manufacturing function. When connected to the supply chain, they can also enable a self-adaptive and autonomous production capability. This will change dynamics across multiple industrial ecosystems by automating unstructured processes, shortening cycle times, and improving product and service quality. Deployments extensively use robotics, cloud services, advanced analytics, machine learning and secure high-speed networks to orchestrate data and processes in real time. Unfortunately, because they connect both the cyber and physical worlds, CPS can also open the aperture to new security and safety threats.

Over time, CPS will replace precursors such as stand-alone conventional production process control and automation, materials handling systems (plus the sensor networks or machine networks), and transactional workflow systems to promote real-time information gathering and processing. Combining multiple platforms and systems underscores the need for interoperability

standards and an increased focus on safety, security and resilience. Several frameworks are emerging, driven by the United States' National Institute of Standards and Technology (NIST), or Germany's Industrie 4.0-aligned RAMI 4.0 framework. Beyond upgrading IT and OT, revamping factory layouts and identifying where to judiciously automate process and data flows in/across the value chain is needed, CPS demands a level of security, orchestration and operating model overhaul that will drive manufacturers to revisit their corporate production systems and value chain relationships.

Other sectors (transportation, advanced weapons systems, smart buildings and healthcare) are advancing ahead of manufacturing. The increased pursuits of digital supply chains, the rise of strategic industrial modernization projects and advanced analytics are encouraging, and push CPS forward on this year's Hype Cycle. The two-to-five year time frame to the Plateau of Productivity represents the continued obstacles created by the variance of factory layouts and production styles — not to mention the maturity levels for both — to fulfilling the full vision for CPS, as well as the unique safety, security and resilience concerns that manufacturing operations need to address.

User Advice: When seeking to establish a CPS, pursue the following actions:

- Incubate small-scale pilots to push the potential impacts on connected products and orchestration of processes. Partner with academia, consortiums, suppliers and distributors in these pilots as necessary.
- Promote the use of standards and implementation recommendations to manage complexity, enable scalability and extensibility, and to ensure focus on security and safety imperatives.
- Expand your risk lens. This involves broadening focus from the means (information) to the outcome (the physical state change implemented). CPS security is particularly critical in production and operational-centric businesses and industries that produce an outcome other than more information. The effect of a disruption or corruption of information can lead to direct physical consequences that can be inherently unsafe. Digital business efforts accelerate this. As the risk lens expands to the physical plane, concerns over physical perimeter breaches, jamming, hacking, spoofing, tampering, command intrusion, denial of service (DoS) or malware implanted in physical assets all need to be taken into consideration.

Business Impact: The future of CPS in manufacturing operations will ultimately be predicated on a blend of operating models, science, engineering, supply chain, safety, security and technology. CPS will carry transformative impacts across:

- **Risk: Medium —** Many building blocks for CPS in manufacturing are too early in their life cycles to associate with risk as pilots are being incubated. However, companies that lag in their convergence and alignment of IT and OT to create transparency and efficiency will be left behind.
- **Technology intensity: High —** CPS requires costly upgrades, mastery of artificial intelligence, sensors, secure connectivity, and capability for integrating and managing information to optimize production and distribution costs at a magnitude larger than today's systems can handle. The rapid proliferation of IoT data alone will challenge existing OT information

infrastructures and disrupt existing approaches to security, process automation and data integrity.

- **Organization change: High —** Self-adaptive and automatically reconfigurable systems change the very nature of decision making — not only who makes them, but also how, why, where and when.
- **Process change: High —** CPS mandates process redesigns across traditional manufacturing silos internally. Extensions to the supply chain will also impact many areas, such as SLAs or pricing and inventory discussions. Evolving regulatory compliance and data ownership policies will impact data governance and privacy policies.
- **Competitive value: High —** When optimized, CPS can dynamically reconfigure product supply networks to accommodate variability, capture new opportunities or achieve new outcomes that add value to the customer.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: AVEVA; Bosch.IO; Fujitsu; Google; Hitachi; IBM; Microsoft; Siemens

Recommended Reading: "Focus More on the Realities of Cyber-Physical Systems Security Than on the Concepts of IoT"

"How to Develop a Security Vision and Strategy for Cyber-Physical Systems"

"Facing New Vulnerabilities — Cyber-Physical Systems"

"Driving Digital Business Transformation for Industry Leadership: A Supply Chain Perspective"

"Cool Vendors in Manufacturing Industry Solutions"

"Cool Vendors in Cyber-Physical Systems Security"

"Magic Quadrant for Industrial IoT Platforms"

Connected Factory Worker

Analysis By: Simon Jacobson

Definition: Connected factory workers are capable of using various digital tools and data management techniques to improve and integrate their interactions with both physical and virtual surroundings. They are able to make faster and better decisions that enable and optimize a process or set of processes that they participate in.

Position and Adoption Speed Justification: The pandemic is casting light on the connected factory worker concept, raising its hype and accelerating the time to plateau. Factory staffing concerns and innovation opportunities have compelled organizations to pivot some investments toward the enhancing the operator experience. Lower staffing levels and social distancing rules accelerate the need to have factory workers better integrated with their physical and virtual surrounding. Removing manual processes and communications can create an awareness and continuity that improves knowledge management, flexibility and speed.

The concept of the connected factory worker is hyped, and no single dominant technology has emerged. Organizations are focusing on short-term, site and function-specific needs. These include using immersive experiences for quality and maintenance tasks, connecting with employees that are not able to be on-site, or wearables for safety management. Digitizing gemba walks and capturing observations are also in scope. Immersive experiences, workflow collaboration tools, plus investments in mobility, various endpoints, and sensors all contribute to connecting workers and their surroundings. The long-term impacts and value of the connected factory worker through access to knowledge and automation are yet to come.

The pandemic has only exacerbated concerns of knowledge and skills erosion that have ebbed and flowed for the past 15 years. Also, the demand for factory skills and capabilities far outweighs supply. The positive is the groups interested in these technologies have widened from manufacturing functions to include HR, for example. Both, along with site management and IT, are working to fill glaring strategic gaps to onboard and upskill factory workers beyond their core skill set so they can fully exploit new tools and techniques as part their daily routines This presents opportunities for the provider market to create partnerships with customers and other vendors to create IP, widen platforms (inclusive partnering with industries), and integrate some point solutions.

User Advice:

- Achieve quick wins with remote expert guidance that accelerates the development of a broader skills arsenal through on-the-job training. Prepare to, over a longer time frame, allocate resources and partner with HR to successfully align desired competencies and skills requirements for both salaried and hourly workforces.
- Meet the diversity of skills and capabilities in factories by developing a broad array of use cases that tie to specific processes that are unstructured or previously executed based on tribal knowledge. Changeovers and equipment settings are an ideal starting point.
- Do not let data outweigh operator intuition. Keep the focus that the connected factory worker requires a solid foundation of lean and problem-solving skills.
- Develop and deploy specific metrics for labor productivity. Integrate these with the existing portfolio of metrics used for tracking manufacturing performance.

Business Impact: The fluctuations of labor availability and costs during the pandemic vary by market and are opportunities to integrate workers with both physical and virtual environments. This is also a big pivot too:

- **Risk: Medium —** Risk levels elevate when myopic planning and singular digital experiences are designed, and multiple personas are not considered. The level of risk also increases when providing operators tools to build their own experiences and redefine standard work without coordination.
- **Technology intensity: High —** Digitizing tacit knowledge and manual process might be the initial focus, but contextualized data, refocused integration strategies and investments in AI for technologies to adapt with the operator cannot be overlooked.
- **Process change: High —** Anticipate refactoring recruitment, retention and training programs. Also, cross-site collaboration will alter significantly. A streamlined approach to standard work should also not be overlooked.
- **Organizational change: High —** This is a fundamental change in behaviors and skills. It is more than using AR, for example, to augment the worker. The integration of information, data, people and processes demands individuals with specific IT and OT expertise. Ideally a blend of engineering and operations expertise is desired, along with an understanding of reliability, security and safety objectives.
- **Competitive Value: High —** Fluctuations in labor availability elevate the importance of retaining and harvesting the corpus of knowledge that can integrate workers with their surroundings to provide reliable output.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Emerging

Sample Vendors: Augmentir; Bennit AI; Drishti; Microsoft; Parsable; Poka; PTC; Rever; Tulip; Webalo

Recommended Reading: "Survey Analysis: Know the Benefits at Different Phases of Digitizing Manufacturing Operations"

"Cool Vendors in Manufacturing Operations"

"Cool Vendors in Manufacturing Operations, 2017"

"Top 10 Strategic Technology Trends for 2020: Democratization"

"Use Gartner Scenarios to Tackle Culture Barriers in Manufacturing Organizations"

Value-Added Manufacturing Services

Analysis By: Sam New

Definition: External manufacturing service providers, also known as "contract manufacturers" or "CMOs" have begun offering a suite of new services. These services, which are a departure from

traditional manufacturing activities, often include engineering, sourcing/procurement, planning, vendor-managed inventory, logistics, global trade management, risk management and compliance, consulting, software, and integration services. In the COVID-19 era, services include an enhanced focus on risk mitigation and services for business continuity management.

Position and Adoption Speed Justification: In the current environment, brand owners, or buyers of manufacturing services, increasingly look to their strategic partners for support with noncore activities. In these partnerships, both brand owners and service providers collaborate around products and a suite of services.

Although these adjacent, value-added services are often hyped and heavily marketed, widespread industry adoption of adjacent services remains limited, and the majority of revenue and business activity from traditional external manufacturing (EM) service providers still derives from core manufacturing activities. Low adoption may at least be partially attributed to concerns regarding quality and regulatory risk. We are positioning adjacent manufacturing services near the peak, as buyer confidence in these services remains underdeveloped and most service providers continue to derive a majority of their revenue from traditional manufacturing services.

User Advice: Leverage external manufacturers to support objectives beyond manufacturing. Consider using partners to support growth opportunities, gain access to scarce commodities through supplier relationships, and provide expertise and shared investments to speed up new product introduction or support after-sales services. Consider also the expertise and proprietary tools that external manufacturers offer for risk mitigation business continuity.

Carefully define requirements and services sought, and encourage manufacturing service providers to propose adjacent activities as optional line items in proposals. Be cautiously optimistic regarding commitments for new services, and seek customer references before engaging. Identify activities that are core to your company's operations, and leverage third-party expertise for noncore functions.

Business Impact: Using adjacent external manufacturing services can help with cost optimization, risk management, business continuity planning, design and development, business continuity management, increasing agility and flexibility, and speeding up time to market and time to volume. Additionally, service providers may be engaged for novel benefits, including the acquisition of specialized knowledge bases, skill sets or technology. Moreover, in heavily regulated industries such as life sciences, service providers may have depth and expertise relative to particular regulatory and compliance needs.

Although there are many benefits associated with using adjacent services from EM providers, supply chain leaders should also consider the following impact areas:

- **Risk: High —** The risk of using an outsourced partner can vary by product, degree of regulation and industry. Substantial risks to intellectual property may arise, enabling competition from service providers themselves. Exposure to natural disasters, political or economic unrest, or potential barriers to trade can also disrupt supply and impact cost.
- **Technology intensity: High —** Multiple technology issues should be considered. These range from the technology included or embedded in the product being manufactured or the

manufacturing process, to the IT infrastructure connecting the buyer and service provider enabling collaboration, performance management and tracking compliance.

- **Organizational change: High —** The impact to the organization is often high, especially if it involves transfers between manufacturing sites, including a shift in personnel needs, to develop the talent and competencies to manage strategic partnerships. Internal cross-functional collaboration will be required. Decisions to outsource many of these activities may require input from functional areas including human resources and commercial partners.
- **Process change: Medium —** Multiple processes change when functions are outsourced. Sales and operations planning and new product introduction and launch need to be extended to include the outsource provider. Supply planning, sourcing and procurement management, quality management, and logistics processes often require adjustments and internal resource commitments to comply with service-level agreements or contract terms and conditions.
- **Competitive value: High —** A brand owner can reduce costs, save time and increase agility by using many of the available services in the EM marketplace. The key to unlocking and sustaining competitive value lies within delineating core and noncore activities, and within the governance and supplier relationship management skills of the brand owner.

Benefit Rating: Moderate

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Sample Vendors: Catalent; Celestica; Flex; Hon Hai/Foxconn Technology Group; Jabil; Li & Fung; Plexus; Thermo Fisher Scientific (Patheon)

Recommended Reading: "Market Guide for Electronics Manufacturing Services"

"External Manufacturing Strategy Guidance for Supply Chain Leaders"

"Toolkit: Self-Assess Your Sourcing and Procurement Maturity"

"How to Structure Supply Chain Outsourcing Master Service Agreements"

Digital Thread

Analysis By: Marc Halpern; Rick Franzosa; Simon Jacobson

Definition: A digital thread is a framework to collect, organize, associate, trace and present data for multiple factors. The multiple factors such as design, manufacturing, services, and repairs influence a product and/or process and their evolutions over their respective life cycles. Integrating and organizing semantically rich data with digital threads allows multiple users to access, integrate, organize, trace and transform disparate technical and knowledge-based data from multiple operational and enterprise-level systems.

Position and Adoption Speed Justification: The concept of a digital thread is not new. However, the positioning on the Hype Cycle reflects the nascence of adopting digital threads to connecting engineering and production in configure-to-order (CTO) and engineer-to-order (ETO) supply chains. Digital threads also apply to assets such as power plants, refineries, and servicing industrial equipment. The potential of digital thread to traceability of parts, materials and processes for maintaining, repairing, and upgrading products and assets remains largely untapped. Early adopters are discovering opportunities to enhance digital threads with analytics. For example, analytics related to manufacturing processes and costs as well as frequency of maintenance and repair needs offer insights into the how and why of improvements to products and assets.

The pace of which digital threads reach the plateau will be a factor of:

- Understanding both the complementary nature of digital twins as well as the interdependencies between digital twins and digital threads. Notably, digital threads are fundamental to digital twins. Simultaneously, the content of digital twins enriches the value of digital threads.
- The rate of advances in technology enablement and best practices in data governance necessary to enable digital threads
- The rate at which companies can adapt the uses of digital threads to product variants created from product platforms where common parts and subsystems can be mixed and matched for a wide variety of products.
- The relationship of digital threads to existing applications such as EAM, PLM, ERP, MES and to digital twin technology, when deployed.

User Advice: Those wanting to invest and manage the digital thread should:

- Focus on building the digital thread for secure traceability of products and the processes that evolve over their life cycles instead of confining it to engineering and production.
- Not restrict traceability to a single technical approach or process whether it be APIs, microservices, blockchain, or any other means. Use a combination of approaches that makes the most sense to retain traceability yet meet role and process business needs.
- Use the digital thread as a tool for improving efficient decision making, cost, quality, traceability and regulatory compliance.
- Adopt an industry data governance strategy for a digital thread by including members of your value network in planning for data oversight, data orchestration, data curation and data management.
- Overcome the absence of a complete data model by investing in standards to capture and normalize data from different systems.

Business Impact: The digital thread is a lever for continuity and traceability across the value chain. Analytics combined with traceability of product evolution from product design and manufacturing can advise customers on more effective maintenance and service. Compliance with regulations government bodies such as FDA and DoD will be more transparent and efficient. Analytical feedback from a product's service life can offer insight into continually improving products.

The digital thread will have the following impacts:

- **Risk: Medium —** Besides more efficient compliance with regulations such as RoHS/WEEE, Reach, FDA and ITAR security, digital threads mitigate IP risk and concerns from OEMs and brand owners for revealing their process structures and suppliers for fear of disintermediation.
- **Technology Intensity: High —** Beyond core systems (MES, PLM, ERP) the broader technologies and tools (cloud services, automated data synchronization/validation), to access, verify, validate, and synchronize data need time to mature. Even greater impact when digital twins are part of the technology stack.
- **Organization Change: Medium —** Initially it will tighten collaboration and alignment gaps between R&D/engineering, manufacturing operations, sourcing, and IT. In the longer-term it will extend to sales and marketing functions which might either promote or allow some customers to have specific, nonstandard configurations; in long-term anticipate new organizations and teams to emerge which in turn creates new job opportunities.
- **Process Change: High —** BOM changes might be a normal occurrence. However, the synchronization of different BOMs — and the ability to assimilate process changes related to BOM changes, as well as where new SLAs that bind responses from suppliers to provide data transparency and ultimately impacts traceability downstream once products are in the market. Not to be overlooked is the need to set up specific processes for data governance.
- **Competitive Value: High —** Cost optimization and time savings come from shortened decision cycles and improved agility on both global and local bases. Accelerating innovation and bringing products to market are also not to be overlooked.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Anark; Aras; AVEVA; Dassault Systèmes; GE Digital; Hexagon Manufacturing Intelligence; iBASEt; Microsoft; Siemens PLM Software

Recommended Reading: “Innovation Insight for the Digital Thread”

“Manufacturing Process Management Is Essential to Digital Thread”

“Choose the Best Integration Tool for Your Needs Based on the Three Basic Patterns of Integration”

“How to Achieve Better Business Model Strategies With Industry Data Governance”

Solution-Centric Supply Chains

Analysis By: Jennifer Loveland

Definition: Solution-centric supply chains (SCSCs) are collaborative networks designed to provide customers with a personalized collection of products, data and services, or products coordinated with later deliveries of additional value (e.g., data) from a digitally enabled ecosystem of partners. This model, which taps into opportunities to capture incremental value, often beyond the scope of individual firms, is increasingly seen in high-tech, medical, consumer and industrial sectors.

Position and Adoption Speed Justification: While many of the world's innovators are on the transformational journey from a traditional linear supply chain design to a highly leveraged network of trading partners, we estimate that 5% to 20% of constituents have deployed this network design. We expect movement closer to 20% this year. The assessment of the maturity of SCSCs as prepeak early adolescent on the Hype Cycle is based on emerging technologies and extent of digital business model, and consumption and outcome-based offerings under development. The continued growth in digital business and rise of business ecosystems will further year-over-year adoption and indicates others will ultimately benefit from this model. However, increased adoption of SCSCs rests on the firm's ability to deploy technologies, such as visibility and analytics. Broader adoption is also dependent on organization's ability to form and orchestrate collaborative partnerships that solve customer problems and provide advantage to all trading partners.

User Advice: Our research reveals that an organization's transformation to a solution-centric model is similar to large-scale change management initiatives. We recommend that chief supply chain officers (CSCOs) act as a catalyst in this transformation by demonstrating how the supply network drives efficient, effective and competitive advantage by:

- Promoting supply chain expertise in value stream mapping, network optimization, sales and operations planning, and advanced analytics.
- Leveraging upstream and downstream linkages to provide required technologies, innovations or services to connect resources, orchestrate activities, synchronize information, monetize assets and align processes around customer-defined solutions.
- Identifying potential points of failure in solution-centric partner networks and developing contingency plans to abate risk from business model experimentation or transformation.

Business Impact: The potential rewards to enterprises that successfully deliver complex, personalized solutions to address customers' critical problems are significant and include collaborative advantage, increased customer loyalty, larger sales volumes and recurring revenue streams. Focusing on addressing customers' most pressing needs shifts the discussion from being purely on cost, or even quality, to providing superior customer experience. The value of a solution from a customer's perspective is typically greater than the sum of parts and services. Our interactions with CSCOs reveal that deploying SCSCs in the delivery of customer solutions not only enables firms to achieve better margins and improve return on assets by leveraging network assets but also addresses the risks of entering new markets by creating stronger barriers to entry for potential disruptors (i.e., new entrants must not only duplicate or better offerings but compete against the capability of the entire network).

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Recommended Reading: "High-Tech Industry Outlook, 2019: Within Chaos Lies Opportunity"

"High-Tech Supply Chainnovator 2019: Dell Wins by Building a Legacy of Good to Tackle Circular Economy"

"Manufacturing Industry Scenarios in 2023: Find the Right Things to Do, and Do Them Faster and Better"

"How to Change Your Supply Chain to Support Digital Products"

Autonomous Things — Manufacturing Operations

Analysis By: Simon Jacobson

Definition: Autonomous things are physical devices that can operate in the real world without human direction. Autonomous things use artificial intelligence (AI) to augment or automate tasks or processes.

Position and Adoption Speed Justification: Autonomous things combine a mix of physical and virtual objects. They can operate along a spectrum of autonomy, from semiautonomous to fully autonomous that spans across:

- Virtual machines that can curate volumes of data and provide input to humans to decide and act.
- Physical machines executing tasks within a defined context.
- Physical machines working together with humans to supplement existing processes.
- Physical or virtual machines acting autonomously and continually learning.

Physical applications in factories can include: autonomous mobile robots (AMRs) or smart robots, and collaborative robots (cobots) that work autonomously or alongside humans in factories. They are capable of learning in short-term intervals from human-supervised training and demonstrations or from experiences on the job. Some are capable of sensing environmental conditions, and recognizing and solving problems. Some can interact with humans using voice language.

COVID-19 illuminated of risks of labor availability has elevated discussions on automation at a functional and corporate level. It's anticipated that the virtual and physical automation levels will increase moving forward. However, lights out production is far off and there will be no demise of factory jobs in the next five years. Cobots and physical form factors drive today's hype; however, the maturation of artificial intelligence (AI) will be what drives the adoption and sustained value. To reap the benefits of more flexible and autonomous decision making requires focus on how autonomous things are managed. Autonomous things, if anything, will create demand for more complex programming and technical skills (programming, analytical acumen) — particularly since this technology is not solely a physical form factor. If autonomous things were simply a physical

form factor, the positioning on the Hype Cycle would be much further ahead. Beyond programming and analytical acumen, 5G and edge cannot be overlooked. These two technologies, along with cloud computing, factor in to the equation to manage multiple equipment recipes or cross-site processes as well as security and safety requirements. Other organizational dynamics include this technology being a potential form of operational technology (OT) for IT and engineering departments to manage.

User Advice: In order to maximize investments and future potential of autonomous things:

- Consider autonomous things as both substitutes for and complementary to your existing workforce and automation layouts. Automating routine human activities is a good starting point; however, matching methods and procedures with the right automation concepts is critical.
- Seek to understand labor versus automation trade-offs when linking intelligence and process to determine where it's best to invest in autonomous things. Similar to warehouse-based investments, labor reduction might be a driver. However, safety, cost and productivity are real indicators of value.
- Be clear on talent and recruitment requirements to fulfill the demand for industrial skill sets that turn operators and engineers into interpreters and trainers capable of interacting and collaborating with machines.
- Understand now that autonomous things will change continuous improvement programs. It will impact the how and who is responsible for operational decisions. It will also provide a faster feedback loop in manufacturing and other supply chain roles for continuous improvement and change.

Business Impact:

- **Risk: High —** Failure to take an iterative approach with expansion over time can delay value and incite rapid devolution back to manual methods. Furthermore, at a time when factory staffing levels are in flux, the introduction of autonomous things must be done with acute clarity and with clear communication to avoid the perception of job elimination.
- **Technology intensity: High —** Growing data volumes alone are challenging to manage. Incorporating AI, value stream mapping and automation programming ups development costs and complexities that might put autonomous things out of the direct reach of many manufacturers for now.
- **Organization change: High —** Autonomous things cannot match the human brain's breadth of intelligence and dynamic general-purpose learning. While there are successful use cases of cobots working alongside humans, the more complex use cases that involve virtual machines will change the overall nature of human-machine collaboration. In turn, new skills are needed to maintain, train and manage these autonomous things.
- **Process change: High —** The increased automation of decision support means realigning and reshaping production systems to incorporate standard work and new metrics. Newly defined decision rights to better manage the accelerated pace of behavioral change between human and machine is required.

- **Competitive value: Low —** Once the technology proves itself, expect faster time to market with new products and services, and implementation of change. In turn, the competitive value will shift too.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Recommended Reading: "Innovation Insight for Autonomous Mobile Robots"

"Top 10 Strategic Technology Trends for 2020: Autonomous Things"

"The Importance of OT Integration for Industrie 4.0"

"Artificial Intelligence Will Make Manufacturing Operations Smarter — But a Learning Curve Comes First"

Machine Learning

Analysis By: Simon Jacobson

Definition: Machine learning is a technical discipline that identifies patterns and generates predictions based on the analysis of large sets of data. There are three major subdisciplines related to the types of observation provided. These are supervised learning (observations contain input/output pairs [aka labeled data]), unsupervised learning (labels are omitted) and reinforcement learning (evaluations are given of how good or bad a situation is).

Position and Adoption Speed Justification: In manufacturing operations, machine learning (ML) can take advantage of available data and rely on the algorithms to identify patterns and correlations. It can also use them to predict outcomes, find the best courses of action and control processes. Typical use cases include eliminating unplanned downtime and stoppages, increasing yield optimization, reducing energy usage, improving product quality or stabilizing production processes.

To manufacturers, the possibility of predicting performance is extremely attractive. This is driving the strong interest in ML. It is an essential enabler of artificial intelligence (AI), smart factories and intelligent automation. The notion of a well-trained model that can, based off a prediction, automatically control set points on a controller or communicate directly with an autonomous object is extremely attractive. The ability to continually optimize production rates as part of a closed-loop system is also a benefit.

Using algorithms is not new in manufacturing. However, the adoption of modern tools lags other supply chain functions, like planning. We expect an increase in pilots as companies become more bullish on automation as a way to efficiently run shifts with lower on-site staffing levels in the next six to 12 months. This zeal is pumping up the ML hype and pushing it forward on the continuum. Adoption, however, will stagger. On one hand, providers, in an effort to modernize incumbent systems, are simplifying their tools to develop algorithms. On the other hand, this needs time to

evolve and mature (especially for advanced techniques such as unsupervised learning), and organizations need to move beyond targeted use cases rather than holistic for the following reasons:

Data complexity: Having the right data in the right format and context to train models on is the biggest expense of time. Heterogeneity of IT and OT across legacy data sources, vision systems, edge devices, and transactional systems — to name a few — provides different kinds of data.

Inconsistent Processes: Predictions might not necessarily map to the current ways that some methods and/or procedures are executed.

Fragmented offerings: On one hand, industrial IoT platforms use ML as an integral part of their platform and/or application of predictive maintenance, condition-based monitoring and asset optimization. On the other, there are vendors that provide algorithms only or those that offer their customers a way to incorporate algorithms from other applications. This complicates many architectures.

Skills Cultivation: Continuous improvement teams, for example, need to work on improving the availability of skills to develop, test, train, and maintain algorithms.

The need for cultivating strategies to scale efficiently so maximum value is gained must not be overlooked. Some companies will have quick wins or scale faster than others. The holistic time to plateau will be on the latter end of the five to 10 years.

User Advice: ML will provide incremental benefits but isn't a panacea. Consider the speed of response and frequency of prediction needed. In many instances, traditional analytic techniques such as descriptive and diagnostic analytics can be more effective.

Quantify the technical resources and skills development required for process engineers, data scientists, and other production workers to not only build and train ML models but also interpret the signals.

Ensure the availability, readiness and context of the data that will be used by ML algorithms. Given the diverse use cases and that ML relies on training datasets to identify patterns and relationships, having the right data is essential.

Business Impact: ML will have the following impacts on manufacturing operations:

- **Risk (High):** Incomplete models can impair the right decisions. Just because the model runs doesn't mean it's correct.
- **Technology Intensity (High):** Look beyond combining complex datasets. Focus on continually ensuring that algorithms are tested, prepared, operationalized, and maintained.
- **Process Change (High):** The speed of decisions will improve. Previously, they were based on rudimentary or manual analysis. However, they can now take advantage of broader volumes of data to identify patterns and insights and predict future outcomes as part of a closed-loop system.

- **Organizational Change (High):** Pursue new teams that blend IT, OT and other skills. Don't exclusively focus on hiring data scientists.
- **Competitive Value (High):** Boost production flexibility with faster responses to changing market dynamics and unplanned events with the most appropriate courses of action.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Emerging

Sample Vendors: Amazon Web Services; Celonis; Drishti; Flutura; Microsoft; Plataine; PTC; Rockwell Automation

Recommended Reading: "Evolve Your Manufacturing Intelligence Strategy to Keep Pace With New Analytics Requirements"

"Artificial Intelligence Will Make Manufacturing Operations Smarter — But a Learning Curve Comes First"

"Machine Learning 101 for Supply Chain Leaders Part 3: Prioritize Use Cases and Gauge ROI"

"Machine Learning 101 for Supply Chain Leaders Part 2: Talent, Organization and Technology Requirements"

"Machine Learning 101 for Supply Chain Leaders Part 1: How It Works and Its Relationship to Other Analytics Techniques"

Immersive Experience in Manufacturing Operations

Analysis By: Simon Jacobson; Marc Halpern

Definition: Immersive experience refers to enabling the perception of being physically present in a nonphysical world or enriching people's presence in the physical world with content from the virtual world. There are three kinds of immersive experiences — augmented reality (AR), virtual reality (VR) and mixed reality (MR).

Position and Adoption Speed Justification: COVID-19 has raised the profile of immersive experience, substantially changing how factory workers perceive and interact with the digital world surrounding them. Connecting the virtual and physical worlds to amplify human capabilities has potential to profoundly change the following:

- The nature of standard work and how certain methods and procedures are executed.
- Enhance judgments about actual or planned items in the physical world, based on the visualization of 3D models and related information. For example, emulating production layouts before capital expenditure (capex) is determined.

- Spontaneous collaboration through remote access and collaborative problem solving. This use case has been popular thus far with corporate travel restrictions.

As adoption increases, digital overlays that incorporate advanced content and guided procedures that create “experiential learning” for on-the-job training will mainstream. More broadly, AI will play a larger role and create a “self-driving” capability for workers to multitask efficiently. Currently there is some natural language processing (NLP) for “ask and answer” being used.

However, this will not come without obstacles, such as:

- **Low benefit ceiling:** Error proofing and resource efficiency (primarily labor) are easily measurable minimal viable outcomes.
- **Ethical concerns:** Incorporating ML to pinpoint training or support multitasking with work instructions matched to worker skill sets may unintentionally create bias.
- **Narrow focus:** Individual technologies — AR, VR and MR — will all drive future immersive experiences. Today, they do this separately through purpose-built solutions. AR is already dominating much of the manufacturing dialogue.
- **Scale:** How well providers cope with balancing rising demand with minimizing the technological sophistication is essential. Integrating and converging multiple technologies to create models; VR provides a computer-generated 3D environment that surrounds a user and responds to an individual’s actions in a natural way. AR exploits real-time information in the form of text, graphics, video and other virtual enhancements integrated with real-world objects. In addition to these foundational elements, the time to create, test, and deploy and/or scale can add up.

With these factors in mind, this technology does advance on the continuum with lots of quick-win potential, but could dwell in the Trough of Disillusionment until the technological sophistication lowers to promote long-tern proliferation within organizations.

Cost to create models, ergonomics of devices and multidimensional user cases will be challenges.

User Advice:

- Focus on the immediate need. Remote knowledge and connecting workers will help create communities of knowledge that are needed to keep operations running during the pandemic.
- For the long term, devise an integration strategy for how immersive experiences will integrate with core processes and incumbent applications (for example, with manufacturing execution systems [MES], product life cycle management [PLM] and/or quality management systems [QMS]). This will help identify feedback loops between operator interactions and these applications.
- Don’t confine the development of use cases to internal operations. Examine how partner use cases, especially for maintenance and quality, can be leveraged. Partners may be developing their own business models for equipment and product as a service, which can supplement your existing resources.

Business Impact: Immersive experiences will transform how some work is done in factories, and the way that factory workers interact with the world around them — with the following impacts:

- **Risk: Medium —** Risk is variable, depending on the characteristics and nature of the processes, and/or technology applied. Set benchmarks against unaugmented and conventional solutions to understand risks and benefits.
- **Technology intensity: High —** Immersive experiences will eventually augment MES and QMS applications, and the large mix of hardware, software and technology platforms. A focus on integration, device costs and feedback loops is needed to avoid personal productivity gains in isolation. Additionally, a maturation of the provider market (inclusive of large vendor partner strategies) is required.
- **Organization change: High —** Immersive experiences will enhance employee job function (for example, delivering context-specific information at the point of need), while contributing to knowledge management gains by exposing new cross-site collaboration and training opportunities across sites and geographies.
- **Process change: High —** Anticipate shortened task execution times, lowered costs and time frames to onboard new employees (or upskill to specialist tasks without risk to the integrity of operations).
- **Competitive value: High —** COVID-19 illuminated the criticality of available labor and the need for multiskilled workers. Providing new digital experiences and collaboration opportunities can sustain resource efficiency and reliable supply.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Apprentice; Augmentir; Microsoft; PTC; Ubimax; Upskill

Recommended Reading: “Supply Chain Brief: Successful Return-to-Work Strategies for Factories”

“Innovation Insight for Immersive Experiences in Supply Chain”

“Top 10 Strategic Technology Trends for Manufacturing Industries: Immersive Experience”

“3D Design and Device Convenience Hinder AR and VR Adoption”

“Top 10 Strategic Technology Trends for 2020: Multiexperience”

Sliding Into the Trough

Smart Factory

Analysis By: Simon Jacobson

Definition: Smart factory is a concept used to describe the application of different combinations of modern technologies to create a hyperflexible and self-adapting production capability. It is an underlying capability of smart manufacturing, which in turn fuels digital supply chain and Industrie 4.0 initiatives.

Position and Adoption Speed Justification: The hype of smart factories is strong and continues to be fueled by:

- Broad themes of Industrie 4.0 and concepts for smart manufacturing or digital supply chains.
- Leadership expectations for manufacturing to be a partner and growth driver for the business.

The smart factory is headed toward the trough as the concepts and leadership expectations are outweighing the organizational tactics, readiness and capability to scale.

To start their path, some companies are simply satisfied by removing paper from their processes. No matter what the approach, common traits are the improvements in cost, quality and service levels (through improved asset reliability and recaptured capacity). Also, despite the rise of vendor and government consortia and wider partnering among different providers, there is no one dominant vendor, technology or combination of technologies that are embraced.

Broadly, the opportunity to develop new and modernized production capabilities is attractive and has captured the attention of manufacturing operations leaders, their supply chain counterparts and other organizational stakeholder. All of which are recognizing the concept's fit within broader programs seeking to establish digital supply chains that improve competitiveness and the customer experience through modern and flexible manufacturing capabilities. There is no indication COVID-19 has paused smart manufacturing investments; however, progress across the continuum will still be on the longer side of the two- to five-year horizon. The work executed in new facilities versus retrofitting existing capacity are two different things that could create challenges for scalability as organizations identify the blend of technologies that enable their definition/requirements for smart factories. Although there are case studies emerging that provide what smart factories can look like and accomplish, the integration with network design and segmentation techniques and clear tactics for repeatability and scale are needed.

User Advice:

- Promote the smart factory concept's role as part of an agile supply system that is integrated and connected to customer demand. This will lessen the risk of establishing success in isolation. It will prevent investments ahead of capability.
- Create templates or archetypes to support the different styles of production and factory models across the factory network. Value stream mapping or demand flow technology play critical roles.
- Plan to sustain big cultural changes by focusing on hybrid teams that blend IT, operational technology (OT), engineering technology (ET) and supply chain functions. This will help the communication, skills development and subsequent scalability.

Business Impact: Smart factories appeal to all manufacturers, and approaches will differ by industry and manufacturing style:

- **Risk: Medium —** Will test innovation and change management potential in existing factories where failure is not necessarily tolerated.
- **Technology intensity: High —** Despite vendor claims that no one dominant technology or provider exists. Create different technology templates (inclusive of harmonized integration standards) by the kind of factory. This will promote scale, leverage and expansion.
- **Organization change: High —** New skills and collaboration necessary; bridging the gaps between IT and OT as well as new operator capabilities should be expected.
- **Process change: High —** Substantial refactoring needed to fulfill supply chain expectations of efficiency with new capabilities to manage and control production processes in a flexible manner.
- **Competitive value: High —** Smart factories are an opportunity to profitable agility across the supply chain by connecting different processes, information streams and stakeholders in a streamlined fashion. This can translate into improved NPI, servicing of demand and cost optimization opportunities.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Recommended Reading: "Top 10 Strategic Technology Trends for Manufacturing Industries in 2019: Smart Factory"

"4 Tactics for CSCOs to Shift Manufacturing From a Cost of Doing Business to a Competitive Weapon"

"Innovation Insight for Engineering Technology: Why ET, IT and OT Are More Than the Sum of Their Parts"

"Industrial Supply Chainnovator 2019: Schneider Electric Wins for Developing Digital Competencies"

Digital Twin

Analysis By: Alfonso Velosa; Benoit Lheureux; Marc Halpern

Definition: A digital twin is a virtual representation of an entity such as an asset, person or process and is developed to support business objectives. The three types of digital twins are discrete, composite and organizational. Digital twin class elements include the model, rules, relations and data properties. Digital twin instance elements include the model, data, unique one-to-one association, and monitorability.

Position and Adoption Speed Justification: The idea of modelling people, physical assets, and processes continues to gain traction, especially as the architecture for the future of applications includes digital twins as features of an application, and as stand-alone supplements to portfolios of applications that address an entity.

- People: Digital twins are the evolution of trends including customer 360-degrees, patient electronic health records, and fitness monitors. Their near-term uses include health monitoring and employee safety, particularly in response to the pandemic.
- Physical assets: Digital twins adoption aligns to Internet of Things (IoT) trends. For owner/operators, near-term use includes lowering maintenance costs and increasing asset uptime for equipment users in factories, hospitals, utilities, etc. For product original equipment manufacturers (OEMs), near-term uses include product differentiation, business model differentiation through new product service models, and obtaining customer data.
- Processes: Digital twins are being developed to model IT organizations, financial exchanges, and processes such as purchase orders.

The digital twin profile has moved past the Peak of Inflated Expectations, based on enterprise confusion driven by conflicting vendor marketing and on challenges implementing digital twins. Gartner's CIO Survey 2020 shows that 6% of enterprises have implemented digital twins, although less than 1% of assets have digital twins. Another 41% of enterprises expect to deploy digital twins within three years. These trends lead us to shorten the time to plateau down to two to five years. In the next decade, digital twins will become the dominant design pattern for digital solutions.

User Advice: CIOs should work to guide and protect business adoption of digital twins:

- Business outcomes: Work with business leaders to establish clear business objectives for digital twins. In parallel, establish an IT vision for digital twins, to establish a coherent approach to support the business units.
- Technology: Start with models that are as simple as possible of the entities that are of interest for your business process, whether basic, such as the location of vehicles or a very high fidelity models of a human heart. Determine what data is necessary to "feed" the models and the types of analytics needed; a corollary here is the need to verify and drive data quality. Don't let the dearth of standards limit innovation. Assess how composite and organizational digital twins will require integration and custom development.
- Governance and accountability: Engage the business unit to identify champions, budget support, and to co-build the digital twin strategy and roadmap. Establish a joint business and IT governance process for digital twins, covering their alignment to business KPIs, short and long term value, and their updates and life cycle management.
- Digital ownership and ethics: Work with business and legal teams to establish a policy on ownership of the digital twin models and data, as well as who may participate. In parallel, establish a digital ethics policy to guide the organization to develop twins that positively support the enterprise while serving employees, customers or citizens. This policy will set guidelines to engage ecosystem stakeholders about what data may be shared and what monetization experiments to conduct.

- Vendors selection: Understand most technology providers are still developing their strategy and mostly offer enabling technology. A small number of technology providers have digital twin portfolios which align with specific vertical markets.

Business Impact: Digital twins are transformational as they enable business to drive new digital business models as well as update existing models. For example, they enable superior asset utilization, service optimization and improved customer experience. They create new ways to operate, such as consumption of physical outcomes instead of the capital expenditure acquisition of industrial assets, or new ways to drive an ecosystem or supply chains. And they will open new ways to monetize data.

Digital twins will challenge most enterprises to change their thinking of master data from an IT practice to one that engages the business units and IT to get a more comprehensive situational awareness of assets, people, or processes. In addition, a digital twin can be expensive to maintain, and its value centers on remaining a live model, synchronized with the entity.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: AVEVA; Bentley Systems; C3.ai; Cognite; GE Digital; Mavim; Microsoft; QPR Software; Schneider Electric; ThoughtWire

Recommended Reading: “Market Guide for Digital Twin Portfolios and Enabling Technologies”

“Survey Analysis: IoT Digital Twin Adoption Proliferates Across Many Sourcing Options”

“Toolkit: Enterprise Readiness for Digital Twin Deployment”

“Market Trends: Software Providers Ramp Up to Serve the Emerging Digital Twin Market” 6

“Software Product Managers Should Exploit the Full Revenue Potential of Digital Twins”

Digital Operating System

Analysis By: Simon Jacobson

Definition: Digital operating systems are the next generation of corporate production systems. They marry the mature, core pillars of a corporate production system with smart manufacturing to create an integrated application of digital, lean and continuous improvement principles, and leadership behaviors. When synchronized with an organization’s supply chain, the operating system will drive agility, sustainable performance improvement and competitive advantage from manufacturing operations.

Position and Adoption Speed Justification: Manufacturers have long relied on production systems steeped in lean, continuous improvement and performance standards to deliver cost

savings and efficiency gains or uncover new improvement opportunities in and across a network of factories. As organizations seek to unlock manufacturing operations' ability to support the supply chain's broader agility imperatives, to sense and respond with speed and flexibility to changing market conditions, they are exposing the limitations and weakness. This includes in established Toyota Production System (TPS), total quality management (TQM), world-class manufacturing (WCM) and similar lean-based systems. They are not equipped to meet the new requirements for agility and speed nor do they effectively leverage technology with the consistency required.

A digital operating system is the next generation of corporate production systems. It is aligned with the operating system for the supply chain and supports the convergence of lean and digital. This, combined with the impact on both the physical and digital worlds, has transformative potential. This is done by expanding the breadth of corporate production systems to balance predigital foundations (lean and continuous-improvement-based methodologies, processes and metrics) with new talent and skills requirements, varied technology services (transactional applications, i.e., manufacturing execution systems [MES] through to autonomous things and multiexperience), different capacity orientations and redefined standard work.

Despite strong foundations to build upon, the methodologies and best practices of a digital operating system for manufacturing operations are still nascent. There are more collections of technology projects than a governed approach that supports economies scale. As supply chain organizations clarify manufacturing's role and alignment, remove organizational complexities and manage the unrivaled heterogeneity of manufacturing operations, digital operating systems will gain momentum and advance across the continuum on the shorter end of the five- to 10-year period.

User Advice: Establishing a digital operating system for manufacturing operations requires:

- Communicating that this is more than an upgrade of existing manufacturing excellence programs or that this is a technology project. This is an initiative to ensure that the correct competencies, skills and new ways of working are in place to synchronize manufacturing activities with customer value. Stakeholder must be aligned accordingly.
- Balance the convergence of lean and digital. Avoid pausing ongoing investment and integration of existing lean and continuous improvement programs so that improvements and projects are transferrable across all sites. Workstreams that are designed from the outside-in with an understanding of functional interdependencies versus in silos are foundational.
- Use a stage-based maturity approach that defines the iterative progress and achievements to focus and define deployment phases. This helps balance the "digital-first" mindset by ensuring the right foundations are in place for sites and production units to leverage technology effectively.
- Prepare restructure organizational designs for cross-functional governance and decision making.

Business Impact: At the extreme, overcoming legacies of siloed organizations and fragmented and localized operations to establish a modern, digital operating system for manufacturing operations is a challenging task.

- **Risk: Medium —** While proven in measurable benefits, the failure to align manufacturing and supply chain goals and/or build a culture around continuous improvement can be detrimental because improvements will not stick.
- **Technology intensity: High —** Prepare to invest in new technologies while simultaneously upgrading existing ones. Don't overlook information governance. Without consistent access to data to support automated processes, shorten the time to insight and compare performance across — the future is unachievable.
- **Organization change: High —** This is a cultural shift and employee engagement is not the challenge — it's unwinding experiential bias, forming new communities of process and technologies, and knowledge management to support new ways of working.
- **Process change: High —** Without ensuring that standard work is present and there are streamlined processes prior to digitalization, all you will do is spend money.
- **Competitive value: High —** The end result of a systemic approach to reducing costs and complexity of manufacturing operations while creating and sustaining agility.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Recommended Reading: "Video: J&J Manufacturing for the Future — Enhancing Customer Value Through Innovation and Digitalization"

"How Schneider Electric Is Making Its Factories Smarter"

"Production Systems 2025: Rewriting the Working Systems for Industry 4.0"

"Supply Chain Brief: Modernize Production Systems to Unlock Manufacturing Operations and Support Agility Imperatives"

"4 Tactics for CSCOs to Shift Manufacturing From a Cost of Doing Business to a Competitive Weapon"

IT/OT Convergence and Alignment

Analysis By: Simon Jacobson

Definition: Gartner defines operational technology (OT) as the hardware and software that detect or cause a change of state through the direct monitoring and/or control of physical devices, processes and events in the enterprise. IT/OT convergence reflects the growing use of standard IT technologies within OT. Alignment is the necessary organizational response to these changes.

Position and Adoption Speed Justification: In 2020, the convergence and alignment of IT and OT continue to make progress. Organizations see the strategic importance of integrated and consistent

manufacturing capabilities (achieved through smart manufacturing initiatives) and are evolving their disciplines. Not to be overlooked is how technology providers have helped expose the issues (and the subsequent need to assimilate toward a solution) too.

While there is progress, there are also sizable challenges in 2020:

- The large backlog of initiatives that has slowly been chipped away at continues to grow as manufacturers endeavor to synchronize production capabilities with their supply chains. This spans augmenting OT with IoT and improving the accessibility and analysis of production data spanning transactional procedures through to increasing automating.
- The pandemic exposed significant gaps for both IT and OT management groups and skilled workers. The heavily tacit and undocumented methods and procedures combined with fluctuating levels of operational knowledge in and across manufacturing networks are risks.

Compounding the challenges for manufacturers is that convergence and integration are much further along than the alignment of IT and OT.

Integrating IT and OT systems does not have to be dependent on alignment (but, ideally, it should). This doesn't necessarily mean that the management groups for the departments managing IT and OT need to be one integrated organization. Instead, alignment adjusts the relationship among traditional custodians of OT systems and other groups that deal exclusively with technology — usually the IT department. Alignment moves them toward commonality across processes of synchronizing standards, support processes, security and architecture plans to build in compatibility between the IT and OT systems.

The criticality of alignment and culture is elevated — and no longer holding forward progress hostage. The pursuit of hybrid projects (e.g., security or asset management) and the development of common standards and transference of knowledge are happening. Yet, the successes are still site-centric versus "fit for scale" (as in fully documented and deliberate).

We expect the emergent talent issues to increase focus on organization and talent pillars as companies modernize their production systems. Additionally, deepening the newly refreshed human resources relationships to align technologies, skill sets and organizational models for factory staffing will also propel the convergence and alignment of IT and OT forward. This bullishness is tempered with concern that realization of convergence will happen long before alignment is undertaken, meaning that changing the governance and management of OT will lag significantly after the new technology deployment and impact.

User Advice: To successfully converge and align IT and OT in manufacturing operations:

- Use the production system to bring IT and OT domains together through new organizational models, technology roadmaps (e.g., cloud computing) and common processes for managing assets.
- Steer governance toward common objectives for responsibility, accountability and scale, not ownership and isolation. Also realize now that alignment, not duplication, is key, as not all knowledge-based practices and processes can be transferred to the OT world and, likewise, to the IT world.

- Pinpoint where the IT organization should collaborate with the OT world in supporting and managing OT systems, and create joint integration plans where data flow benefits need to be realized. Coordination with line of business stakeholders is needed. Reference architectures and industry standards can also help.

Business Impact: IT and OT are inseparable, and the criticality of lines of business giving them added attention is massive. Their alignment and integration are a paradigm shift that emphasizes culture and governance ahead of technology, impacting:

- **Risk: High —** Not acknowledging the convergence and alignment between the two domains with overall manufacturing strategies will perpetuate cultural and system divides that increase downtime and create security concerns.
- **Technology intensity: High —** Standards-based IT technologies have existed in the OT world. However, the pace of change that augmentation with IoT, the incorporation of advanced analytics, and the need for increased security create new complexities and trade-offs.
- **Organization change: High —** Alignment of IT and OT requires involved sponsorship, new and/or innovational organizational designs, job description changes, certifications, reskilling, and recruitment of new competencies.
- **Process change: High —** Realignment of responsibility across IT and groups traditionally most involved in managing OT will result in changes to security, technology acquisition and upgrades. Knowledge management cannot be overlooked and requires attention.
- **Competitive value: High —** Having the ability to successfully manage the fluctuating labor availability and nous to leverage information assets and operational efficiency in and across factories will drive resiliency and new collaboration opportunities.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: AVEVA; AWS; Cisco; GE Digital; Microsoft; PTC; Rockwell Automation; Siemens

Recommended Reading: “2020 Strategic Roadmap for IT/OT Alignment”

“The Importance of OT Integration for Industrie 4.0”

“Show the Value of OT and IT Alignment, and Realize Digital Business Results”

Prescriptive Analytics

Analysis By: Noha Tohamy

Definition: The term “prescriptive analytics” describes a set of analytical capabilities that finds a course of action to meet a predefined objective, such as maximizing revenue or minimizing costs.

The most common examples of prescriptive analytics are optimization methods such as linear programming, rule-based decision making and heuristics. Prescriptive analytics differs from descriptive, diagnostic and predictive analytics, in that its output is a recommended action.

Position and Adoption Speed Justification: Although the concepts of optimization, heuristics and decision analytics have existed for decades, their adoption has steadily increased in the supply chain with greater awareness of advanced analytics, better algorithms, cost-effective cloud-based computing power and available data. Increased interest is also driven by executives' desire for more actionable recommendations to support users; fact-based decision making. Prescriptive analytics augments a user's decision making by recommending a course of action to achieve a defined objective. Furthermore, prescriptive analytics is used to fully automate supply chain processes such as replenishment or materials sourcing.

Traditionally, supply chain organizations have used prescriptive analytics to solve functional problems in the strategic or tactical time horizon, such as network design, sourcing strategies or production planning. Today, organizations seek to leverage prescriptive analytics in near-real-time decision making within areas such as replenishment, pricing or rapid planning.

Historically, prescriptive analytics tools operated as black-box engines, with limited visibility into the inner workings of the model and rationale behind its findings. Today, solution providers have improved solution transparency, explaining the drivers or constraints behind a certain recommendation and providing what-if analysis capabilities. With more transparency, there is broader adoption of prescriptive analytics as users become more comfortable with the validity of the solutions.

Just like predictive analytics, over the next three to five years, Gartner expects prescriptive analytics to reach the Trough of Disillusionment as organizations realize that, while critical, prescriptive analytics does not automatically result in better decision making. Reaping the benefits is heavily dependent on the organization's culture and willingness to rely on prescriptive analytics in their decision making across the supply chain. With improvement not only in prescriptive analytics solutions, but in data quality, talent and organizational culture, prescriptive analytics will continue to advance, reaching the Plateau of Productivity in five to 10 years.

User Advice: To take advantage of prescriptive analytics, supply chain leaders responsible for analytics strategy must:

- Identify the prerequisites for success, ranging from organizational buy-in to redesign of current processes.
- Ensure that organizational structure and governance will enable the company to implement and maintain functional as well as cross-functional prescriptive analytics recommendations.
- Ensure the availability, quality and readiness for data required to conduct prescriptive analytics.
- Secure the internal or external skill sets to generate, implement, and consume prescriptive analytics. Identify the supply chain processes that can benefit from prescriptive analytics and clarify how the output will be embedded in the process. This includes identifying the level of process automation and human intervention.

Business Impact: The impact of prescriptive analytics is significant in the supply chain. Prescriptive analytics can improve decision making in functional areas like planning, sourcing and logistics. More importantly, prescriptive analytics can be deployed to improve the end-to-end supply chain performance because it can recommend a course of action that best manages the trade-offs among conflicting functional goals. This has been an elusive goal, given the complexity of the decisions that must sometimes consider hundreds of thousands of constraints and alternatives.

Although traditionally, prescriptive analytics has been relegated to the strategic and tactical time horizon, more advanced capabilities can support real-time or near-real-time decision making. This means, that for processes such as pricing or available to promise, fact-based decision making can be supported or altogether automated with prescriptive analytics.

With prescriptive analytics, many supply chain processes that have heavily relied on human judgment, like inventory positioning, transportation routing or maintenance scheduling, can now be automated. This might have a significant impact on the role definition and job profile that organizations look for in their supply chain talent.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: AIMMS; FICO; Gurobi; IBM; River Logic

Recommended Reading: “Market Guide for Supply Chain Analytics Technology, 2018”

“Toolkit: Supply Chain Analytics Maturity Assessment”

Supply Planning

Analysis By: Pia Orup Lund; Amber Salley

Definition: Supply planning translates demand expectations into time-phased and quantified requirements of capacity, materials, labor and services across the supply network. Success is determined by the fulfillment of customer demand while efficiently utilizing capacity and minimizing waste in the consumption of labor, material, freight capacity, inventory and other resources.

Position and Adoption Speed Justification: As manufacturers and suppliers strive to increase the strategic alignment and effectiveness of their decision making through mature S&OP/integrated business planning (IBP), supply planning is central to ensuring that business tactics for maximization of financial results can be converted into feasible operating plans. Midterm supply plan models analyze key constraints to define key network resource requirements (e.g., internal capacity, third-party services and suppliers, product distribution and inventory levels) and inform the development of aligned individual site and functional operating plans.

Many users have been limited in their capability development by a lack of investment in constraint-based modeling functionality. More mature supply planning capabilities, enabled by the right technology solutions, provide optimization modeling and simulation of what-if scenarios to analyze, visualize and socialize performance trade-offs quickly for more effective management of risks, opportunities and events. Increased emphasis on supply agility drives manufacturers to increase the degree of synchronization between midterm supply planning, operational planning and detailed scheduling for postponed decisions that maintain more dynamic supply balancing with demand. This expands the focus from isolated midterm supply planning to multilevel orchestration of a volatile demand signal to an agile supply response. The move toward multienterprise planning between manufacturers and suppliers will necessitate a focus on supply planning across a supply network. As technology providers integrate more capacities for real-time data sharing across partners, this will transition into a mature mainstream capability.

User Advice: Manufacturing, retail, distribution and service companies rely upon supply planning to translate network capabilities into demand fulfillment outcomes. Approach improved supply planning as the path to enable more integrated supply chain decisions for improved overall performance. At the same time, supply planning cannot completely overcome structural disconnects between network capabilities, demand realities and customer expectations. Develop plans or strategies to operate by three principles for supply planning success:

- Align supply planning and inventory strategies, metrics and incentives with network capabilities and outcome objectives.
- Create feasible midterm supply network plans that balance decision agility with modeling precision. Monitor supply plan and production schedule adherence, but emphasize feasibility and fulfillment of performance outcomes.
- Align tactics with demand and product realities by applying the right combination of agile scheduling and optimized supply and inventory planning for each segment of the product portfolio.

Supply planning capabilities go beyond software selection to aligning with solution partners who can assist the configuration of network models that enable decisions to fulfill demand and maximize value. As competition and performance standards increase expectations on decision speed and precision, supply planning must evolve to orchestration down through execution. This convergence is impacted by a number of factors that will vary based on industry and supply network details.

- Complexity: The number of factories and production units, bills of material structures, product portfolio size, suppliers and market channels served.
- Dependency: Vertical integration, interplant shipments and common suppliers.
- Constraints: Material lead time and availability, processing and storage capacities, labor, and inventory targets.
- Pressure: Short-order lead times and changes, customer-specific product specifications, inventory target policies, and demand profiles.

Business Impact: For product-based supply chains, the following impact areas apply:

- **Risk: High —** Supply plan models reflect the complex details of product portfolios and supply networks, making master data setup and accuracy critical. Software tool deployment and model testing and user training are critical to success. Change management to migrate from legacy methods such as spreadsheets is imperative.
- **Technology intensity: High —** Technology solutions translate demand signals into detailed resource requirements expressed in quantities, timing and location. Supply planning complexity is directly related to product portfolio and supply network complexity.
- **Organization change: Medium —** Supply planning solutions reduce manual planning effort by 20% or more, enabling faster decisions and increasing the scope of analysis across the entire supply network for better alignment with the business.
- **Process change: Medium —** Supply plans must be converted to individual operating plans for sites, functions and suppliers, requiring clarification of roles, task sequences and information handoffs.
- **Competitive value: High —** Supply planning aligns operations across the network to deliver outcomes efficiently by ensuring the capacity and resources are available with the right quantity, timing and location. Absence of supply planning may result in manufacturing activities that are misaligned with business objectives or harshly subjected to inefficiencies imparted by the volatility of an unfiltered demand signal.

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: Adexa; AspenTech; Asprova; Dassault Systèmes; Infor; Optessa; Oracle; ORSOFT; PlanetTogether; SAP

Recommended Reading: "Make the Business Case for Supply Planning by Answering Five Questions"

"Follow a 5-Step Supply Planning Process to Support Business Objectives and Drive End-to-End Supply Chain Profitability"

"Operationalize Inventory Reduction Targets With Integrated Supply Plan Proposals"

"Optimize Supply Chain Network Capacity Utilization for Manufacturing Competitiveness"

Supply Chain Convergence

Analysis By: Dwight Klappich

Definition: Supply chain convergence is where supply chain functional silos are broken down and end-to-end business processes span, synchronize and optimize across traditional functional domains.

Position and Adoption Speed Justification: Supply chain convergence refers to the growing need for supply chain organizations to do a better job of orchestrating and synchronizing processes, subprocesses and activities across supply chain (e.g., customer service, warehousing, transportation and manufacturing) functional domains. End-to-end (E2E) processes like order-to-cash or procure-to-pay span functional and application boundaries, as well as outside the enterprise for procurement, sales and customer service.

Convergence is a concept Gartner first published in 2008, but it was too early at that time. Most companies continue to this day to organize, manage, buy and implement systems vertically by functional domain.

Early stages of supply chain management (SCM) application convergence are underway, with certain technology vendors building analytical umbrellas over the top of functionally siloed application suites. Some vendors that offer multiple SCM applications are building data and process integration among their various applications. However, these are steppingstones to the more robust convergence that will enable synchronization and optimization of E2E processes. As some leading SCE vendors migrate their applications to true microservices architectures, we see the beginnings of the right platforms to drive convergence forward.

User Advice: Supply chain organizations recognize that, to get to Stage 3 supply chain maturity and beyond, they must embrace convergence as both a business and an IT vision and integrated strategy. Today, companies struggle to systematically integrate E2E business processes in the fragmented supply chain functional and IT environments prevalent in most organizations. At best, companies pass data back and forth between applications, but coordinating, let alone optimizing, E2E processes across application silos remains elusive.

SCM organizations must break down functional silos by assembling composite processes that bring together subprocesses and activities across specific domains. The urgency to pursue convergence grows as companies seek Stage 3 supply chain maturity or higher, and as new business models (like digital) drive transformational change. Functional areas (like manufacturing, logistics, sourcing and customer service) should evaluate how fundamental operational processes are linked with and affected by processes that are controlled by other functional groups and systems within and outside their organizations. A key first step will be to break down the departmental or functional barriers within and between organizations. Then the second step will be to automate these new processes to ensure that they are instantiated in the business.

Supply chain maturity and supply chain convergence attainment are closely aligned, wherein higher-maturity organizations are more likely to address the cultural and operational issues necessary to reach higher levels of convergence.

Business Impact: New opportunities for process improvement will require organizations to adapt their cultures and operational environments to enable coordination and synchronization of E2E processes, such as selling, buying or making. This will require supply chain capabilities and systems to converge across and between traditional SCM functional silos.

Consider the following impact areas:

- **Risk: Moderate —** Tools are nascent, but the value of convergence far outweighs the risk.
- **Technology intensity: Moderate —** Technical complexity sits on the vendor's shoulders, reducing the technical complexity for users.
- **Strategic policy change: Moderate —** SCE organizations must adapt their cultures and operational environments to enable coordination and synchronization of E2E processes.
- **Organization change: Moderate —** The first step toward convergence requires companies to shift their paradigms from a vertical (functional) view of the world to a horizontal (E2E process) view of the world.
- **Culture change: High —** Low-stage-maturity organizations will struggle to break the contentious functional bias inherent in many supply chain organizations in order to have any hope of evolving to convergence.
- **Process change: High —** Processes are horizontal even if most organizations remain vertical, so once a company makes the commitment to think horizontally, aligning processes will be straightforward. If the company cannot think horizontally, then converging processes will remain problematic.
- **Competitive value: High —** Convergence will drive the next wave of business value, and early adopters will be able to leverage dramatic process improvements to gain a competitive advantage.

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Emerging

Sample Vendors: Bringg; Deposco; E2open; Manhattan Associates; Oracle; SAP; Softeon

Recommended Reading: "Unify End-to-End Supply Chain Processes With Supply Chain Convergence"

MOM Application Suites

Analysis By: Rick Franzosa; Marc Halpern

Definition: Manufacturing operations management (MOM) application suites are a collection of applications for managing end-to-end manufacturing processes with a view to optimizing production. These application suites extend traditional manufacturing execution systems (MES) beyond production execution management to include detailed production scheduling, production resource management (materials, assets, labor), process and product reliability (quality), and manufacturing data analytics.

Position and Adoption Speed Justification: The impetus for MOM application suites is based on the premise that built-for-purpose capabilities across the manufacturing plant spectrum provide

product plants more flexibility and agility. They accomplish this by minimizing the need for communication with upstream systems (ERP/PLM/SCP) to make better decisions and respond in near real time on the plant floor. MOM descended from the Peak of Inflated Expectations nearly to the Trough of Disillusionment as the realities of making it work have stripped away the hype surrounding MOM vision. As the MES market has matured, users have recognized that they need capabilities beyond core MES to continuously improve upon efficiency, quality and cost. Most vendors in the space have expanded their offerings to include additional functionalities that qualify as MOM capability. The vendors have delivered the MOM capabilities via approaches ranging from organic development to merger/acquisition. However, end users are on a steep learning curve regarding best practices and tuning the software ease of use to those best practices.

By their very nature, MOM application suites are positioned as production applications, not enterprise applications. They rarely have the same level of functionality as the built-for-purpose applications in production scheduling, resource management, quality or data analytics found in enterprise suites. Additionally, the preferred vendor approach to building MOM application suites involves adopting a platform approach that can add complication and cost in integration points between the MOM platform and enterprise applications. This may slow the movement of MOM application suites through the Trough of Disillusionment.

User Advice: Concentrate on the following when identifying a MOM application suite that's right for your environment:

- Successful MOM application suite deployment requires a culture of problem solving/continuous improvement. These systems are more complicated than the MES systems they replace/augment, and they should be aligned with corporate production systems to ensure success.
- Determine the functional capabilities a MOM application suite can offer in support of the process issues that need a solution and the degree of industry vertical domain specialization required. Keep in mind that what you choose will impact similar applications in other domains (e.g., the impact of MOM detailed production scheduling on supply chain planning and ERP).
- Before adopting MOM application suites, work to standardize processes against the backdrop of manufacturing capability as value creation for the business. Define global process templates that will speed deployments and foster standardization.
- Although defining your enterprise strategy is key to success in MOM deployment, base initial investments on boosting plant-level capabilities. This will satisfy initial ROI concerns and provide a platform for longer-term benefits.
- The biggest challenge in adopting a MOM solution is determining where it makes sense to provide a capability (e.g., production scheduling, materials management and quality) as part of a MOM application suite. The alternative is an integration between MOM and an existing enterprise application. Trade-offs include varying levels of functionality and the cost and complexity of integration.
- Manufacturers will also need to consider trade-offs between different MOM application suites, as none of the available suites on the market are best-in-class in all application areas. Some manufacturers have developed their own manufacturing operations platforms and are

integrating point solutions through their platform, rather than choosing any of the MOM application suites and accepting a less than optimal total solution.

Business Impact: Understand the following impacts of MOM application suites on manufacturing operations:

- **Risk: Medium —** MOM application suites will enable process optimization across manufacturing process disciplines. The trade-offs are required process changes and integration discipline between MOM suites and other enterprise applications.
- **Technology intensity: Low —** Most MOM application suites take a different approach to manufacturing operations that is more process-intensive than technology-intensive.
- **Organization change: Medium —** MOM application suites will change how users interact with manufacturing operations applications versus traditional interactions with MES, ERP, SCM and PLM, for example. This will make cross-domain governance more of a challenge, but this is an excellent opportunity to drive alignment across these domains.
- **Process change: High —** Process change will be high as MOM applications foster manufacturing operations process optimization by focusing end-user attention on MOM applications rather than requiring them to master multiple disparate applications from different vendors.
- **Competitive value: High —** MOM application suites' integrated manufacturing operations technology improves shared data visibility, which enables better decision making and improves speed, agility and throughput.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: ABB; AspenTech; AVEVA; Critical Manufacturing; Dassault Systèmes; iBASEt; iTAC Software; Rockwell Automation; SAP; Siemens Digital Industries Software

Recommended Reading: "Critical Capabilities for Manufacturing Execution Systems"

"Market Guide for MES/MOM Implementation Providers"

"Magic Quadrant for Manufacturing Execution Systems"

"Supply Chain Brief: Modernize Production Systems to Unlock Manufacturing Operations and Support Agility Imperatives"

Environmental, Social & Governance

Analysis By: Sarah Watt

Definition: Environmental, social and governance (ESG) refers to a collection of corporate performance criteria that assess the robustness of a company's governance and its ability to effectively manage environmental and social impacts. ESG-based analysis aims to link a company's performance in ESG indicators to its overall financial performance. Corporate social responsibility (CSR) is a management concept that leads businesses to account for the short- and long-term environmental, societal and economic implications of their business decisions.

Position and Adoption Speed Justification: Leading companies use CSR to uncover opportunities and manage risks, to achieve sustainable business outcomes. What has changed compared to previous years, is that momentum behind CSR has accelerated. Firstly, investors continue to focus on ESG performance — boards must act now to oversee strategic long-term plans, based on materiality, that are likely to include action on climate change, responsible sourcing and water scarcity among other macro issues. Secondly, consumer concern around issues such as climate change and end-of-life plastics continues to increase.

CSCOs must prepare for increased demands from stakeholders to comprehensively disclose and set ambitious improvement targets for their environmental and social impact. CSR is unlikely to go away as many countries, as a result of COVID-19, consider tying economic stimulus to CSR and carbon reduction activities.

User Advice: Get started now! An effective CSR-based strategy will identify opportunities and risks. Don't wait for negative shareholder votes, customer boycotts or a reputation crisis before initiating and developing a CSR governance infrastructure.

- Become familiar with fundamental CSR concepts, such as stakeholder engagement, materiality and CSR reporting standards, and data collection methods. Ensure actions are aligned with the UN's Sustainable Development Goals.
- Assess the maturity of your organization's governance infrastructure for managing CSR within supply chain and determine strategies to advance to the next level (see "How Supply Chain Leaders Can Start and Advance Their Sustainability Journey").
- Learn more about the complex environmental and social issues affecting your industry or company by talking to peers, customers and stakeholders.
- Collaborate with investors and others to prioritize the material areas of environmental or social risk exposure. Take note that the emphasis on strategies for reducing greenhouse gas emissions has increased in the last 24 months (see "Supply Chain Brief: Set and Invest in Radical Goals for Greenhouse Gas Emissions Reduction").
- Mobilize resources on signature, audacious projects. Although companies initially start these projects within their own organizations, more mature CSR programs bring about change across the ecosystem.
- Advocate for the company to promote its CSR strategy when recruiting "millennial" workers who evaluate a company's environmental and social impact as they consider their supply chain management employment options (see "Supply Chain Brief: How to Compete for Millennial and Gen Z Talent").

Business Impact: Businesses using CSR as a platform for strategy, risk management, talent management, innovation and growth must significantly reorient their decision-making frameworks to widen their focus beyond short-term profits, costs and service. Given the complexity, the changes associated with adopting a CSR-based strategy and governance infrastructure involve a transformational and potentially revolutionary journey with changes in processes, roles, performance metrics and trade-off decisions.

Leaders must organize an ecosystem of partners inside and outside the enterprise. For example, CSCOs must work with finance, legal and compliance, as well as suppliers and logistics partners, on effective risk assessment and mitigation strategies. Leading companies engage in precompetitive problem solving with third parties (consultants, nongovernmental organizations) or industry consortia.

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Recommended Reading: "How to Lead Supply Chain in the Big Shift to Sustainable Business: A Gartner Theme Insight Report"

"Supply Chain Brief: Help Stakeholders Adapt to Sustainability by Sharing Fundamental Definitions"

"Supply Chain Brief: Make Strategic Choices for Measuring and Reporting Sustainability Performance"

"Use 3 Change Leadership Strategies to Build Backing for Early-Stage Supply Chain Sustainability Initiatives"

"The Need for Multispeed and Sustainability in Retail's Last Mile"

"A Guide to the Packaging Sustainability Initiatives of the 2019 Gartner Supply Chain Top 25"

"Strategies to Build and Advance Sustainability Programs in Logistics"

Manufacturing Segmentation

Analysis By: Jennifer Loveland; Michael Dominy

Definition: Segmentation, as it applies to manufacturing operations, creates multiple standardized approaches to production and assembly processes. Each approach is optimized for a specific goal such as efficiency, cycle time, customization or flexibility. It is an application of targeted supply chain segmentation to manufacturing processes.

Position and Adoption Speed Justification: Manufacturing leaders have traditionally either allowed each site to operate very independently or focused on creating a single global or regional standard for manufacturing. Segmentation groups site or line with similar objectives and defines a

standard production approach for each segment. This helps manage the complexity of the business while still providing economies of scale. Segmentation can be an enabler of overall manufacturing network design (determining the location, ownership and charter of sites) by identifying two to five standard processes rather than treating individual locations independently.

To handle the complexity of expanding product lines and customer options, leaders have begun viewing the manufacturing network as a collection of capabilities that must be optimized. To optimize, they are moving from a one-size-fits-all standard to a portfolio of approaches focused on different needs for different products, businesses, markets and customers. This results in two primary manufacturing segmentation approaches often used in parallel:

- **Segmentation across sites in the manufacturing network —** Different standardized production processes are used at different manufacturing sites based on business requirements (product, market or customers) and on how each site supports the overall network strategy. A site will use global standard metric definitions with target sets based on region, product line or focus on efficiency, responsiveness (cycle time) or agility (customization or flexibility).
- **Segmentation within a manufacturing site —** Different production strategies for lines within a site are based on the characteristics of products and equipment or business needs. This is most common where large variation in products necessitates frequent changeovers or where equipment setup times are lengthy. Dedicating lines for high-volume products or customized for small batch runs is common.

Manufacturing segmentation has moved further toward the Trough of Disillusionment as we see adoption nearing 50%, as indicated by use of a mixture of in-house and outsourced manufacturing site. As each site is focused on specific capabilities, segmentation begins. Often, this segmentation is not ideally executed and has room for improvement in its definition and impact to the business. As manufacturing leaders experiment with new technologies, such as 3D printing and smart robots, and new concepts, such as multimode facilities and mobile factories, interest in standardizing a handful of production approaches will increase, with this technique moving toward the plateau in the next two to five years.

User Advice: To apply manufacturing segmentation:

- Formalize any segmentation that has unconsciously arisen within manufacturing sites with differentiated metrics targets.
- Consider segmentation within sites with large product variety or long equipment changeover times.
- Use segmentation as a part of manufacturing network design by targeting specific sites to customer-centric attributes, such as price, speed of delivery and availability.
- Consider how external manufacturing partners are utilized based on spend and supply complexity
- Define how your manufacturing segmentation fits with other targeted or end-to-end segmentations present in your supply chain.

Business Impact: Manufacturers will use segmentation to define distinct outcomes required to serve a market and optimize a process for each option. The goal of applying segmentation to manufacturing operations is not one of adding capacity at cost. It's about aligning capabilities to boost productivity and demand-response times in and across sites.

Consider the following impacts:

- **Risk: Low —** Risk that will vary based on the design of the standardized production processes.
- **Technology intensity: Medium —** Consistent master data across sites and analytics capabilities to quantify cost/capability trade-offs.
- **Organization change: High —** Changing behaviors at all levels of the organization with potential for matrix-oriented structures to align sites with demand.
- **Process change: High —** Impact on plant charters and incentives, supplier and partner relationships, capacity allocations and factory productivity levels.
- **Competitive value: High —** Disruptive innovations that shorten time to market, enable new manufacturing models (e.g., multimode factories, 3D printing for dedicated markets), and shed excess capacity and cost.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Recommended Reading: "Segmentation Strategy for Manufacturing Operations"

"Segmentation 101: Apply Supply Chain Segmentation to Serve Diverse Needs and Reduce Waste"

"Five Phases for Successful Supply Chain Segmentation"

"4 Tactics for CSCOs to Shift Manufacturing From a Cost of Doing Business to a Competitive Weapon"

"Simplify Supply Chain Network Design to Improve Success of Implementation"

Cloud Computing in Manufacturing Operations

Analysis By: Rick Franzosa

Definition: Cloud computing in manufacturing operations is a style of computing in which scalable and elastic IT-enabled capabilities that support manufacturing operations are delivered as a service using internet technologies.

Position and Adoption Speed Justification: Cloud's progress across manufacturing operations is varying by industry, use case and enterprise. It is unlikely that manufacturers will totally abandon

on-premises models for mission-critical applications (manufacturing production) in the near term. The hybrid cloud model in local plant production will soon be supplemented by edge devices, 5G technology and "on-site cloud replication" that will provide a safety net for continuous production. Having reached peak hype three years ago in this space, cloud computing has since evolved with more focused applications and business processes. As of 2020, few clients have gone full cloud in manufacturing. Instead, many organizations are moving pieces of their operations to the cloud, while they and their vendors refine systems and applications:

- Business initiatives for connected factories and digital supply chains have made cloud attractive in manufacturing operations. This continues to accelerate cloud computing's positioning on the Hype Cycle.
- Customers and vendors are still evaluating and establishing the long-term total cost of ownership (TCO) benefits of cloud over traditional approaches. Buyers have apprehensions regarding control of cloud (SaaS) costs and vendor monetization of data.
- Provider offerings have evolved, spanning quality management, manufacturing execution systems (MES), production planning and analytics. Edge computing is also maturing. Not to be overlooked are new market entrants that are taking a "cloud-first" approach. Pockets of concern over data security, latency and exchange (between on-premises and cloud) are receding, and the push to "work from anywhere" makes cloud attractive.
- Manufacturers are now concentrating on the details (e.g., cybersecurity, vendor lock-in). In the case of mission-critical systems, does the added flexibility of cloud overcome long-held beliefs about security and availability? In addition, there are concerns of scalability of the ecosystem and maturity levels of solutions for some of these new entrants to the market.

For these reasons, cloud computing in manufacturing operations is located in the Trough of Disillusionment.

User Advice:

- Identify use cases for cloud computing with broad applicability to enhance existing process capabilities and overcome IT skills deficiencies across multiple sites without compromise to capacity utilization or quality. Minimize disruption through hybrid deployments that leverage existing on-premises systems.
- Make sure terms for retrieving data from application providers and cloud service providers are well-understood.
- Validate that on-premises data can be moved to cloud while using the cloud-based applications.
- Demand that candidate vendors provide clarity around their cloud offerings — especially contract life cycle pricing, data ownership and long-term TCO, as well as service levels and security models.
- Establish a clear understanding of the expected benefits of a move to the cloud. Benefits and trade-offs (how much control to give up) should be well-understood. Cloud computing involves

many components (spanning software as a service through business process as a service), and some aspects are more mature than others.

- Continue to investigate and pilot edge and on-site cloud replication technologies (e.g., Amazon Web Services Outposts) to determine their maturity and effectiveness for mission-critical production use.

Business Impact: Cloud computing innovates manufacturing new services for technology consumption and information access models, and contributes toward a flexible and agile manufacturing network with the following impacts:

- **Risk: Medium —** Risk is variable depending on the volume of data being sent to the cloud, characteristics and nature of the processes, and/or cloud service used. There is also the inherent risk of lost internet connection or some other technical IT issue shutting down manufacturing operations. Develop an internal understanding of the challenges of cybersecurity in cloud and hybrid cloud offerings.
- **Technology intensity: High —** Over time, the cloud will reduce on-premises IT total cost of ownership (hardware and personnel). Other factors such as service-level agreements and security will require more consistent attention and can change the nature of the relationship with key providers. In addition, cloud does not eliminate the need for complex integration.
- **Organization change: Low —** Specializations will be needed based on capabilities provided by cloud computing that enable new skills and organizational interactions.
- **Process change: High —** Clarity on functional requirements is needed to avoid the mass customization of cloud-based applications to site-specific needs. This includes clearly defined change controls and an understanding of touchpoints with other functions (e.g., planning and logistics).
- **Competitive value: Medium —** The cloud will increase an organization's ability to scale systems (up and down) and connect internal and external manufacturing network partners. This can also enable more agile redistribution of manufacturing activities across multiple factories and provide more visibility to operations performance from remote locations.

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: 42Q; Amazon Web Services (AWS); ComplianceQuest; GE Digital; MachineMetrics; Microsoft Azure; Plex; Rockwell Automation; Siemens; ThinkIQ

Recommended Reading: "What Manufacturing CIOs Must Consider Before Adopting Cloud Applications"

"Top 10 Strategic Technology Trends for Manufacturing Industries: Smart Factory"

"Toolkit: A Decision Framework for Adopting Manufacturing Applications in the Cloud"

"Optimize Supply Chain Network Capacity Utilization for Manufacturing Competitiveness"

Internet of Things — Manufacturing Operations

Analysis By: Simon Jacobson; Eric Goodness

Definition: IoT is a core building block for digital business and digital platforms. It is the network of dedicated physical objects that contains embedded technology to communicate and sense or interact with their internal states and/or the external environment. IoT comprises an ecosystem that includes assets and products, communication protocols, applications, and data and analytics. In manufacturing operations, using IoT to augment different OT has become a core building block for future digital supply chains and smart factories.

Position and Adoption Speed Justification: Augmenting operation technologies (OT) with various sensors, gateways, and edge devices in manufacturing operations continues to create new methods to access vast sources of data, analyze performance, and illuminate opportunities for automation. IoT is expanding in manufacturing operations. Use cases for asset performance and energy reduction have proven themselves. Meanwhile new opportunities for quality management, process optimization, edge architectures, and digital twins are emerging. This evidences that wider potential is slowly being realized and the momentum pushes IoT in manufacturing operations forwards this year — but not too far. It is in the trough as there are obstacles:

- Underestimated resource requirements (skills, cost, integration).
- Security issues are exposed; regulatory compliance is ever-evolving.
- Navigating a sea of standards (e.g., MTConnect, OPC), reference models (NIST, RAMI 4.0), and proprietary protocols.
- Architectural debates specific to edge and cloud.
- An ever-proliferating set of provider options in an already crowded market which creates complications for manufacturing systems' strategies.

The shortened time to plateau reflects two things. First the ROI in initial investments is proven and adoption continues. Second is a bullish expectation for systematic approaches for repeated successes across multiple sites will be cultivated. Should the organizations desired levels of scale not be achieved then IoT in manufacturing operations will be treated to a lengthy stay in the trough.

User Advice:

- Develop a plan to scale by deconstructing IoT and then mapping data, processes and use cases with site capabilities. Align this with a performance maturity continuum to accelerate connecting manufacturing with customer value.
- Ensure alignment between IT, OT, engineering technologies (ET), and line-of-business stakeholders to identify new skills and competency requirements, and lessen concerns on

scalability and integration costs with clear documentation of projects. This ensures accurate budgeting of resources, identifying the role of standards, and clarification of expected benefits.

- Segment use-case pursuits into those that will enhance the core of operations as well as those that will foster future innovation and process capabilities.
- Extend IoT pilots beyond optimizing assets to connecting production resources and knowledge workers in and across factories.
- Surface opportunities for experimentation and specific pilot programs to ensure feasibility of new technologies and processes by leveraging bimodal principles.

Business Impact: IoT will improve reliability across networks of factories. New levels of data and process transparency will lay a path to enable the most optimal integration with the supply chain.

- **Risk: High —** Accessing new and previously untapped data sources adds value locally but failure to devise a plan to cost-effectively (that is appropriate budgeting of time and capital) align with standard work as well as scale and integrate across the network delays value.
- **Technology intensity: High —** Both IT and OT are impacted IoT exposes opportunities for advanced analytics, AI, digital twins, and automation. This impacts IT and OT. Integration requirements need scoping while security and upgrades cannot go unattended.
- **Organizational change: Medium —** Over time, there will be some revised organizations with new specialization as IT and OT converge and align, and not just integrate. Expect to invest in operator-centric skill sets to engineer new solutions.
- **Process change: High —** To see the benefits of optimized processes, efficient servicing of demand, and ecosystem-driven collaboration then a strong prioritization of projects and validation of use cases require attention for scalable implementation must be balanced against ongoing cost optimization and improvement objectives.
- **Competitive value: High —** There is faster decision making based on available information, new options for customer intimacy and monetization.

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: Altizon; Flutura; GE Digital; Litmus Automation; Microsoft; PTC; SAP; Software AG; Tulip

Recommended Reading: “Survey: Manufacturers See Quick Return on IoT Projects”

“Competitive Landscape: IoT Platform Vendors”

“Innovation Insight for Internet of Things in Supply Chain”

“Innovation Insight for Engineering Technology: Why ET, IT and OT Are More Than the Sum of Their Parts”

“Magic Quadrant for Industrial IoT Platforms”

“Industrial Enterprise Customers Want to Accelerate IT-OT Convergence”

“Top 10 Strategic Technology Trends for Manufacturing Industries: Smart Factory”

3D Printing in Manufacturing Operations

Analysis By: Rick Franzosa

Definition: 3D printing (3DP) in manufacturing operations refers to the use of 3DP to produce a finished item, subassembly or intermediate product. It can also be used to print tools, fixtures, dies and molds used during the production of finished goods.

Position and Adoption Speed Justification: Commercial-scale production environments are not likely candidates for 3DP outside of “boutique” offerings (custom athletic shoes, etc.). These operations will continue to be challenged to change from existing methods for finished goods or intermediaries until 3DP can demonstrate a positive impact on total cost of ownership and productivity. However, we expect a bump in popularity in the postpandemic world where cost concerns may be overruled by safety concerns and supply chain disruption. Manufacturers may look to overcome these challenges with smaller, focused manufacturing sites that leverage 3DP.

Discrete industries have been the main adopters of 3DP for producing intermediates or finished goods. Here, use cases for cost and time reductions are expanding beyond prototypes to component production (especially the ability to manufacture innovative components that cannot be produced by traditional manufacturing methods). Process manufacturers have seen benefit in using 3DP for maintenance parts and spares, which helps to minimize production downtime. We have seen manufacturers move from the pilot phase to applying 3DP where it makes sense, the same way that they would apply the use of other tools in their manufacturing arsenal. This is a clear sign of a maturing technology, as the hype begins to recede and the benefits accrue.

User Advice: We recommend:

- Identifying, during product planning and design phases, whether 3DP or traditional manufacturing processes should be considered. There will be opportunities for designing parts that have a level of complexity that would preclude the use of traditional manufacturing, but will provide demonstrable benefit to the end product. These will be natural candidates for 3DP (for example, parts with high strength-to-weight ratio for aerospace applications).
- When estimating the cost and time to 3D print products, the cost does not include just material costs, costs of the 3D printer. It must include changes positioning/orientation of the parts during the 3D process. Also, parts need to be finished (grinded, polished, etc.). Also, the cost of maintaining the 3D printers need to be considered.

- Identifying to what degree 3DP can be integrated into the existing processes (PLM, SCM) by applying criteria such as size/complexity of 3D printed items, required raw materials, material handling constraints, energy consumption and software/hardware integration. In addition, most efficient manufacturing might not just be 3D printing — It could be hybrid manufacturing — using combinations of 3D printing and machining operations (milling, drilling, etc.).
- Supply chain and IT leaders may want to support 3DP integration with end-to-end supply chain to meet specialized demand in a timely manner to ensure on-time and on-budget delivery. For that reason, 3DP may be beneficial for finishing products close to customers, including outsourcing/3DP service bureaus, etc.

Business Impact: Understand the following impacts of 3DP on manufacturing operations:

- **Risk: Medium —** IP protection is required and experimentation is needed to identify the product lines and production styles for which 3DPs are most suitable. Examine whether co-development with suppliers and 3D print service bureaus can ensure reliability of supply and materials.
- **Technology intensity: Medium —** Structural integrity is a massive factor when considering quality over a product's life cycle. Investment in libraries to maintain geometric product representations could be needed.
- **Organization change: Low —** In the short term, roles and job descriptions do not change.
- **Process change: High —** Process change will be high in areas that adopt 3DP, as it can remove steps in bringing a product to market. It may change processes spanning manufacturing network design and logistics networks and/or expand into material sourcing and supplier management. Extensive testing to ensure consistent, repeatable quality and high part performance must be conducted before parts are put into production.
- **Competitive value: High —** Improved cost position, higher design reuse, faster product launch and introduction, and better aftermarket services will improve competitive value.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: 3D Systems; Azoth Analytics; Carbon; Dassault Systèmes; EnvisionTEC; SAP; Siemens Digital Industries Software; Stratasys; Ultimaker

Recommended Reading: "Supply Chain 2029: Disruptions Impacting Future Innovation"

"Top 10 Strategic Technology Trends for Manufacturing Industries: 3D Printing"

Operational Technology Security

Analysis By: Ruggero Contu

Definition: Operational technology (OT) security is the practice of protecting critical production and operation systems and services in asset-centric enterprises. OT security addresses industrial automation and control as well as other nonindustrial use cases where physical state changes depending upon secure, safe and reliable function. It also addresses the impact of using IT, IoT and physical security technology and practice when doing so. OT security is part of comprehensive digital security for digital transformation.

Position and Adoption Speed Justification: OT security technologies provide controls to secure OT environments, with the aim to preserve reliability and safety of production and operations environments. Established international standards, such as IEC 62443, European NIS, NIST 800 Series guidance frameworks, among others, provide product and service providers with direction related to function with vertical specific requirements that the OT security market is starting to address.

The OT security market consists of IT security companies that have extended capabilities of existing solutions to address specific OT functional differences and requirements. They also extended capabilities to address specific OT system providers adding security controls to their OT platform offerings and specialist OT security companies that have come to market to address specific OT-related security needs. Recent offerings address industrial IoT (IIoT) requirements as well.

Obstacles in OT security remain in coverage across all verticals and all major OT systems. They also address legacy OT system requirements, keep pace with regulatory requirements and changes to those requirements, provide cultural and organizational challenges in IT/OT integration, and provide scalability and support globally. OT security providers are making progress and expanding market presence (as 2020's Hype Cycle shows) as a result of improved maturity on the buyer side. A selected number of products are entering a phase of significant adoption. IIoT security technologies are leading future evolution with less expensive offerings, more extensive data collection and flexible command functionality.

User Advice: Security and risk managers should:

- Pursue a cyber-physical approach to achieve an IT/OT/IoT alignment and integration strategy for digital security that underscores governance, strategy and planning as a more centralized process reporting, toward an adaptive security approach.
- Accelerate OT security assessments with reputable and specialist consulting firms to assist in finding risks and gaps to be addressed by the security controls and infrastructure, and implement skills training and awareness schemes for converging IT and OT where possible.
- Map OT leading performance indicators against IT/OT leading risk indicators to write security policies consistent with maintaining and improving performance.
- Apply OT security controls based on digital security policies across OT infrastructure where needed.
- Build repeatable processes for service portfolio management to manage the growing security service portfolio supplementing in-house OT security systems.

- Develop coordination in the OT supply chain to assess partner security controls affecting your organization.
- Focus early infrastructure purchasing on asset discovery, monitoring and reporting, anomaly and incident detection and response, vulnerability management, access control, endpoint security and network segmentation.
- Focus on organizational and cultural challenges by restructuring as required and establishing complete communication and awareness programs between IT and OT.
- Apply pressure on equipment vendors to ensure that their (future) systems are secure by design.
- Apply defense-in-depth strategies to OT security.

Business Impact: OT security is of major relevance to asset-centric organizations such as those considered to be part of national critical infrastructure (for example, energy and utilities, transportation, oil and gas, manufacturing, and natural resources) and other general industrial verticals. It is also found in commercial markets in areas such as building automation and facilities management, healthcare, and retail. OT security is also useful in addressing specific engineering needs for protecting real-time, event-driven systems that have high impact on safety of people and environments. As such, adoption rates for OT security solutions have risen year over year as understanding and market availability have provided options for organizations.

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: Barracuda; Cisco; Claroty; Forescout Technologies; IBM; Kaspersky; Microsoft; Nozomi Networks; PAS; Radiflow

Recommended Reading: “Competitive Landscape: Operational Technology Security”

“Secure Your OT With Basic Security Hygiene”

“OT Security Best Practices”

“Market Guide for Operational Technology Security”

“How to Develop a Security Vision and Strategy for Cyber-Physical Systems”

“Market Insight: Act Before Convergence Kills Your Stand-Alone OT/IoT Security Product Solution”

“Market Trends: IoT Edge Device Security, 2020”

Climbing the Slope

Asset Performance Management

Analysis By: Nicole Foust; Kristian Steenstrup

Definition: Asset performance management (APM) comprises software tools and applications for optimizing availability of operational assets (such as plant, equipment and infrastructure) essential to the operation of an enterprise. It uses data capture, integration, visualization and analytics to improve operations, maintenance timing, and maintenance and inspection activities to perform on mission-critical assets. APM includes the concepts of asset strategy and risk management, predictive forecasting and reliability-centered maintenance.

Position and Adoption Speed Justification: APM has become an important core competency for asset-intensive and asset-centric organizations. Realizing the business can move beyond the key use case of equipment reliability, organizations are leveraging APM to improve overall business operations. Innovation in enabling technologies such as cloud, IoT and AI/ML are widening the scope and decreasing the deployment cost, aiding more awareness and use of APM. The potential of reduced maintenance cost and downtime, coupled with higher levels of operational reliability is attracting other industries, however, all are progressing at a varied pace. Those that depend significantly on availability of their assets, such as manufacturing, utilities and natural resources industries, tend to be further along in their asset management strategy, and usually invest more heavily in APM. Other industries that rely on physical assets to some degree, such as retail and public sector, are beginning to embark on this journey but may not invest as heavily in APM solutions.

User Advice: Asset-intensive industries' CIOs seeking the next level of asset performance improvement should deploy APM. However, organizations should recognize that APM is characterized by a variety of approaches, including analyzing performance history to develop databased maintenance strategies; using advanced analytics to detect patterns and predict equipment failure; and in some instances, simply using visualization of real-time operating and condition data to make better decisions.

Assess the maturity of your enterprise asset management (EAM) system and have a sustainable integration plan with your APM before investing in APM; this will ensure a solid foundation for advancing your asset management strategies. APM ideally follows the deployment of updated and sometimes the need to consolidate disparate EAM software. Although newer EAM products include APM capabilities, CIOs should not expect to get all APM capabilities from the EAM vendors themselves. While some EAM vendors continue investments in this area, most can only achieve support of a basic maintenance activities which includes condition based maintenance. This means that, in practice, third-party APM products may need to be interfaced into EAM.

Organizations realize the need for a combination of asset maintenance strategies to support a variety of asset types and situations across the business through a toolbox approach. Most APM vendors do not offer all levels of APM maintenance strategies, across all industries and asset types. Thus organizations may need more than one APM product, depending on the complexity of their

businesses, the types of assets and their asset maintenance goals. (See “Mapping a Route to Asset Management and Reliability.”)

OT, which is extended and augmented by the IoT, is the source of data concerning a physical asset. Asset maintenance capabilities will need to source data from the Internet of Things (IoT) and operational technology (OT) systems. Therefore, CIOs should ensure compatibility with the technical and process needs of reliability systems by getting involved in the planning of IoT monitoring of plants and equipment. Integration of APM with asset investment planning (AIP) tools and EAM is common in order to include data on asset condition, maintenance costs, criticality, budgets and risks, and then analyze it to produce capital investment plans over extended time. AIP is designed to support both short- and long-term capital investment decisions, integration with APM can be used to drive better forecasting.

Source good data — that is, historical service data and operational data — is a necessary condition for successful APM projects. Therefore, organizations looking to invest in APM should also expect to make investments in information management infrastructure to capture operational data where it doesn’t exist today. APM leverages the convergence of IT and operational technology (OT), and will require resources familiar with both worlds’ data structures and communication conventions. In some instances, companies looking at APM projects will benefit from cloud-based approaches to data sharing and multiparty collaboration.

Business Impact: APM is an important investment area for asset-intensive industries, including manufacturing, mining, oil and gas, transportation and utilities. Successful APM deployments can deliver measurable improvements in availability, as well as reduce maintenance and inventory carrying costs. Most APM projects are executed on the premise that data-driven decisions will improve equipment reliability and, therefore, reduce operational risk. Benefits such as improved uptime and cost savings can be substantial, typically delivering benefits measured in millions of dollars per year.

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: ABB; AspenTech; AVEVA; Bentley Systems; GE Digital; IBM; SAP; SAS; Siemens; Uptake

Recommended Reading: “Best Practices for Choosing an Asset Management System Integrator”

“Market Guide for Asset Performance Management Software”

“Financially Optimized Maintenance Planning Using Asset Performance Management”

“Mapping a Route to Asset Management and Reliability”

“Optimize Utility Capital Expenditures With Asset Investment Planning Solutions”

"Magic Quadrant for Enterprise Asset Management Software"

Digital Supply Chain Strategy

Analysis By: Michael Burkett

Definition: A digital supply chain strategy prepares the supply chain to create a short- and long-term vision that aligns stakeholders behind an integrated set of principles, digital-enabled capabilities and investments. The strategy defines a supply chain digital roadmap that supports the ambitions of their enterprise while balancing both transformation and optimization initiatives.

Position and Adoption Speed Justification: Digital supply chain strategy is climbing the slope with nearly half of companies aligning with the digital ambitions of their enterprise. Eighty-two percent of executives say they have a management initiative or transformation program underway to make the business more digital. (See "2019 CEO Survey: The Year of Challenged Growth.") Nearly half of supply chain organizations have actively begun to define, are implementing, or have already implemented a digital supply chain roadmap. Long-term vision remains a challenge where (42%) of survey respondents planning or actively implementing digital supply chain roadmaps define a time horizon of only one to three years for their roadmaps. Alignment with executive business plans is another gap where only 49% indicate their digital supply chain strategic planning process is primarily driven by an executive-level strategic business planning process. (See "Supply Chain Brief: Compare the Progress of Your Digital Supply Chain Roadmap.")

User Advice: The chief supply chain officer (CSCO) and supply chain leaders responsible for strategy should become knowledgeable about their enterprise's digital business ambitions. They should ensure their digital supply chain strategy enables that ambition while optimizing and transforming the supply chain operating model.

These supply chain leaders should:

- Engage the executive team to develop a vision of the enterprise digital business ambition. Take the lead in driving this if others are not.
- Communicate to all stakeholders the digital supply chain vision and its value to both top and bottom-line business goals.
- Develop a cross-functional digital workforce and the IT skills to architect a digital supply chain strategy and roadmap.
- Design the digital supply chain roadmap to support future business scenarios by prioritizing a mix of digital initiatives that simultaneously optimize and transform current capabilities.
- Implement a governance process that aligns digital supply chain to business goals and then ensures execution toward the long-term vision.
- Prepare the supply chain now to fulfill the promise of your company's digital business ambition.

Business Impact: Digital supply chain opportunities will extend beyond the short-term benefits of optimizing existing operating processes. The greatest impact will occur when companies exploit

digital technologies and supporting capabilities to transform their business by creating robust new digital business models.

One example is L'Oréal's Operations 4.0, which focuses on new business and consumer trends to shorten time to market. It has deployed flexible and agile solutions in factories to cope with highly volatile markets, accelerating the development of personalization solutions at both point of sale and through e-commerce. (See "The Gartner Supply Chain Top 25 for 2019.")

The CSCO and supply chain leaders responsible for strategy will see digital optimization and transformation impact their supply chains in new ways, including:

- The enablement of new digital business models
- Increased innovation cycles and demand variability, as new solutions target granular market segments
- Enhanced supply chain visibility and control garnered from billions of connected devices across supply chain nodes
- Deep insights from analytics applied to big data generated from a variety of new sources across partner ecosystems
- Smart machines participating in decision making and negotiations with customers and suppliers
- Smart robots and AGVs supporting lights-out operations
- Cybersecurity added to supply chain risk profiles, as supply chain information is exposed to the internet

Benefit Rating: Transformational

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: Cisco; GE; Intel; Schneider Electric

Recommended Reading: "Driving Digital Business Transformation for Industry Leadership: A Supply Chain Perspective"

"Converging the Physical and Digital Supply Chains: A Gartner Trend Insight Report"

"Supply Chain Brief: Compare the Progress of Your Digital Supply Chain Roadmap"

"6 Ways to Earn New Digital Revenue: A Supply Chain Perspective"

"Ignition Guide to Creating a Digital Supply Chain Roadmap"

"Data Is the Future of Supply Chain: Build a Data Foundation"

"Jump-Starting Your Digital Roadmap"

"Selecting the Most Appropriate Digital Roadmap for Your Logistics Organization"

Manufacturing Network Design

Analysis By: Kamala Raman

Definition: Manufacturing network design is about optimizing locations, capacity and product flow paths for an efficient landed cost structure. It should include considerations for internal production versus outsourcing. Large global disruptions and the push for agility are requiring diversification of and flexibility in network capacity. Manufacturing leadership in leading organizations views the network as a collection of capabilities rather than a collection of sites to find the right balance between cost efficiency and resilience.

Position and Adoption Speed Justification: Key trends exponentially driving up the option value of reviewing and redesigning manufacturing networks include:

- Companies desiring proximity to their demand centers or supplier ecosystems for agility and resilience are exploring a decentralized approach to manufacturing using multisourcing or regional sourcing models.
- Trade-offs between financial benefits (tax credits to incentivize local manufacturing) and geographic or political risk that have driven facility location decisions have now been amplified by a shift away from friction-free global trade in many countries.
- Large-scale disruptions driven by the pandemic and an increase in protectionist trade policies are pushing companies to view a diversified production footprint as a cost of doing business rather than an inefficiency.
- The role of automation that changes cost structures. This includes multimode lines, hyperflexibility with equipment, lot sizes and labor, and mobile factories.
- Evolving technology (e.g., IIoT; 3D printing; configurable robots that overcome inflexible automation; platform, product or plant harmonization; human machine collaboration models to sense and respond to shifting demand patterns) that drives quality and productivity improvements.
- Cost advantages especially with labor shifting away from established ecosystems in China to other locations.
- The 100x increase in computational power driven by 5G in operational and analytical technologies, which will enable real-time decision making.

User Advice: Optimize the network with input from design, manufacturing, sourcing, logistics, finance, legal and trade compliance. Define strategic objectives and identify how key suppliers/ partners fit in with these objectives. Identify business constraints, create an optimized design and analyze trade-offs between flexibility to switch capacity across the network, cost and resilience for the network options. Also test sensitivity of the new design to changes in key cost variables.

Balance factor costs of producing at each location against total landed costs, and evaluate the advantages of individual locations, country risk profiles, and type and local availability of resources

required. Explore cost-to-serve models with suppliers, customers and logistics partners to tailor service levels for customer segments, assess the availability of and access to capacity and determine where to decouple production or packaging activities for increased flexibility.

Constraints may be by site (capacity limits, contractual need to stay open), capability (manufacturing processes), resiliency (minimum number of sources or production sites), current and planned product portfolio, and regulatory/tax needs. Make-versus-buy-type decisions should include sourcing raw materials and components but also include purchasing manufacturing services. Complexity of implementation, market perception of social and environmental impact, and brand value of the ability to mitigate disruptions may also factor into the decision making process.

The importance of manufacturing network design has significantly increased due to the disruptions of the last few years. However, the complexity of modifying processes and being disciplined to holistically view conflicting objectives of cost efficiency and resilience might mean that this capability will take longer than a couple of years to mature.

Business Impact: Consider the following impact areas:

- **Risk: Medium —** Visibility to the network including products and their costs, production processes, the role of partners, network resources and their interdependencies is needed to create a realistic network model.
- **Technology intensity: High —** Network modeling tools will enable decision making on optimal placement of capacity and product flow design. Robust planning systems may enable vertical and horizontal alignment of planning decisions.
- **Organization change: High —** Changing network capacity or product flows will impact business processes. Successful usage of smart factory technologies or analytics may require upskilling of frontline labor. Business process experts are required to build and create network models to understand trade-offs.
- **Competitive value: High —** Growing digital manufacturing capabilities and the higher profile for resilience and agility bring an increase in opportunities. Providing the ability to flexibly move or modify capacity across the network amid high uncertainty by accommodating changes in demand or supply patterns, lead times or cost factors in product flow optimization can lend a strong competitive advantage.

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: anyLogistix; AIMMS; IBM; LLamasoft; River Logic

Recommended Reading: “Enabling a Manufacturing Ecosystem Needs a Long-Term View”

“Evaluate These Factors in a Global Manufacturing Site Selection Activity”

“Top 10 Plausible Directions Resulting From COVID-19”

“Industrial Supply Chainnovator Finalists 2020: Enabling Analytics at Scale”

“Weathering the Storm: Supply Chain Resilience in an Age of Disruption”

“Presenting Your Strategy for Navigating Tariff Uncertainty to the C-Suite”

“How to Use Manufacturing Analytics for Intelligent Decision Making”

“Top Reasons Supply Chain Design Initiatives Fail and What to Do About It”

Synchronized BOMs

Analysis By: Marc Halpern

Definition: Practices and technologies for synchronized bills of materials (BOMs) associate and update equivalent items from different BOMs, such as engineering, manufacturing, sales/marketing and service BOMs, while allowing each of the BOMs to be labeled and structured differently.

Position and Adoption Speed Justification:

BOM management has often been perceived as a technical issue, hidden from executive visibility. However, BOM management improves efficiency and effectiveness of design through service activities throughout the organization. Commercial software vendors have made significant progress in delivering synchronized BOM capabilities. The technology offerings mostly focus on leading-edge manufacturers of complex engineered systems, such as transportation vehicles, aircrafts, defense systems, heavy machinery, consumer electronics, complex healthcare equipment and other electromechanical systems. Leveraging advanced technologies, some manufacturers have made progress using semantic search to make synchronization more efficient. Some easy-to-use cloud-native solutions are also emerging. Adoption is accelerating, although it remains low compared with demand. However, recent cloud-native offerings bring synchronized BOMs to small-to-midsize manufacturers. End users have seen the greatest progress synchronizing engineering BOMs and manufacturing BOMs. Now the focus also includes:

- Aftermarket services, such as maintenance, repair and overhaul (MRO)
- Greater penetration throughout the supply chain, linking second and third tier suppliers to original equipment manufacturers.

Best practices for synchronizing BOMs, based on the experience of practitioners, are also advancing. For example, practitioners are learning techniques to simplify BOMs and even eliminating engineering BOMs. At the same time, they’re aligning the structure of service BOMs to master BOM structures that support manufacturing operations.

User Advice: Manufacturers are learning that planning for BOM synchronization is as important as the technology that supports it. The discussions leading to consensus can be highly contentious, but that might be necessary to achieve a constructive solution. Examples of the primary best practices being identified include:

BOM structure must reflect manufacturing processes as closely as possible.

- "Intelligent" naming for BOM items should be dropped and replaced with "nonintelligent" item names that computers can track and link to other content. Intelligent naming refers to structured naming conventions that describe the BOM item. That practice predates computers and leads to complexity and mistakes as business conditions change. Nonintelligent names are random strings of characters that computers can manage and link the BOM item to other relevant content.
- BOMs should be structured with as few levels as possible to improve transparency across the supply chain.
- BOMs should be modularized based on features, and not by the combinations of features that create individual SKUs. This approach can reduce the data management demands by an order of magnitude.

Stakeholders at these manufacturers must be ready to work consultatively with software vendors specialists from service providers as they reach internal consensus. The stakeholders should be prepared to invest extensively in data architecture, master data management techniques, and training and cultivating talent through implementation experience. Where appropriate, manufacturers should ensure that synchronized BOM capabilities can manage software, firmware and embedded application components as a part of products and systems.

Business Impact: Manufacturers and service organizations investing early anticipate that successfully deploying synchronized BOM strategies increases the efficiency of using BOM content throughout the product/service life cycle. This shortens the time from design completion to product manufacturing while reducing cost and enhancing product quality. Accurate BOM synchronization reduces scrap, rework, inventory shortages, and expedited or imperfect customer orders, and it helps ensure continuity of supply. In addition, BOM synchronization is key to enabling efficient traceability and to tracking the genealogy of the complex assemblies required in regulated manufacturing industries.

Areas of impact include the following:

- **Risk: Medium.** Technology and best practices for synchronizing BOMs are commercialized by multiple vendors. Although the number of technical options grow, manufacturers still struggle with how to implement this. Success requires cooperation among a core team of stakeholders representing engineering, manufacturing, procurement and sourcing.
- **Organization change: Medium.** Synchronizing BOMs eliminates manual work. The roles it impacts most — engineering, manufacturing, procurement and service — remain the same. However, the relationships among those roles should change; each of these roles has a need to review, understand and provide feedback on requested BOM changes.
- **Process change: High.** When BOM synchronization works properly, manufacturers can eliminate steps in manual BOM translation processes. However, it might require changes to process steps to ensure that the business roles and attributes associated with each item in a BOM are comprehensive.

- **Competitive value: High.** When properly working, synchronized BOM technology will reduce errors in product data and streamline design-to-manufacturing workflows substantially.
- **Industry disruption: High.** Synchronized BOM technology will accelerate the product time to market to such a degree that the manufacturers adopting it will be able to introduce products noticeably faster than competitors — and at lower costs.

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: Aras; Arena; Dassault Systèmes; iBASEt; OpenBOM; Proplanner; Siemens

Recommended Reading: "Manufacturing Process Management Is Essential to Digital Thread"

"Toolkit: Defining the Functional Requirements for Manufacturing System Selection"

"Toolkit: Assess Your PLM Digital Platform Maturity in Discrete Manufacturing"

"How to Deploy Manufacturing Process Management for Digital Manufacturing"

"Best Practices in Bills-of-Material and Recipe Management"

Track and Trace and Serialization

Analysis By: Andrew Stevens

Definition: Track-and-trace and serialization solutions are comprehensive software (and sometimes hardware) solution stacks .They map closely to regulatory requirements for anti-counterfeiting and span manufacturing through to final use of the product with the patient. At their core, these solutions focus on data configuration and capture, generation of serial numbers (bar codes) and enabling interoperable exchange of key datasets across networks of healthcare-value-chain stakeholders, governance bodies and regulatory agencies.

Position and Adoption Speed Justification: Anti-counterfeiting regulations for track and trace and serialization continue to develop. Most companies have already run pilots, small scale implementations, or are already in production .Solution stacks have evolved in areas such as serial number generation, data governance and data capture capabilities. Data is frequently integrated and communicated at the enterprise, data management and physical transaction levels. It is anticipated mature solutions targeting compliance mandates are only three to five years out although this could be impacted by anticipated waves of further regulations. Gartner expects clients will make continued investments in track-and-trace capabilities, since most midsize and large manufacturers have products moving across international borders. More streamlined solutions for startup biotech will also shape further solution development. Some technology solutions are now extending value propositions to deliver digital, networking and Internet of Things (IoT) enablement with post-compliance value propositions building out from foundational core serialization

infrastructure For this, track-and-trace and serialization capabilities are in the Slope of Enlightenment phase and will reach the plateau in the next two to five years.

User Advice: The need for track-and-trace and serialization solutions to work across multiple enterprises will require companies to revisit their end-to-end supply chain IT system architecture and interconnectivity across trading partners, healthcare networks, patients and consumers. Supplier networks may also come into scope, especially in other industries such a food and beverage and consumer products.

Companies should assess the key differentiators and enablers of track-and-trace and serialization solutions in areas such as:

- Enterprise level for global integration of common datasets, emerging standards and links to central repositories.
- Interoperable communication networks, including end-consumer connectivity.
- Data management solutions for governance, aggregation, randomization, data storage and encryption.
- Operational-line level for material flow, automation, scanning, routing, and data capture through vision systems and camera technology.
- Final-mile logistics and customer fulfillment aligned to specific regulatory or trade management mandates and specific logistics or network communications infrastructures.
- The data configuration, security and capacity capabilities of the bar codes such as 2D data matrix and RFID, and the value realization opportunities for that data.
- Strategic collaborative initiatives and deployments focused on risk mitigation, especially for counterfeit or falsified products.

Business Impact: Solidifying protocols and systems for track and trace and serialization will aid in decreasing overall enterprise and business risks. Other areas and degree of impact are:

- **Risk: High —** Failure to act for compliance or counterfeiting incidences can result in detrimental brand performance.
- **Strategic policy change: Medium —** It is variable, based on localized compliance and regulatory considerations, and other externalities.
- **Organization change: Medium —** A focus on end-to-end capabilities will change collaborative models across an increasing number of healthcare value chain stakeholders.
- **Culture change: High —** New thinking and approaches are additive to existing customer-centricity focuses. Change management for technical and regulatory serialization compliance across partners will become critical. Business leaders need to scope serialization potential beyond compliance-based activity.

- **Process change: Medium —** It requires redefining business process and information flows inside the organization and with trading partners, healthcare providers and customers.
- **Competitive value: High —** Compliance comes first, but mandates will taper off in the future. Future value will be realized through increased operational and transactional efficiencies as well as interoperable communication of existing and new types of data across stakeholders. Other opportunities in industry sectors such as food and beverage and consumer products could influence cadence.

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: Adents; Advanco; Covectra; Navitas Life Sciences; SAP; SEA Vision; TraceLink; Vimachem

Recommended Reading: "Market Guide for Track-and-Trace and Serialization Providers in Life Sciences and Healthcare Value Chain"

"Toolkit: Vendor Selection for Track-and-Trace and Serialization Providers in Life Sciences and the Healthcare Value Chain"

"An Assessment of Global Regulations Across the Healthcare Value Chain Requiring Track and Trace With Serialization"

"An Assessment of Global Regulations Across the Healthcare Value Chain Requiring Product Authentication and/or Verification With Serialization"

"Serialization Regulatory Outlook for Anticounterfeiting and Fake Medicines Across the Healthcare Value Chain"

Corporate Production Systems

Analysis By: Simon Jacobson

Definition: Corporate production systems contain a harmonized set of common, core practices that synchronize the activities and behaviors across people, processes and technologies. This provides a structure for reliability of product supply in manufacturing operations.

Position and Adoption Speed Justification: Corporate production systems are a core competency, mature in concept and have universal applicability to any manufacturer regardless of industry or size. Manufacturers have long relied on production systems steeped in lean, continuous improvement and performance standards to deliver cost savings and efficiency gains or uncover new improvement opportunities in and across a network of factories.

The majority of what is in place today reflects how businesses have defined "transactional" goals and objectives that emphasize cost savings and efficiency gains at a site or function level with

visible and quantifiable results. Those goals and objectives and performance measures often focus on asset utilization, variable cost reductions, quality improvements and some service-level metrics. It is this core nature and conventional application of production systems alone that accelerates the concept toward the plateau in 2020.

In 2021, it will be off the Hype Cycle in and replaced by the next generation of production systems, Digital Operating Systems, which has entered the Hype Cycle this year. This new approach to production systems minimizes the weakness in established Toyota Production System (TPS), total quality management (TQM), world-class manufacturing (WCM) and similar lean-based systems. This does so by marrying technologies and digital dexterity with the preexisting, integrated application of manufacturing principles, practices and leadership behaviors that, when fully embraced, will systemically drive agility, sustainable performance improvement and competitive advantage from manufacturing operations.

User Advice: To maximize the use of corporate production systems:

- View a corporate production system and the supporting lean methodologies as a means to stabilize the performance of a site or production unit. Increasing efficiency can drive bottom-line improvements while streamlining processes.
- Use a stage-based maturity approach to define the iterative progress and stage-based achievements to phase the deployment of your corporate production system.
- Recognize the need for a formalized communication plan and measures to hold stakeholders accountable. Traditionally, this has been something left in the hands of functional experts.
- Deliberately align people and process investments with technology for codification of common processes, consistent forms of measurement, open collaboration and transparency of information in and across production units. This way, all stakeholders for process improvement and refinement can remain informed.

Business Impact: Companies that treat manufacturing operations as a brand asset and develop a codified system of standard best practices that evolve based on performance-based maturity, can expect the following impacts:

- **Risk: Low** — While proven in measurable benefits, the failure to align manufacturing and supply chain goals and/or build a culture around continuous improvement can be detrimental because improvements will not stick.
- **Technology intensity: Low** — Sensor- and dashboard-based projects for short interval control, eliminating unplanned downtime and managing kaizens eliminate the costs of managing multiple systems while streamlining and replicating projects and performance standards.
- **Organization change: High** — This is a cultural shift and employee engagement is not the challenge — it's empowering operators to own the system and leverage the tools for ongoing performance improvements that need attention while keeping leadership focused and engaged.
- **Process change: High** — Without removing waste to improve processes, all you will do is spend money.

- **Competitive value: Medium** — The end result of a systemic approach to reducing costs and complexity is improved reliability of individual lines and production units.

Benefit Rating: Moderate

Market Penetration: More than 50% of target audience

Maturity: Mature mainstream

Sample Vendors: Competitive Capabilities International; EFESO Consulting; EY; Leading2Lean; Porsche Consulting

Recommended Reading: "Supply Chain Brief: Modernize Production Systems to Unlock Manufacturing Operations and Support Agility Imperatives"

"Production Systems 2025: Rewriting the Working Systems for Industry 4.0"

"Understanding the 5 Stages of Gartner's Maturity Model for Manufacturing Operations"

Overall Equipment Effectiveness (OEE)

Analysis By: Simon Jacobson

Definition: Overall equipment effectiveness (OEE) is a manufacturing performance metric with roots in lean manufacturing and total productive maintenance (TPM) programs. It is the measurement calculated as the cross-product of manufacturing asset availability (as a percentage of total time) with production (as a percentage of target) and product quality (again, as a percentage).

Position and Adoption Speed Justification: Driving OEE closer to the plateau in 2020 are the large population of manufacturing leaders who see the metric for what it is: one of many metrics to describe the health of manufacturing operations. OEE is an anchor metric for local, site-specific performance improvements in manufacturing operations. It is germane to many different continuous improvement initiatives. OEE is often introduced (or reintroduced) to stabilize and create baselines of line performance or individual production units to compare achievement of target relative to intended capacity during the periods they are scheduled to run. Achieving a level of 80% to 85% is generally considered exceptional, and a substantial number of manufacturers still aspire to that level of performance.

Organizations are looking beyond OEE as the ultimate metric and are developing a broader portfolio to describe the performance of manufacturing as part of the end-to-end supply chain. They have realized that OEE is a metric that loses gravity the further away from the factory it gets. A plant might be operating at 80% OEE, but that's not an indicator of manufacturing's impact on overall supply chain performance. For example, products produced could be misaligned with the forecast or have quality issues that negatively impact customer satisfaction. Broad supply chain agility objectives, targeted designs for factory flexibility or customized products all require a wider view of manufacturing's performance as part of the end-to-end supply chain. In some cases, the trade-offs between service levels, cost and inventory might require a de-emphasis of OEE.

User Advice: Manufacturing operations leaders responsible for strategy and performance seeking to maximize the potential of OEE should:

- Use OEE at a site or unit level. Introduce (or reintroduce) it to stabilize and baseline production performance by tracking how consistently products are produced at designated run rates by shift and item level.
- Ensure the calculation of OEE is consistent and, therefore, standard across sites. This is essential for future site-to-site achievement of target comparisons.
- De-emphasize any dependency on OEE over time by examining its interdependencies and touchpoints with other metrics used to describe manufacturing's contribution to the overall health of the supply chain.

Business Impact: OEE is a proven metric for stabilizing processes, reducing costs and improving efficiency, and adds greater value when part of a wider portfolio of metrics:

- **Risk: Low —** Letting it be a euphemism for and sole measure of "manufacturing performance" is a trap. OEE doesn't tell the entire story needed for ongoing improvement.
- **Technology intensity: Low —** Technology support is ubiquitous. It is rare for any technology and services provider serving the factory to not have some OEE dashboard or reporting feature as part of the product portfolio. Organizations with broader performance management/ measurement aptitude do two things: (1) incorporate a wider range of data to model OEE against other KPIs and (2) separate technology from data to ensure those KPIs are represented correctly.
- **Organization change — Medium —** Cultures steeped in lean have familiarity with the metric and understand its benefits and limitations. As OEE is analyzed against other metrics and shared accountabilities emerge, unwinding the mental model could prove arduous.
- **Process change: High —** Understanding causal factors of unplanned downtime and runtimes will impact changeovers, maintenance and production planning. Wider processes, including production planning/scheduling, are impacted as OEE usage is de-emphasized as part of a broader performance management plan.
- **Competitive value: Low —** Line- and unit-level performance will translate into improved efficiencies and cost savings. There also could be identification of excess capacity at a factory level. Agility is accelerated when OEE is married to a set of wider manufacturing metrics (schedule adherence) and supply chain measures (i.e., plant utilization).

Benefit Rating: Moderate

Market Penetration: More than 50% of target audience

Maturity: Mature mainstream

Recommended Reading: "Use the Hierarchy of Manufacturing Metrics to Connect Manufacturing and Supply Chain Performance"

"The Hierarchy of Manufacturing Metrics: Frequently Asked Questions"

Entering the Plateau

Supplier Quality

Analysis By: Bryan Klein

Definition: Supplier quality is a set of processes and procedures to manage suppliers' performance related to product, service and documentation standards outlined by the buyer.

Position and Adoption Speed Justification: Disruptions from digital business and changes in supply network designs and product offerings continue to push more activities (e.g., product testing) upstream into the supply base and other ecosystem partners. This only increases complexity and risk — and continues to elevate the importance of supplier quality.

As a result, supplier quality management is something almost every company conducts to varying degrees. In fact, only 10% of companies lack standardized supplier quality management processes — be that globally, regionally or in a single business unit. While the gap between a company's quality management teams and its sourcing and procurement teams, as well as the overall scope of quality in the supply chain, still needs to be bridged, best practices have emerged.

Existing cost, product and delivery objectives are now augmented by new initiatives for visibility, aligned processes and shared metrics as organizations continue to work on integrating quality with broader strategies for a 360-degree management of supplier performance. Many of these initiatives are supported by projects that have quick, targeted results such as hosting supplier days for level setting rules of engagement, supplier quality risk assessments and comprehensive supplier development programs. These factors push supplier quality further toward the plateau in 2020.

User Advice: We suggest the following:

- Identify current and future impacts of digital business designs (e.g., connected products, outsourced services) on supplier ecosystems to determine how this will impact quality of product and service.
- Use the ROI from initial projects such as those to improve integration and visibility between manufacturing and supply chain processes to build momentum for future scale and investment.
- Broaden the supplier risk-management plan by integrating supplier quality with existing sourcing and procurement processes.
- Globally orchestrate and locally execute the functions and activities for supplier quality by clearly defining accountabilities and linkages that most closely aligns to your end objectives. Add councils, centers of excellence (COEs) or shared services where appropriate.

Business Impact: Robust supplier quality programs feature interconnected people, process and data that go beyond a "compliance" mindset. Digital business ecosystems do this by linking product, service requirements and regulations, and also enable faster response to supplier-based

product, service and recall issues, into differentiation for an organization — with the following impacts:

- **Risk: High —** Failures impact public perception and brand value, hinder responsiveness and inflate compliance, working capital and other cost elements. It directly factors into each impact listed below.
- **Technology intensity: High —** Growing volumes of quality-related transactions and performance data generated through new and existing IoT ecosystems require solutions capable of leveraging different information streams to manage product performance, rate suppliers, manage costs (including cost of poor quality [COPQ]), identify discrepancies in (upstream) production and draw correlations with aftermarket services.
- **Organization change: High —** Establishing governance requires destruction and integration of silos (across manufacturing, procurement, quality and other supply chain functions) and creation of new responsibilities and job descriptions to lead and manage change as supplier quality becomes an integrated organization.
- **Process change: High —** Improved and changed governance will alter decision-making processes. Additionally, and in concert with increased technology intensity, new levels of automation will emerge and result in changes to supplier auditing, continuous improvement, product testing procedures, specification and BOM changes/costing/compliance, and other SLAs.
- **Competitive value: High —** Building brand reputation based on quality products and services, plus reduction in COPQ, enhanced profitability and competitive advantage are all outcomes. Corporate engagement and functional mastery of quality processes and technology have become essential to competitive positioning in all industry verticals.

Benefit Rating: Moderate

Market Penetration: More than 50% of target audience

Maturity: Mature mainstream

Recommended Reading: "Supplier Quality Management—Activity Map"

"Supplier Quality Management Maturity Self-Assessment"

"Supplier Quality Management Benchmark"

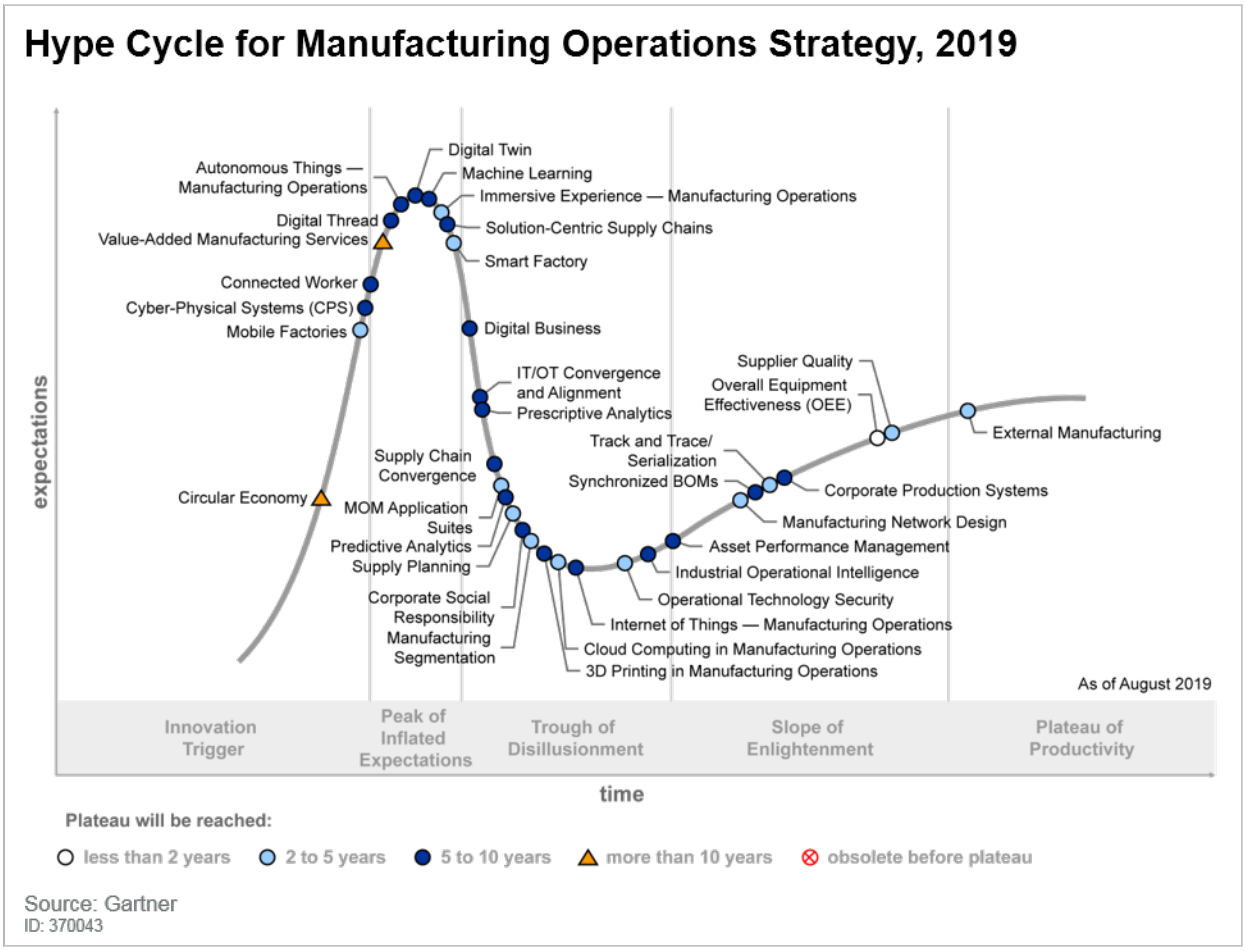
"Supplier Quality Management 2020 Benchmark Report"

"Ignition Guide to Creating a Supplier Quality Risk Assessment"

"Increase Suppliers' Discipline with Change Control Practices"

Appendixes

Figure 3. Hype Cycle for Manufacturing Operations Strategy, 2019



Source: Gartner
ID: 370043

Hype Cycle Phases, Benefit Ratings and Maturity Levels

Table 1. Hype Cycle Phases

Phase	Definition
Innovation Trigger	A breakthrough, public demonstration, product launch or other event generates significant press and industry interest.
Peak of Inflated Expectations	During this phase of overenthusiasm and unrealistic projections, a flurry of well-publicized activity by technology leaders results in some successes, but more failures, as the technology is pushed to its limits. The only enterprises making money are conference organizers and magazine publishers.
Trough of Disillusionment	Because the technology does not live up to its overinflated expectations, it rapidly becomes unfashionable. Media interest wanes, except for a few cautionary tales.
Slope of Enlightenment	Focused experimentation and solid hard work by an increasingly diverse range of organizations lead to a true understanding of the technology's applicability, risks and benefits. Commercial off-the-shelf methodologies and tools ease the development process.
Plateau of Productivity	The real-world benefits of the technology are demonstrated and accepted. Tools and methodologies are increasingly stable as they enter their second and third generations. Growing numbers of organizations feel comfortable with the reduced level of risk; the rapid growth phase of adoption begins. Approximately 20% of the technology's target audience has adopted or is adopting the technology as it enters this phase.
Years to Mainstream Adoption	The time required for the technology to reach the Plateau of Productivity.

Source: Gartner (August 2020)

Table 2. Benefit Ratings

Benefit Rating	Definition
Transformational	Enables new ways of doing business across industries that will result in major shifts in industry dynamics
High	Enables new ways of performing horizontal or vertical processes that will result in significantly increased revenue or cost savings for an enterprise
Moderate	Provides incremental improvements to established processes that will result in increased revenue or cost savings for an enterprise
Low	Slightly improves processes (for example, improved user experience) that will be difficult to translate into increased revenue or cost savings

Source: Gartner (August 2020)

Table 3. Maturity Levels

Maturity Level	Status	Products/Vendors
Embryonic	■ In labs	■ None
Emerging	■ Commercialization by vendors ■ Pilots and deployments by industry leaders	■ First generation ■ High price ■ Much customization
Adolescent	■ Maturing technology capabilities and process understanding ■ Uptake beyond early adopters	■ Second generation ■ Less customization
Early mainstream	■ Proven technology ■ Vendors, technology and adoption rapidly evolving	■ Third generation ■ More out-of-box methodologies
Mature mainstream	■ Robust technology ■ Not much evolution in vendors or technology	■ Several dominant vendors
Legacy	■ Not appropriate for new developments ■ Cost of migration constrains replacement	■ Maintenance revenue focus
Obsolete	■ Rarely used	■ Used/resale market only

Source: Gartner (August 2020)

Gartner Recommended Reading

Some documents may not be available as part of your current Gartner subscription.

Understanding Gartner's Hype Cycles

Evidence

Gartner's 2019 Realization of Industry 4.0 Survey. From April through July 2019, Gartner Supply Chain Research sent invitations to complete an online survey to Gartner clients, community members and to a wider group of practitioners in supply chain and other functions globally. We received 221 completed responses during the survey period for this Realization of Industry 4.0 Survey. We had participants across industries and mostly worked in functions such as supply chain (39%), manufacturing/production (21%), operations (12%), engineering (6%), IT/IS/Technology (5%) and logistics/transport and distribution (5%), etc. 35% of respondents were from North and South America, 44% from EMEA, 20% from Asia and Australia, and others the rest of the world. More than 50% of the participants were at VP/director level or above. 57% of the participants were from $10 billion-plus companies.

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