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SUPPLYCHAIN MANAGEMENT REVIEW

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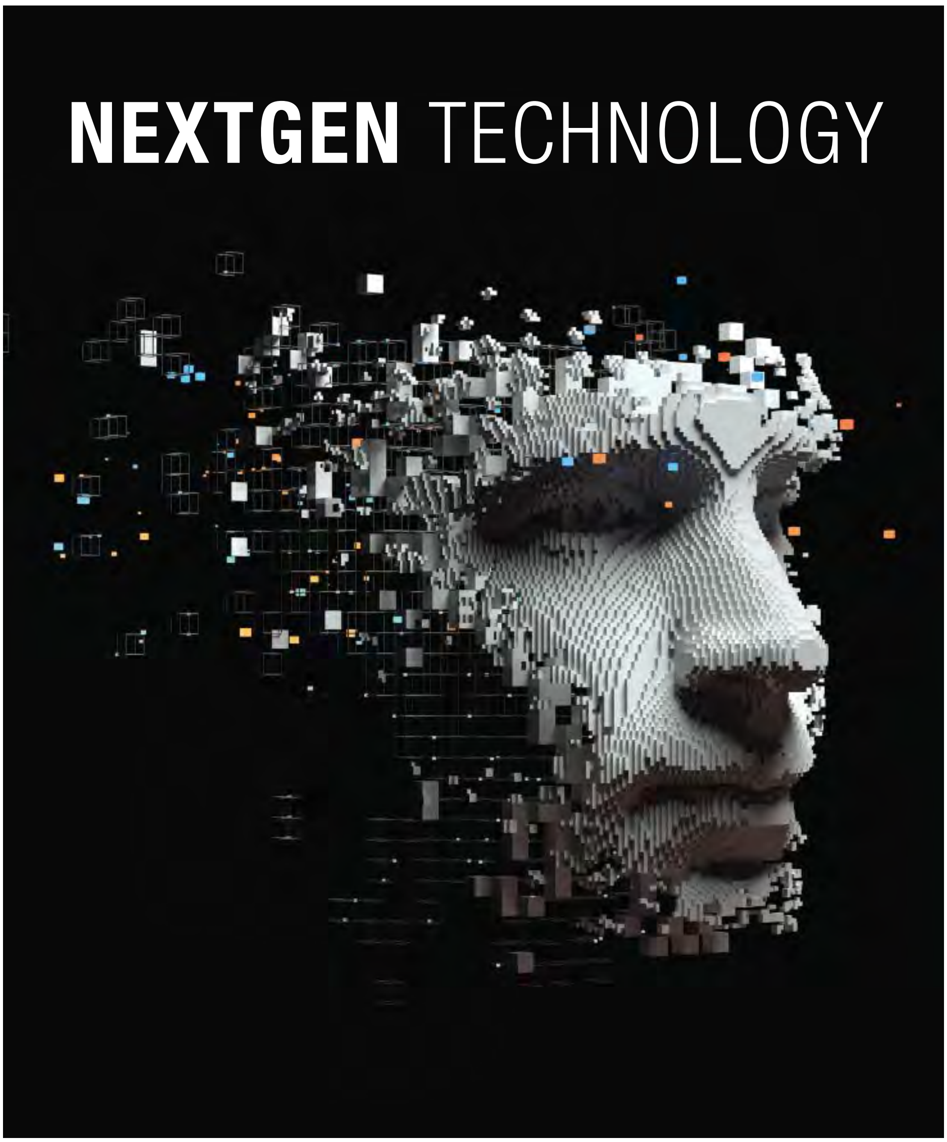

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Are you ready for NextGen technologies?

Bob Trebilcock, Editorial Director
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Just the other day, I had the opportunity to tour one of Amazon's highly automated robotic fulfillment centers. I expected to be dazzled—and I was. But it wasn't because of the automation. While Amazon Robotics is exclusive to Amazon, there any number of goods-to-person picking solutions on the market, including robotic solutions, and well, anyone can buy a Dematic conveyor system and shipping sorter. What was so dazzling were the things you couldn't see: That's Amazon's overall supply chain as described by spokesperson Todd Walker, my tour guide for the morning, and the analytics behind every step in the process. In other words, everything Amazon has learned from shipping billions of packages and then translated into the analytics software developed by the world's leading e-commerce platform. That's Amazon's secret sauce—and it can't be easily replicated.

The tour was a reminder that there's no question that NextGen technologies such as Artificial Intelligence, blockchain, robotics, 3D printing and 5G are going to be the differentiators in tomorrow's supply chain. The question is: Are you ready?

NextGen Technology is the theme of this issue of *SCMR*. We lead off with two views on AI. In the first, our Special Project Editor Gary Forger takes a clear-eyed view of where we really are with AI in the supply chain. That's followed by a four-step approach to putting AI to work in your supply chain from T S Krishnan and Damini Gupta. Next up Infosys' Sylvie Thompson and Gina Sweidan look behind the hype around 5G while Ohio State's Steve DeNunzio discusses the potential for the Physical Internet—an idea whose time may be coming. We round out the issue with articles on disruption, including the role of 3D printing in manufacturing, and robotics, AI, wearables and other technologies in the warehouse of the future.

Relatedly, at our NextGen Supply Chain Conference in Chicago, on April 28, *SCMR* will honor 10 practitioners and solution providers using these technologies that are sure to shape tomorrow's supply chains. This year's winners are: NFI Industries and Tompkins Robotics (Robotics); Lenovo and IBM (Blockchain); Dell Technologies and LeanDNA (Analytics); Reyes Holdings and LevaData (AI); and GE Appliances and JD.com (Digital Transformation). If your company isn't listed above, I encourage you to apply next year. You'll be in good company.

And, if you haven't done so already, I hope you'll register to attend the NextGen Supply Chain Conference, which will be held April 27-29, at the historic Chicago Athletic Association hotel in Chicago. Designed for senior-level supply chain executives—like you—the conference will offer a full breadth of educational sessions and networking opportunities to learn about the emerging technologies that will power tomorrow's supply chains. You can find more information on the conference at nextgensupplychainconference.com.

As always, I look forward to hearing from you—and hope to see you in Chicago in April.

Bob Trebilcock

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 BY LARRY LAPIDE

Rely on AI to make decisions? Yes, but warily

"Before AI can solve the world's problems, it must overcome the challenge of understanding humans—a feat we ourselves won't achieve soon."
— *Matthew Hutson,* Wall Street Journal

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There has been a lot of hype about the future of Artificial Intelligence (AI). It's not the first time around the block for AI, and in the past, it didn't get very far. That leads some people (including me) to wonder: Is now the time that AI will be embraced by corporations to significantly improve business performance? Or, is it "déjà vu all over again?" as the late, great New York Yankee catcher Yogi Berra quipped.

In this column, I'll discuss my views on the usefulness of AI for business decision-making. They may be counter to what you're reading in other articles, but they are colored by having watched the development of AI over the years. They also reflect my experiences as a technologist. Throughout my career, I've taken the position that technology merely enables business process improvement. Computers should be decision support systems (DSSs), but not necessarily make final decisions; those are best made by managers.

Of course, this doesn't take away from the fact that many decisions, especially those without significant consequence, can be made without managerial intervention. Take inventory management, for example. An ABC Pareto analysis can help an inventory manager determine the best-stocked items on which to focus his or her time. "A" items may represent the fewest number of SKUs in stock, but they may also generate the largest share of revenue. Thus, they require a lot of a manager's time to ensure that a computerized inventory management system doesn't skimp on the amount of stock on the shelves. "B" items, meanwhile, represent a larger share of inventory, but less revenue. For those, the inventory manager can let the computer do most of the inventory management and intervene on an exception basis. Lastly are the "C" items that represent the largest number of SKUs, but the smallest share of revenue. A manager can put those on autopilot and let the system do the work, intervening only in a crisis. In this scenario, AI inventory management technology would be most useful for "C" items; but AI is less useful for "B" items and least useful for the all-important "A" items. Those rely on a manager's experience.

A brief history of AI

I've spent most of my career around computers, and for years I've been intrigued by efforts to create systems that can replicate and improve upon human intelligence. IBM, for example, has been researching AI since the 1950s. That work led to the development of a chess-playing computer system known as Deep Blue that beat a reigning world chess champion in 1996; and, more recently, to Watson, a computer system capable of answering questions in natural language. In 2011, Watson beat the two most successful contestants of the TV game show Jeopardy.

In the early years, governments heavily funded AI research. Progress, however, was slow, and by the 1970s, the funding stopped. This led to the "AI winter." Some time later, promising initiatives out of Japan inspired a new round of investment in the space, but progress again was slow. By the late 1980s, disappointed investors withdrew their funding. Fast forward to the beginning of this century, and for a third time (think AI 3.0), interest in AI started to boom once again.

Despite those ups and downs, there has been incremental success. AI has been imbedded into smart TVs and refrigerators and underlies the intelligent software that supports driving a car and flying an airplane. However, I don't believe we have yet seen a game-changing, killer AI app that enables significant business process improvement. Despite IBM's rich history in this space, it has had trouble selling AI products and services.

System-1 versus System-2 thinking

That leads to a question: If now is AI's time, what decision-making role should it play in the supply chain? In one of my business decision-making courses, I used a textbook that discussed two types of cognitive thinking. These are often referred to as "implicit" and "explicit" or by the more neutral "System-1" and "System-2," as coined by the authors Stanovich and West in their seminal article "Individual difference in reasoning: implications for the rationality debate?" published in 2000 in *Behavioral and Brain Sciences*.

The most commonly used type is System-1, in which an untold number of routine and insignificant actions are taken predicated on gut feel, tried-and-true methods and heuristics. These actions are quick, effortless, intuitive and require little analysis. System-2 represents rational decision-making; the actions taken are critical, strategic and impactful. The analysis is slow, conscious, effortful and logical. AI will be very useful for automating System-1 decisions, which are fast, with minimal latency, like automating the management of "C" inventory items. For System-2 decisions, which are slower and thoughtful, not so much. This has to do with system latency, optimization and moral decision-making.

Built-in latency is important

Latency is defined as the time from when data that triggers the need for an action is received until the action is taken. I once debated a software analyst who argued that zero latency should be the long-term goal for computerized systems. I took a contrary position, pointing out that all complex systems—think System-2 decision-making—need latency buffers for stability and survival. For instance, try to turn around a big ship too quickly and it will capsize and sink. I also recalled a cartoon showing two workers watching another at work on a computer. One of them said: "I hope he realizes that the computer might be making wrong decisions a thousand times a second." The point: Fast decisions are beneficial only if they are good decisions.

In a column* I wrote about the 2008 financial meltdown, I discussed how financial quants digitized the investment industry starting in the early 1960s. I noted that the decision support systems that they created made automatic trades on a real-time, global trading system with no built-in latency. Essentially, these were viewed as System-1 decisions, made quickly with little thought. And therein lay the crux of the issue: Automated trading systems might not have triggered the meltdown, but without evaluating the trades before they were placed—a latency buffer—they drove financial markets into a downward tailspin. Automated trading systems were a disaster waiting to happen. Similarly, utilizing AI to make impactful System-2 decisions without a latency buffer might also lead to business disasters.

Realistic optimized decisions

Advanced planning and scheduling systems often have optimization software engines, turning them from only supporting managers with "what-if" analyses, to prescribing "what's best" decisions. AI will improve upon these, and automated real-time optimization is certainly appealing to forecasters. Still, there may be exceptions that require experience. Let me give you an example.

An analyst I know once asked plant managers if they turned on their planning and scheduling system's optimizer. By and large, they said no because they knew their plants' production capacities were constrained by materials. Thus, they were only interested in learning which materials were constrained so they could go find more supply to produce more goods. Basically, why accept the system's so-called optimal answer if you know you might improve on it by increasing the supply of necessary materials?

Similarly, I teach linear programming optimization methods in my business analytics course. A textbook example is a furniture manufacturer that needs to decide how many tables and chairs to make to maximize profits given labor-hour constraints. When the optimal system solution shows that three tables should be made for every four chairs, I ask my students if that seems right? They typically answer: "Why not, it's the most profitable." After some discussion of our own experience with tables and chairs, I convince them that the optimal solution will result in a surplus of unsold tables. Maybe the company ought to make an average of three to five chairs per table? We then look at whether we can overcome the labor constraint by adding in overtime or an additional shift. My point is that you shouldn't necessarily accept constraints. The so-called optimum solutions generated by the computer need to be vetted among managers before taking action. In short, because optimization usually involves System-2 decisions, no one should just accept an optimal computer decision without enterprise-wide collaborative vetting.

AI might disregard justice

I once read a newspaper article that discussed a small-town judge presiding at a trial. When one of the lawyers put into evidence a computer printout, the judge quipped: "If the computer says it, then it must be true." As we all know, that is oftentimes far from the truth because humans program computers. Thus, decisions made by a computer might be susceptible to being socially unjust as well.

In one of my Insights columns** I discussed the book: "Weapons of Math Destruction: How Big Data Increases Inequality and Threatens Democracy," by Dr. Cathy O'Neil. A former financial quant, she wrote about how she became disillusioned with mathematical models that affect society and, in the words of one reviewer, "...threaten to rip apart our social fabric."

The book's premise is that the vast amount of Big Data on the Internet is being used in ways that are opaque, unquestioned and unaccountable—if the computer says it, it must be true. She argues that the detailed data used is not transparent to the person affected by the decision-making it supports; the use of the data is beyond reproach in the modelers' minds; and modelers refuse to defend the model other than to say "it is what it says." She also discusses a variety of applications that have "vicious, self-reinforcing feedback loops" whereby things get worse for those affected—especially minorities and the poor.

I bring this up in the context of AI because one has to remember that humans will develop AI software, and so it will be always be subject to potential bias, corrupt behavior and just plain errors. In addition, AI will have no empathy and feeling for the people who are affected by its decision-making.

I recommend that supply chain professionals be wary of using AI to make System-2 decisions. While fast, real-time planning has appeal, it should largely be used to automate operational execution rather than planning processes that are more tactical, strategic and impactful. The hard part of taking this recommendation will be that managers need to segment their decision-making processes into ones that are System-1 versus System-2. And therein lies the challenge: All managers believe their decisions are extremely consequential. Use AI, but warily.

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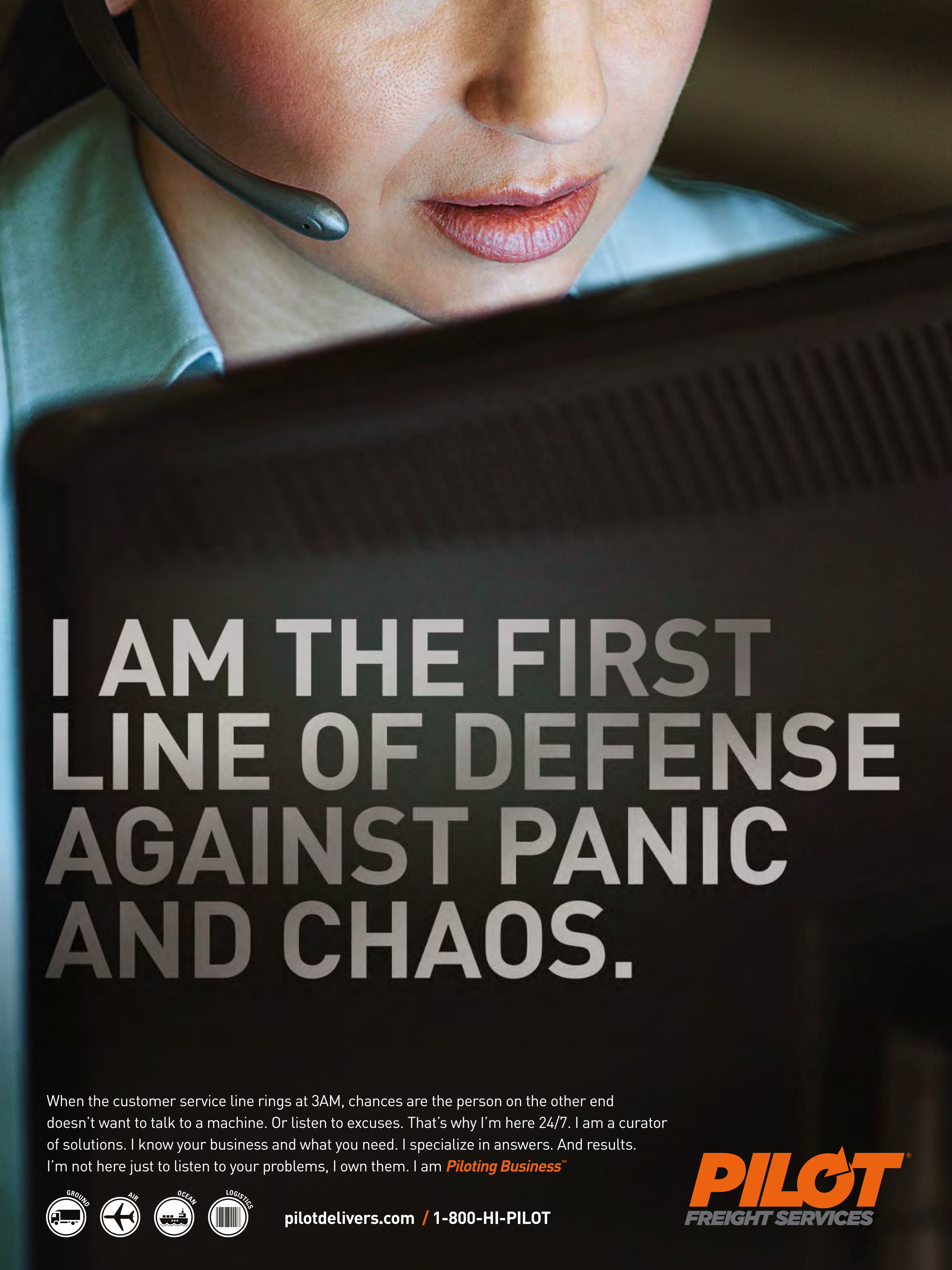
"Take the Supply Chain Modeler's Oath," Supply Chain Management Review, *July/August 2011*

****"Don't build weapons of math destruction,"* Supply Chain Management Review, *March/April 2019*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Leading change management for digital change

Managers must take the lead on change, but don't forget that they need motivation, too.

By Marisa Brown, senior principal research lead, APQC

Marisa Brown is senior principal research lead, supply chain management, APQC. She can be reached at mbrown@apqc.org.

Multiple internal and external forces are changing the face of supply chain. Internally, organizations face the expansion of Cloud computing and digital capabilities and a shift in procurement processes to creating value rather than simply obtaining goods and services at the lowest price. Externally, organizations feel the pressure of continued globalization, increasing market volatility due to natural disasters and geopolitical events, an increasingly fast society that requires more agile supply chains and the continued evolution of a service economy that requires more strategic outsourcing.

Organizations are adopting more technology to address many of these factors. According to research conducted by APQC, 75% of organizations overall are undergoing a digital transformation, meaning that their technology needs are evolving to meet customer and business needs. When considering only supply chain organizations, the amount jumps to 83%.

Leaders must be proactive in getting employees on board with the digital change that must happen to meet the changing business landscape. Yet even the change management tactics needed are changing. Organizations must focus on getting employees involved and providing motivation for them to embrace the new tools and ways of working needed to meet the changing face of supply chain.

APQC has found that organizations must consider change from multiple perspectives. Middle managers play an important role in making employees part of the change. Both senior and middle managers must exemplify the change to others, but they must also be motivated by promotion opportunities and financial rewards. All of these efforts should be part of a comprehensive change strategy used at all levels.

Motivating employees to change

Organizations undergoing change have always faced some resistance from employees who do not see the value of or who feel threatened by the need to do things differently. Supply chain organizations feel this more acutely given the rapid pace of change in the industry. In fact, in a poll conducted by APQC, employee resistance is the top challenge that managers have with regard to change.

Interestingly, the same poll revealed that employees believe their managers do not share enough information about change. Traditionally, organizations undertaking change management have considered it sufficient to conduct one-way communication on the change. However, this method will do little to ease the fears of employees who see digital change as a threat. Leaders must therefore consider ways to more directly involve employees in the change so that they feel their input is valued.

Figure 1 lists eight behaviors APQC recommends managers adopt to motivate their employees to embrace change. To successfully lead their employees through a change initiative, managers must consider that change starts with the individual. Considering individual employee concerns and behaviors will go a long way in engaging supply chain employees.

FIGURE 1

Behaviors for motivating change

BEHAVIOR	DESCRIPTION
Ask	Involve employees in determining what needs to change and how.
Explain	Detail what does and does not need to change and share the reasons why.
Watch and listen	Be attentive to both the practical and emotional concerns employees have.
Personalize	Work with employees to find ways for the change to benefit them directly.
Show	Demonstrate how to make the change. Make the change yourself first if you can.
Be patient	Give employees sufficient time to learn new ways of thinking and working.
Recognize	Catch employees in the act of change and offer positive feedback.
Support	Equip employees with the knowledge, skills, and tools to make the change.

Source: APQC

Adopting these behaviors does require more effort from managers, and with the amount of responsibilities supply chain managers have it can be tempting to skip them in favor of traditional methods of pushing change. However, the empathy and engagement shown through the behaviors will pay off. Employees will feel they are a valued part of the team, making them strong supporters of digital change.

In addition to the behaviors listed in Figure 1, APQC recommends managers make six commitments to ensure effective communication with employees regarding change:

1. Have a plan. Managers must establish communication norms and schedule regular communications.

2. Be available. They should set aside time daily to answer employee questions and observe what is going on with their team.

3. Fully communicate. They must provide ample communications about both strategic and tactical issues, and they must share messages that are relevant to both the team overall and the individuals on it.

4. Tailor methods. They should use a variety of channels for communicating with employees and, when possible, tailor communications to employee preferences.

5. Explain why and how. Managers should explain not only what needs to happen, but also the why and how.

6. Listen to understand. Managers must listen to understand the meaning and feelings behind what employees say, and repeat back what they hear and see to confirm that they understand what employees convey.

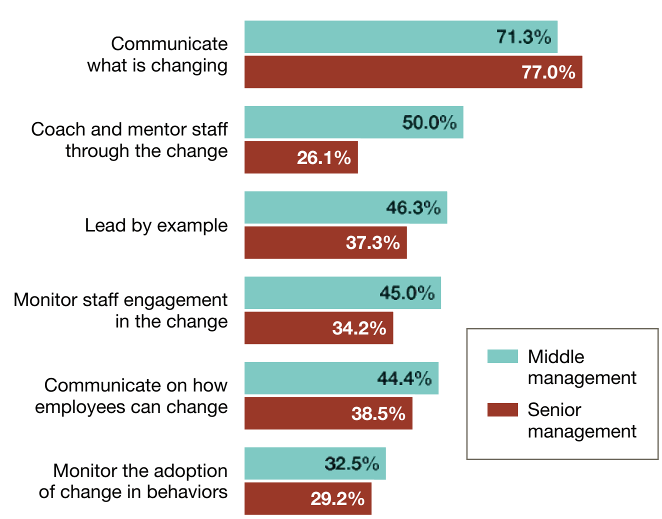
The behaviors necessary for leading employees through change require managers with specific strengths and skills. To ensure that they have managers able to lead employees through change, chemical company BASF, for example, has adopted impact-based hiring, which focuses on job success outcomes rather than solely traditional requirements and qualifications. Although technical expertise is important, the organization considers what successful performance in the role looks like and looks at candidates' transferable experiences, achievements and motivations. This allows BASF to identify both internal and external candidates who can adapt, learn and grow with the organization.

Leadership responsibility for change

The role of leadership in change management is not limited to motivating employees. Leaders must be accountable (not just responsible) for change. This is essential in the supply chain field, where digital change initiatives are integral to ensure organizations keep up with changing business needs. Organizations must empower their leaders to make decisions related to the change and to take ownership of it.

FIGURE 2

Management's role in leading change



Source: APQC

However, the responsibilities of individual leaders will vary based on their role. This is already taking place at organizations to some degree. Figure 2 shows the results of an APQC survey on change management initiatives and the responsibilities of management. Senior leaders often take primary ownership of communicating what will change but are much less likely to coach and mentor staff through the change or communicate how employees can change. Interestingly, less than half of organizations have middle or senior management who lead by example.

To ensure that change sticks, leaders must take on more responsibilities for driving change. APQC recommends senior managers be responsible for the following tasks:

- providing high-level guidance on the behaviors necessary for change;
- developing and executing strategic communications that explain the what/why/how of the change;
- leading by example and modeling changes others should make; and
- incorporating feedback and removing roadblocks to change.

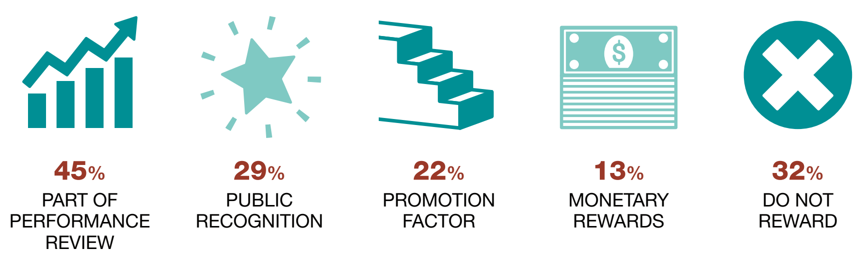
Middle managers have the opportunity to connect more with employees to increase engagement. However, senior and middle managers must stay in contact to ensure that potential problems arising in day-to-day activities can be sufficiently addressed. Middle managers should therefore be responsible for the following tasks:

- explaining what the change means for each member of their team;
- listening to employee feedback on the change and, when necessary, elevating feedback to senior management;
- coaching and mentoring employees through the change; and
- tracking adoption and monitoring staff to ensure that change sticks.

Leading organizations recognize the important role middle managers play in change management initiatives. These individuals often experience pressure from above to accomplish organizational initiatives and pressure from below to adequately support their staff. As an example, the engineering, construction and project management organization Bechtel gives middle managers clear roles regarding change management. It also provides these individuals with training and rewards to help them motivate their employees and succeed in supporting change.

FIGURE 3

Change rewards



Source: APQC

Using rewards to encourage change

Digital change initiatives present a need for both supply chain employees and leaders to change the way they work and take on different tasks. Just as managers must motivate employees to embrace change, organizations must also consider ways to entice managers to embrace the change and their role as change leaders.

A best practice for change management is to tie leaders' financial rewards and promotion opportunities to effective implementation of change projects. However, most organizations have room for improvement when it comes to rewarding change. As shown in Figure 3, only 22% of organizations consider change participation when determining promotions, and only 13% hand out monetary rewards for change participation. About one-third of organizations do not reward employees for engagement in change at all.

Opportunities for professional development can also motivate managers and employees to embrace change. Technology company Cisco Systems considered ways to encourage innovation and change among its employees. It conducted surveys to find out what would drive employees to engage in digital innovation, and one of the top choices was having time to work on innovative ideas and being recognized for this work. Cisco, therefore, set aside more time and opportunities for employees to work on novel ideas. It also gives awards to employees for significant contributions to innovation, which can lead to additional career opportunities for winners.

Tactics for responsive change management

Ensuring the adoption of digital change in supply chain goes beyond merely pushing out information about the change. Managers must engage employees in identifying what needs to change and listen to employee concerns. Moreover, organizations must ensure that middle and senior managers have clearly defined roles within the change effort so that employees see them as having to make the change as well. To motivate managers to be change leaders, organizations should use promotion opportunities and monetary rewards.

These efforts should be part of a set of tactics adopted by an organization to ensure across-the-board engagement in the face of evolving digital change. APQC recommends organizations use the following tactics to ensure a more responsive change management approach.

1. Conduct a current state assessment of cultural preparedness for change and employees' fluency with relevant technologies.

2. Use a portfolio approach to manage the change aspects of smaller initiatives involved in the overall transformation.

3. Deliver tailored communications to answer: "What's in it for me?" for different roles, teams and departments.

4. Leverage peer-led trainings and communications to cultivate buy-in and decrease the burden on leadership.

5. Use value and behavioral measures—not just milestones reached and activities completed—to evaluate the progress of the transformation.

6. Incorporate desired behaviors into employee evaluations and promotion considerations.

A digital change effort means work across the organization—from the leaders who initiate the effort, to the managers who communicate with and encourage employees, to the employees who incorporate new behaviors and technologies into their day-to-day routines. The evolution of technology to meet business needs means that supply chain organizations no longer have the option to haphazardly adopt change or see change initiatives languish due to internal pushback.

About APQC

APQC helps organizations work smarter, faster, and with greater confidence. It is the world's foremost authority in benchmarking, best practices, process and performance improvement, and knowledge management. APQC's unique structure as a member-based nonprofit makes it a differentiator in the marketplace. APQC partners with more than 500 member organizations worldwide in all industries. With more than 40 years of experience, APQC remains the world's leader in transforming organizations. Visit us at apqc.org, and learn how you can make best practices your practices.

Historical accidents and getting ahead

Competing today is about being open to how emerging technologies are being integrated and leveraged to create change in business processes, models and competition.

By Mark Newberry and Aaron Benningfield

Most supply chains are historical accidents… really. Think about it: rarely is a business started and launched from a supply chain set of capabilities. Granted, many logistics service companies have instances where supply chain came first, but they're harder to find.

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As supply chain practitioners, we're always "catching up" to our organization's latest strategy or sales and marketing initiative. The latest example is omni-channel strategy. In this case, the front end of the sales engine was created as a slick method to digitize the product offering (which, by the way, kept expanding) to offer new ways and options for consumers to shop, order and have their purchase delivered—instantly. The trouble is that supply chain professionals ended up with a new fulfillment demographic and requirements that affected cost and capacity to execute. And, setting up new network nodes and transportation capabilities to satisfy the delivery expectations is not trivial.

For most companies, this is the new normal. New capabilities were developed; partners were brought on board to execute; and new warehouse and transportation management systems were implemented. All of that, of course, after the fact and decidedly in a hurry, essentially creating the historical accident that we now call omni-channel fulfillment.

There are two new concepts that may give us, supply chain practitioners, a chance to get ahead of the curve: servitization and the emerging understanding of supply chain as an ecosystem. We admit that these are new ideas for most organizations. Apple, Caterpillar, Rolls Royce, IBM and others have developed new business models to add a service revenue stream to their existing product-based businesses. And, they're leveraging this new servitization business model to develop "ecosystems" to support the operations and delivery methods customers need—yesterday.

Let's explore these two concepts together as they are typically intertwined in execution (see Figure 1). Servitization is a transformation journey: It requires organizations to develop the capabilities they need to provide the services and solutions that supplement their traditional product offerings. For example, Apple invented the iPod and iStore, which turned the physical product into a delivery method for a service business—iTunes and more. The app store leverages an ecosystem of developers to build the apps, and iTunes has the entire music industry as an ecosystem (much to its chagrin).

Not unlike supply chain leaders, the music business was caught on its back foot with a new business model and a less lucrative commercial picture for artists.

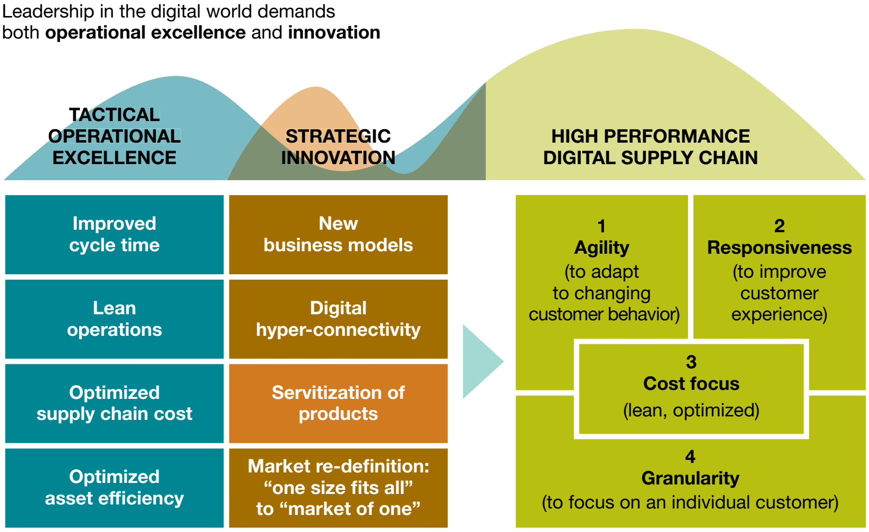
In Apple's case, it created a servitization business and convinced consumers that they had to have it. Apple went on to leverage and integrate multiple digital technologies such as navigation, imaging, telecommunications and computing into a new offering. This was considered a radical approach to servitization, whereas others approached servitization as a strategy more apprehensively, slowly and incrementally. Caterpillar built an incredibly capable spare parts business; then, over time, it developed the offering into a service business that thrives today. The CAT example is a great story for supply chain professionals because it is domain relevant and most supply networks have similar capabilities that can be leveraged.

Think about the possibilities for servitization in the supply chain. Just like the criminal element we need access, opportunity and motivation. In our data, we have access and opportunity to troves of information that can be commercialized given a little creativity, persistence and motivation, especially motivation. Imagine a life sciences firm that manufactures various vaccines, in this case, the flu vaccine. More and more, vaccines are highly susceptible to being drawn (often kicking and screaming) into the omni-channel world, disintermediating the traditional manufacturer to distributor to provider to patient flow. Imagine the possibilities to servitize the data associated with vaccine shipments. Would the CDC be interested in where those vaccines are being shipped? Maybe they would want to conflate the shipment data with flu outbreaks to determine any relationships between the two? That's one case that we hope will motivate you into creative thinking mode.

FIGURE 1

Supply chain journey

Leadership in the digital world demands both **operational excellence** and **innovation**



Source: Authors

A portfolio designed for revenue generation

Servitization opens a new world for capturing revenue from existing resources waiting to be transformed from a cost center to a profit generation engine. Among organizations today, we see a number of different capabilities in play. Capabilities to be commercialized can be looked at from a broad perspective such as human resources or supply chain, down to a more tactical level of business intelligence for your supply network.

Let's look at the case of a company making the transformation from selling physical products to selling electronic information as a product. This scenario requires a different customer interaction process than the current one. Deciding the type of information product this company will offer as a service entails a different mindset. Developing the new information product will require expertise from IT architects and product subject matter experts (SME) acting in concert with other teams such as field service technicians, customer support activities, R&D and manufacturing activities. Collaboration between various business units incorporated in the offering is required to derive the most value for the organization.

Thinking back to the capabilities mentioned earlier, we can define a strategic portfolio whereby we identify which of our companies' capabilities provide the best fit for transformation. The portfolio business case should be designed to address the need for internal company collaboration by setting the stage for the best method of bringing organization together in a team format.

A portfolio should be designed in a manner that the individual offerings in the portfolio can be easily repeated globally across a variety of our customers. Another portfolio benefit is the creation of a template that eliminates many uncertainties experienced during the implementation of a service with our customers. An example of eliminating uncertainties is bringing industry qualified information to the service offering by having qualified expertise embedded in the template model. Tactically, this is displayed through showcasing our resources and personnel required for delivering a particular servitization offering.

Ecosystem thinking and technology enables servitization growth and scale

Rich Sherman, our colleague at TCS, has recently published several articles in *Supply Chain Management Review* ("I can see clearly now… the constraints are gone" and "Working the chain out of supply chain management") that introduce and describe the transformation of supply chain management to enterprise supply network (ESN) management. He provides a Digital Business 4.0 Maturity Model that is an assessment roadmap for companies to create digital twins to transform and evolve to ecosystem commerce management.

Ecosystem commerce operating as a digital community enables the concept of servitization. Transforming to ecosystem thinking and embracing omni-channel strategies, we can now see many more possibilities for commercializing our supply chain operations and the effects created by its operations. Many companies are embracing a licensing approach as a form of servitization—leveraging a logo or brand, for example, as an asset that can be commercialized through servitization. As servitization expands, ecosystems should be looked at as strategically critical to the business and competitive landscape; not just to move freight, or execute fulfillment in a 3PL environment, or to consume your product as a downstream customer. Rather, it's a growth model that any company in a market ecosystem can leverage.

This makes the platform discussion very relevant. The amount of connectivity required to fully realize your ecosystem's power is beyond significant. You'll need a robust way to manage the data, drive superior speed and scale through the architecture of the IT systems, and a governance and federation process to ensure security and mitigate risk for all participants.

You may be saying: "That's going to cost a fortune and take forever to complete." Perhaps optimistically, we think most of the hard work has been done. Networks are generally already set up. We've arranged suppliers to support our manufacturing and logistics. We have third parties clearing international shipments and auditing our freight bills. Some operations have been outsourced. The heavy lifting has been done—the technology is here and we should finish what we started.

Competing in the 21st century is less about inventing a new technology or the discovery of a magic wand. As practitioners, it's more about being open to how emerging technologies are being integrated and leveraged to create change in our business processes, models and competition. Servitization is less about invention and more about innovation—adopting new methods and technologies to get in front of new initiatives and create change versus reacting to change. This is a must for supply chain practitioners who want to avoid being a historical accident.

AI STARTS TO MAKE SOME SUPPLY CHAIN DECISIONS

Is it prime time for AI? Not yet. But, it is edging into the physical world of the supply chain. And there's no going back.

BY GARY FORGER, SPECIAL PROJECTS EDITOR

Artificial intelligence finds itself deep in a world of seeming contradictions these days. On the one hand, AI is believed to be a black box of universal truth. Yet, it is often not as sophisticated as a three-year-old. Most think of AI as a form of general intelligence. Yet, its most advanced forms are actually narrow intelligence. Some view AI as a stand-alone technology. Yet, it is also a feature of other technologies and applications.

Until most recently, AI lived almost entirely in a digital, academic world. Yet, it is now breaking into the physical world of the supply chain. Fortunately, AI is doing just fine living with all this turmoil. And there is one certainty about AI: It has already made the leap from the Tuesday Science section of *The New York Times* to the daily Business section. And it's not going back—especially in the supply chain.

Early on

The contradictions of AI should not alarm: They are simply manifestations of how it is developing and being perceived—sometimes in exaggerated ways.

Despite how fresh it may feel, AI is not new (yes, another contradiction). Its origins trace back to the 1950s. Some link the concept of machine learning directly to Alan Turing, who created a model for a general-purpose computer in 1950. That said, 2020 is still an early time for AI.

"Things that are hard in AI today are easy for a three-year-old," says Pieter Abbeel, co-founder of the AI robotics company Covariant and a Berkeley professor. Keep in mind, the whole point of AI is to make decisions as well or better than humans can make them. The example used by Melonee Wise, founder of Fetch Robotics, is a drawing of a giraffe. "Show a child a drawing of a giraffe and she can identify the giraffe at the zoo the next day. No AI algorithm can do that today or even make the inference," she says.

AI itself is still learning. And there's lots more to learn and plenty of maturation to come. While some might look at that three-year-old and see certain promising characteristics for future greatness, it's way too early on in development to declare victory. But to read the popular press, it's easy to think that not only is AI fully formed, but it is also a very short time away from eliminating a wide swath of people from the workforce. Not so, in either case. There is no black box of AI sitting on the shelf at Best Buy. But one day, AI will have a direct impact on the jobs people do in the supply chain and the jobs that machines do. And that time starts now; consider the following examples.

About three years ago, JDA Software bought an AI company called Blue Yonder. Today, the company is now called Blue Yonder, reflecting its commitment to making AI a foundational component of its supply chain software. It is already offering AI features in certain programs related to demand planning. These include AI to support pricing strategies as well as replenishment solutions. The latter creates accurate, granular intra-day demand forecasts that optimize product availability. Beyond that capability, AI drives automated store replenishment, substantially reducing out-of-stocks.

Then just last month, *The New York Times* ran a story (yes, the lead story in the Business section) on the use of an AI-directed order-picking robot at Obeta's electrical parts distribution center outside Berlin. The Knapp picking robot is powered by Covariant's AI. "While it may not seem like much, this component-sorting robot is a major advancement in artificial intelligence and the ability of machines to perform human labor," the article said.

Speaking with *SCMR*, Peter Puchwein, vice president of innovation and research and development at Knapp, explains this development didn't just happen overnight. Knapp and Covariant worked together for more than a year to develop this application and its narrow intelligence—finding the right parts in a single tote and picking them to fill orders. Better yet, the robot picks as quickly as humans with equal accuracy—less than a 1% error rate, explains Puchwein. It's also worth noting that this was not a new idea for Knapp. They had been looking for an AI partner for five years and had rejected at least 20 AI companies as unable to perform.

Knapp is not alone. As the *NYT*'s article points out, robot supplier ABB ran a contest last year to find its own AI partner. It invited 20 companies; half of which failed conclusively. Some came close. As it turned out, only Covariant "could handle every task as swiftly and efficiently as a human," said *The Times*.

If it looks like AI...

AI isn't easy. And for that matter, it isn't always easy to know what AI looks like. Because it's so early in its development, there are many different views on the state of AI. So, knowing AI when you see it all depends on what you see and who you speak with. Here's a greatly distilled rundown on what makes AI AI today.

Some say there is very fine line between a fancy algorithm and AI. Worse yet, there are some who try to pass off a fancy algorithm as being AI. At one end of the spectrum is Wise of Fetch Robotics. She'll tell you straight out that "there is no such thing as AI."

Her contention is that it is still so early in the learning-to-learn stage, that AI, well, doesn't exist quite yet. Now don't get her wrong, Wise is not an AI naysayer. Instead, she is very close to the challenges of AI and is being quite definitive about its state of development. She continues to say AI is just a term used to describe what people are trying to accomplish with machine learning (more on that to follow). "AI doesn't exist today. It's a branding problem," concludes Wise.

Two Harvard Business School professors, Marco Iansiti and Karim R. Lakhani, talk about weak AI and strong AI in the January/February 2020 issue of Harvard Business Review and on a webcast. "You need only a computer system to perform tasks traditionally handled by people" to have what they call weak AI. On the other hand, "machines that can think and act in a way that matches or surpasses human intelligence" are strong AI, Lakhani and Iansiti say. That's a pretty good baseline.

That said, AI needs to learn to become AI in the first place. In other words, Wise' statement is not as outrageous as it may seem at first. It's all a matter of degree. AI needs data (lots and lots of it) before it can start to create the algorithms that guide decision-making—and ultimately outcomes. That data can come from people or from data networks. In a more primitive form of learning, people feed data that will teach AI to learn and alter its decision-making process, resulting in new algorithms and outcomes. Step it up a major league notch and machine learning takes over, moving from people-directed data input to that fed by data networks. People don't have to get involved, but typically do.

Drilling down one level deeper in machine learning, there is deep learning. The idea behind deep learning is to imitate how people learn. Deep learning can run either unsupervised by humans or supervised by humans. Other forms include reinforcement and transfer learning.

Deep unsupervised learning speaks for itself, literally, but today is very rare. The vast majority of AI has at least some human involvement. Quite simply, AI, for the most part, is not running on its own in the supply chain or anywhere else, for that matter.

Deep supervised learning relies, at least in part, on human input. As Maria Jesus Saenz, director of MIT's Digital Supply Chain Transformation research program, explains humans don't have to supply all of the data, but they can provide relative insights and intuitions, and augment the data streaming into the AI. As the technology learns to learn, people can teach it about data from other sources and incorporate it into the learning process. There are great opportunities for the AI applications when the expert human and smart algorithm team up.

Reinforcement learning is what makes the robot at Obeta smarter every day. As Abbeel and Puchwein explained to *SCMR*, all of the robot's actions during the day, both successes and failures, are recorded and sent back to the AI engine. At the end of day, it evaluates what went well versus not so well, making adjustments in how to pick on the next shift. It reinforces what has already been learned with new learnings that enhance decision-making and performance.

Transfer learning is the fourth variant of deep learning today. It takes data and decisions that solved one problem and transfers those to another problem. There are sure to be plenty of opportunities for transfer learning in the supply chain in coming years.

While machine learning comes in different forms, its output or intelligence all has a similar profile at this stage of its development—we're a long way from any intelligence that could be called general. AI is not making sweeping changes in the supply chain. Instead, AI is at the front end of developing narrow intelligence that performs a specific action or makes a tightly defined decision.

It is also worth noting that AI in any field is not a universal truth regardless of its variant of machine learning. In fact, AI can look quite different depending on the humans who are involved—or even its country of origin. People still affect how AI learns and the decisions it makes. In fact, that's the basis for claims of bias in AI applications such as facial recognition.

AI and an ocean of data

Given all the hype surrounding AI, it's easy to exaggerate what it can do. Many have already.

"Expectations are outsized," says Sergio Caballero, research scientist at MIT's Center for Transportation and Logistics (CTL). "People expect AI to have a huge impact on business. But what many of these people lack is a clear understanding of what AI is and what it can do at this point," adds Caballero.

As captivating as it is, AI is not the center of the digital supply chain. It is just one component, albeit a potentially very important one. The possibilities go so far beyond an order-picking robot. But at this point, there are many other possibilities that lie in the future. There's work to be done first, and it's not just in the development of smarter AI.

Before AI can reach its potential, the supply chain has to put its digital landscape in place. That's the only way all that needed data can flow to where it will be put to work. Quite simply, AI has to sit in an ocean of data to be effective to any degree. And the only way that is going to happen on a large scale is with a successful digital transformation of the supply chain.

"Digital transformation requires a previous analysis of the main value propositions for supply chain transformation, not to mention digital technologies and transaction data," says Saenz of MIT. "These value propositions bring the 'what that supply chain wants to achieve' and more importantly the 'why they want to achieve it in the first place,'" she adds.

"Digital transformation requires a technical exercise known as digitization that collects all transaction data of any form from all of the silos and puts them into an electronic state in a central location," explains Rich Sherman, senior fellow with Tata Consultancy Service.

Doing that consolidates previously siloed data. That means, that not only is all data commonly available, Sherman says, but it can be shared across all functional silos. It also codifies data across the company's supply chain, and puts all decision-making on the same footing. Suddenly data becomes Big Data when it's available on such an unprecedented scale.

And the Cloud is increasingly becoming the home of all that data. Wise of Fetch Robotics sees the availability of Cloud data as essential to giving AI a seat at the decision-makers table on the plant or warehouse floor. "The Cloud delivers the computational power that will allow AI to scale and manage Big Data sets with high accuracy and have the maximum impact on operations," she says.

In other words, Big Data is still just data until something is done with it. As Sherman says, "Big Data is like crude oil. It needs to be refined into something before it becomes valuable." And the value of data here is its ability to create time in the supply chain by shrinking time in individual supply chain processes. "The real value of the digitization of data is that it removes latency from the supply chain," Sherman continues. "Digitization removes the time delay in communicating conditions across the supply chain as they change in real time. That gives people more time to respond to change and makes decision making more timely," Sherman says.

AI is one digital tool that also removes latency from the supply chain. And its potential is huge. "Ultimately, AI will be able to predict having the right amount of stuff at the right time in the right place," explains, Michael Feindt, founder of Blue Yonder.

"Digitization and what's going on in AI today are early steps toward building the autonomous supply chain from orders to warehousing and transport," he continues. "We are at the very start of this. The next step is to move AI into the distribution center then back up the supply chain back to manufacturing. Carry this goal all the way to its logical conclusion and AI will ultimately predict what people want to buy," says Feindt.

He says it's all about repeatedly making decisions based on real time data. Key decisions can go as far as predicting customer behavior correctly to precisely drive replenishment decisions that are both customer facing and supplier facing. Feindt even sees AI as a powerful pricing tool. "With all of its influences in the supply chain, AI will ultimately determine price and profit of even seasonal products," he adds.

Can it work here?

Getting to Feindt's vision will not be easy. Just ask Caballero: He sees it every day.

MIT's CTL works with about 80 companies on various supply chain research projects. Caballero estimates that 50% of them currently do not use AI in any form. About 25% have some AI pilots, and only 25% are actually using AI to any degree.

Those that actually use AI are fundamentally different from other companies, says Caballero. "They understand up front that AI is not magic and is not a solution for everything. Beyond that, they have a solid idea of what AI can do for them. And they understand the need for abundant data," he says.

Saenz of MIT agrees and says not every company is a candidate for AI or any other innovative supply chain technology for that matter. "Those that will succeed already have an innovative culture and are able to rise up to the challenges of innovation," she says. "For too many companies, innovation is not part of their culture; it's not part of their way of thinking. They feel comfortable in their present state and are not likely to succeed at innovation," she says.

Saenz sees some other key characteristics, too. Ten to be precise. These companies are:

- agile;
- responsive;
- customer focused;
- technology savvy;
- data driven;
- collaborative;
- comfortable with experimentation;
- constantly challenging the status quo;
- adaptable to change; and
- ambidextrous.

That last one is the most important of all. Quite simply, a company must be able to go right or go left based on circumstances and not some predisposition. If a company is not ambidextrous, it will fail at innovation. "Ambidextrous is a state of exploring and exploiting," explains Saenz.

Making decisions differently

Going right or going left solely based on conditions is not a natural state for many people let alone companies or supply chain operations. There are rules, more rules, and often even more rules. Supply chain professionals are often committed to the faithful execution of processes because otherwise, chaos waltzes in. Freelancing is not generally encouraged. Well, AI is here to break many of those rules. But AI will only do that when appropriate, when it has a smarter outcome. Accepting that value proposition will not be easy, however. Mostly that's because we generally think humans and our existing processes are smarter than machines no matter how much learning they've done. As Feindt of Blue Yonder says, it's good to remind ourselves that AI is in the time of narrow intelligence, delivering tangible benefits.

Obeta is the perfect example of that. Despite the initial success of the AI order-picking robot there, Puchwein of Knapp knows this a long game. He hopes to install 100 robots over the next two years. But over time, his vision is to move from 20 human order-pickers to one technician overseeing 20 robots. Quite simply, Puchwein's customers tell him that they can't find the workers to do those monotonous jobs any longer; they need robots in their facilities. At the same time that this is narrow AI, it solved a highly complex problem, explains Abbeel. The robot is not picking a perfectly positioned item from a geometrically stocked shelf. Items are randomly placed and often have reflective surfaces that can drive the robot's vision system crazy. So, while this might be narrow intelligence, the Obeta robot relies on really smart narrow intelligence.

Beyond robots, demand planning is another emerging domain for AI in the supply chain. "AI should compare expected demand with actual demand to determine what really drives accuracy and how best to balance inventory flow," explains Saenz of MIT.

Consider Reyes Holdings use of AI to improve the forecast for its beer products. In late 2018, Pamela Armella, Reyes' data science leader, launched the company's first machine learning models. The absolute forecasting percent error declined was cut in half from 38% to 19%. That was reported by Armella and MIT's Caballero in the September/October 2019 issue of *SCMR*.

A company must be able to go right or go left based on circumstances and not some predisposition.

Over time, that error rate declined as the model learned further. It also allowed purchasing to modify some of its practices. "AI/machine learning is a disruptive technology that challenges current thinking and ingrained practices…The (data science) team asked users not to trust their intuitive judgment, but not to dismiss it either because the models were still learning," the article said.

The two primary benefits of AI, says Caballero, are improved visibility and more accurate predictions of supply chain activities. "If you know today what orders will come in during the next few days, you can start filling them now," he adds.

Feindt of Blue Yonder says that AI is all about progressing from today's solutions to future more intelligent solutions. "Even narrow AI can help to unify supply chain processes. The result will be improved efficiencies and ultimately profitability," says Feindt.

It should prove to be a fascinating ride.

MAKING AI WORK

To build lasting AI capability in your organization, take a layered approach.

BY T S KRISHNAN AND DAMINI GUPTA

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"The rise of AI presents an opportunity for executives in every industry to differentiate and defend their businesses. But implementing a company-wide AI strategy is challenging, especially for legacy enterprises."

—Andrew Ng, adjunct professor of computer science at Stanford University and founder of the Google Brain project (Harvard Business Review).

Recent years have seen the convergence of data science and supply chain management. It has been driven by the increased utilization of business intelligence and Big Data along with the growing interest in artificial intelligence (AI). AI promises new levels of insight, actionable intelligence and automation that just aren't possible by conventional technologies or people alone. Rather, AI can complement and expand the capabilities of your supply chain organization. That's the opportunity to differentiate and defend your business referred to in Andrew Ng's *Harvard Business Review* article above.

As with any emerging technology, the question for an organization is where to start? In many instances, that question may be directed as much to the data science team within your supply chain as to the day to day practitioners. As Ng noted, it's not easy—especially for legacy enterprises.

In this article, we offer a strategic path for established and successful organizations that are yet to embark on a journey to effectively implement AI. To build lasting AI capability, we take a layered approach. It consists of four layers that are akin to an inverted sand cone.

Starting at Layer 1, a legacy organization can build lasting AI capability, sequentially and cumulatively proceeding all the way up to Layer 4. In each layer, the organization builds capability by carefully fine tuning and learning-by-doing through trial-and-error. Capability in Layer 4 is built cumulatively on the capabilities developed in the layers illustrated below. Based on the nature of data from Layers 1 through 4, we propose a sequence of capability building with respect to cognitive technologies that goes from numerical to textual to image and finally to advanced data such as speech and video.

Text, images and advanced forms of data need to be reduced to numerical forms for further processing. Hence, building capability on numerical data—Layer 1—is foundational. There is a level of complexity associated with converting non-numerical forms of data to numerical forms. The conversion complexity of each data type is proportional to its Boolean complexity, or it's logical incompressibility. The conversion complexity increases with each data type because it is more complex to convert images to a numerical form than it is to convert textual data to numerical form. Similarly, conversion complexity of advanced data forms (speech and video) is higher when compared to the conversion complexity of images.

Our proposed strategy is drawn from prior academic research from individuals such as Ng, who has written in the *Harvard Business Review* about how to choose your first AI project, and Babson College's Thomas H. Davenport, who laid out a high-level strategic framework that includes content, technology components, people, change management and ambitions. It also draws on our deep experience in implementing AI for established and successful organizations that are yet to embark on an AI journey. In proposing this approach, we assume that organizations are in the maturity stage of their digital transformation process, which is a prerequisite to any AI implementation.

While the audience for this strategy might initially be a data science professional, who is becoming part of supply chain team, we believe this is useful for supply chain professionals who intend to make cognitive technology a core capability that can be implemented across multiple projects, processes and products. You'll note that in the accompanying tables, we have included potential use cases for AI in supply chain management. Let's work through each of the layers.

Layer 1

Layer 1 begins with a focus on developing rigorous AI models for numerical data. Numerical data is intuitive to work with. The data has low dimensionality, as it is structured and tabular, and it can be labeled or un-labeled (Figure 1).

Labeled or tagged data refers to data that has pre-defined inputs and outputs correspondence. An example is historical credit card transaction data in which fraudulent transactions have already been identified. Supervised learning algorithms are most suited for this kind of data.

Un-labeled data refers to data that has no pre-defined outputs. An example here is historical transaction data where the fraudulent transactions have not yet been identified. Unsupervised learning algorithms are used to analyze un-labeled data.

Numerical data could also be either cross-sectional or time-series. Cross-sectional data refers to observations collected at the same time period across multiple entities. Examples would include transaction data of multiple stores collected over a single day or the event log data of multiple pieces of equipment such as forklifts, conveyor belts and automated guided vehicles collected at the same time.

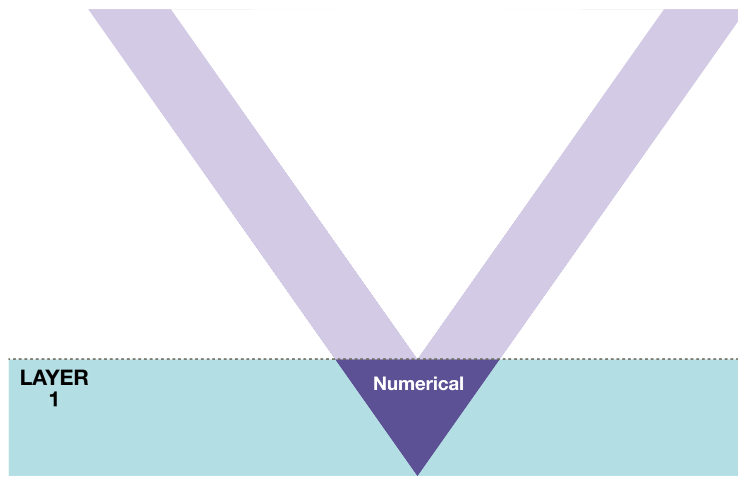
FIGURE 1

Layer 1

Data type Numerical

Technique Supervised Learning
Unsupervised Learning

Algorithm Linear regression, Logistic regression, Hierarchical regression, SVM, Decision Trees, Naïve Bayers, Random Forest, XGBoost, AdaBoost, KNN, DBScan, K-Means clustering, Hierarchical clustering, ARMA, ARCH, GARCH, Co-integration



Source: Authors

FIGURE 2

Layer 1 use cases

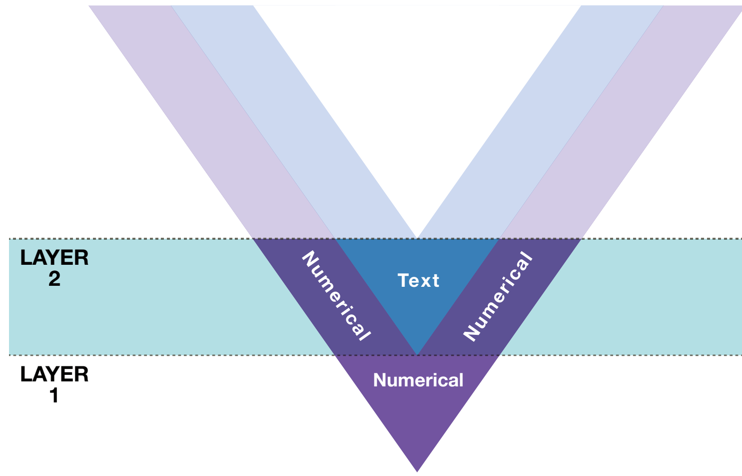
USE CASES	EXAMPLES	TYPICAL ALGORITHMS/TOOLS
Problems are well-defined a) Key Driver Analysis b) Classification c) Predicting Churn	**Problem statements are well-defined** a) What drives higher sales – discounts or bundling or SKUs, time of the day or day of the week? b) Predict frauds/anomalies from transactional data with buyers, suppliers, and customers. For example, is incoming credit card transaction fraudulent or not? c) Predicting customer churn/employee attrition. For example, predicting customer churn for a telecom service provider	**Supervised learning algorithms for well-defined problems with labeled data** Linear Regression, Logistic Regression, Hierarchical regression, Random Forests, Decision Trees, Support Vector Machines, Naïve Bayes, XGBoost, AdaBoost
Problems are exploratory in nature d) Segmentation	**Problems are exploratory in nature** d) Identify customer segments based on their transaction history. For example, segment telecom customers based on their usage of call, message and data to create optimal telecom plans	**Unsupervised learning algorithms for exploratory problems with un-labeled data** K-Nearest Neighbor, Density Based Clustering, K means Clustering, Hierarchical clustering
Time Series e) Forecasting	**Time Series** e) Predict sales volumes, stock-outs, cash flow volatility	**Time Series algorithms** Autoregressive, Moving Average, ARMA, ARIMA, Vector Autoregression Co-integration- ARCH, GARCH

Source: Authors

FIGURE 3

Layer 2

Data type	Text, Numerical
Technique	Supervised Learning Unsupervised Learning Optimization Techniques
Algorithm	**Text** TFIDF based classification, Part of Speech tagging, Named Entity Recognition, LSA, LDA, LSI **Numerical** PCA, Discriminant Analysis, Singular Value Decomposition, Linear and non-linear programming



Source: Authors

FIGURE 4

Layer 2 use cases

USE CASES	EXAMPLES	TYPICAL ALGORITHMS/TOOLS
Text a) Sentiment Analysis b) Document Classification c) Identify names of individuals/ companies/places d) Topic Modeling	a) Analysis of public discussions on social media to see how the general public feels about the organization (its brand, products and services) or its buyers/suppliers b) Classifying e-mails for routing to predefined work queues c) • Extract names of CEO and company's board of directors from annual reports • Extract the names of places mentioned in a travelogue d) • Organizing news articles based on content similarity into topics that are not pre-defined • Categorize customer complaints based on the product categories and assign it to relevant department	**Supervised** TFIDF based classification, Stemming, Lemmatization, Part of Speech tagging, Named Entity Recognition, n-grams **Unsupervised** Latent Semantic Analysis, Latent Dirichlet Allocation, Latent Semantic Indexing

Source: Authors

Time series data refers to a series of values obtained at successive equal time intervals for the same entity. Examples might include the sales volume data of a single product collected over multiple days or the price of a specific raw material collected across a period of months.

Examples of use cases that can be leveraged to develop a critical mass of capability in Layer 1 are summarized in Figure 2.

The focus of Layer 1 is to develop key capability in the algorithms mentioned in Figure 2 that can be used to work on numerical data. You want to develop a critical mass of capability (the small triangle at the vertex) in this layer. Then, you can proceed to the next layer by leveraging this acquired capability.

Layer 2

The new capability acquired at Layer 2 (Figure 3) is related to textual data, while simultaneously improving/ expanding the capability related to numerical data that was acquired in Layer 1. The capability acquired at Layer 1 enhances the capability needed for Layer 2 (i.e. it's cumulative).

At Layer 2 you acquire Natural Language Processing for processing textual data. Textual data is free-form and unstructured. Sentences follow no set pattern and information presented in successive sentences vary considerably. Moreover, writing style changes between authors.

The data could be labeled or unlabeled. Examples of labeled data in the supply chain would be the technical descriptions of causes of delay, such as a supplier issue, a natural disaster, or a transportation or customs issue. Examples of unlabeled data would be the un-segregated collection of documents that include commercial invoices, packing lists, delivery orders, airway bills, transport receipts and bills of lading.

Figure 4 highlights examples of use cases that can be leveraged to develop a critical mass of capability in Layer 2.

Some examples of use cases that can be leveraged to improve/expand the AI capability for numerical data in Layer 2 are summarized in Figure 5 below.

Layer 3

The capability acquired at Layer 2 would enhance the capability needed for Layer 3 (Figure 6)—again, it's cumulative. Layer 3 work is done while simultaneously enhancing efforts to improve the capability generated in Layer 2. The goal is to develop a critical mass of capability in Layer 3 (image data), while simultaneously improving and expanding the capabilities in Layer 1 and Layer 2. Images are high dimensionality data with colored images having additional dimensions. An apple is an apple because of information present in the color (red/maroon) and the specific shape. That means the pixels (individual portion) in an image acquire meaning only when processed along with neighboring pixels to the left, right, top and bottom. In Layer 3, the focus is only to work with labeled images, images that have image tags associated with them.

Some examples of use cases that

FIGURE 5

Use cases that can be leveraged to improve/expand the AI capability for numerical data in Layer 2

USE CASES	EXAMPLES	TYPICAL ALGORITHMS/TOOLS
Numerical a) Salient Drivers/ Features of decision-making b) Routing optimization c) Assortment optimization	a) What drives higher sales-reducing a large set of variables to a few dimensions b) Optimal delivery route planning for vehicles. c) Optimal product mix/assortment planning.	Discriminant Analysis, PCA, Linear and non-linear programing

Source: Authors

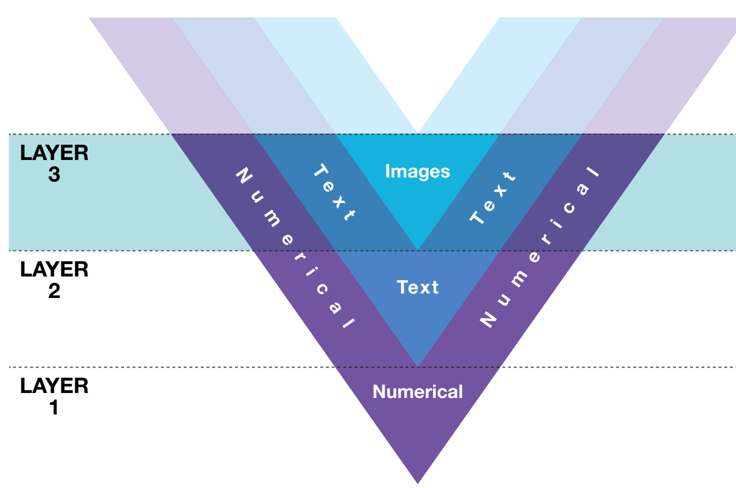
FIGURE 6

Layer 3

Data type Image, Text, Numerical

Technique Neural Networks
Optimization Techniques

Algorithm **Image Processing**
CNN, RCNN, Mask R-CNN, RNN, GAN
Text
Natural Language Generation: Article Summarization
Natural Language Understanding:
LSTM, Neural Word Embeddings, Q&A,
Coreference resolution, Bi-Directional RNNs
Numerical
Vanilla Neural Networks, Auto-encoders,
Deep Belief Nets, Dynamic Programming



Source: Authors

FIGURE 7

Layer 3 uses cases

USE CASES	EXAMPLES	TYPICAL ALGORITHMS/TOOLS
Images a) Classify images b) Object identification in images c) Style transfer d) Pre-processing scanned documents/ images for better quality data extraction	a) • Classify parcels damaged during delivery • Flag objectionable images uploaded on e-commerce/social websites b) • Identify left arterial enlargement from chest X-rays • Identify individuals in images • Assess the extent of damage to vehicle in motor insurance claim c) • Transfer color, patterns from a style image to the shape of a product. For example, generate a fabric design which uses color schemes and patterns used by Picasso, on basic flower pattern bedsheet. • On e-commerce website, display clothes on uploaded picture of shopper d) Data extraction from poor quality invoices with noise (stray marks, hatches, etc.) by de-noising	Convolutional Neural Networks, Recurrent Neural Networks, Generative Adversarial Networks

Source: Authors

can be leveraged to develop a critical mass of capability in Layer 3 for image analysis are highlighted in Figure 7.

The focus area for Layer 3 is to develop Deep Learning AI capability and apply it to images, textual data and numerical data. Some use cases that can be leveraged to improve and expand the capability associated with textual and numerical data in Layer 3 are as show in Figure 8.

FIGURE 8

Use cases that can be leveraged to improve and expand the capability associated with textual and numerical data in Layer 3

USE CASES	EXAMPLES	TYPICAL ALGORITHMS/TOOLS
Text a) Chat bots b) E-mail bots c) Contextual spell check	a) Service desk chat bots to answer most common employee queries related to password resets, available leaves, HR policies etc. b) Insurance E-mail bot to answer policy specific questions e.g. when is the next premium due, coverage of policy, etc. c) Correct OCR errors using contextual spell check to extract correct product description from scanned invoices	**Semantic NLP** *Natural Language Generation:* Article Summarization *Natural Language Understanding:* LSTM, Neural Word Embeddings, co-reference resolution, Bi-Directional RNNs
Numerical a) Fraud detection b) Network Analysis c) Dynamic pricing optimization d) Cybersecurity e) Hyper-personalization	a) Detecting Payment Fraud in online purchases b) Predicting server/device failure and its effect on connected downstream applications e.g. in power transmission c) Dynamically changing ticket price e.g. of hotel rooms, air travel, movies, plays and events to maximize revenue d) Detecting changes in network traffic e.g. to identify malicious software and DDOS attacks e) Targeted interventions e.g. hyper-personalized dietary plans or learning plans or insurance plans or goods to buys, or movies to watch	Artificial Neural Networks, Auto-encoders, Deep Belief Nets, Dynamic Programing, recommendation systems

Source: Authors

Layer 4

The capability acquired at Layer 3 enhances the capability needed for Layer 4. Work in Layer 4 is done while simultaneously enhancing efforts to improve capability in Layer 3. The goal here is to develop a critical mass of capability in Layer 4 (speech and video data), while simultaneously improving and expanding the capabilities already developed in Layer 1, Layer 2 and Layer 3. The focus area for Layer 4 is to start working with continuous and streaming data such as videos and real-time conversations. This layer is porous: There is no strict distinction between numerical, textual, image and other data types. In this layer, the use cases present a combination of data types. Some examples of use cases that can be leveraged to develop capability in Layer 4 are highlighted in Figure 10.

Completing the AI journey

The four layers we just outlined can be built at the company level or at the business unit level. Established organizations can choose to build the layers on their own or partnering with AI vendors. Thus, to build lasting AI capability, the first focus should be to enhance numerical data analysis capability. While the efforts to enhance this capability are being expanded, the focus should also be to improve textual data analysis capability. While the efforts to enhance numerical and textual are expanded, the focus should also be to improve image analysis capability. Finally, while all these three layers are being improved, the focus moves to advanced data forms, such as speech, video and connected intelligence. This layered approach fills the gap noted by other professionals. A recent McKinsey report notes the lack of clarity on strategies to profitably implement AI in organizations. Their survey found that 41% of organizations are still in the experimental stage of AI implementation.

There are exceptions to our proposed layered approach. From a strategic point of view, based on the distinctive competence of the organization, development of Layers 2 and 3 can be switched. Consider an established successful organization in the cargo-insurance business. For this organization to develop a lasting AI capability, image processing ought to be

FIGURE 9

Layer 4

Data type Connected intelligence, Video, Speech
Image, Text, Numerical

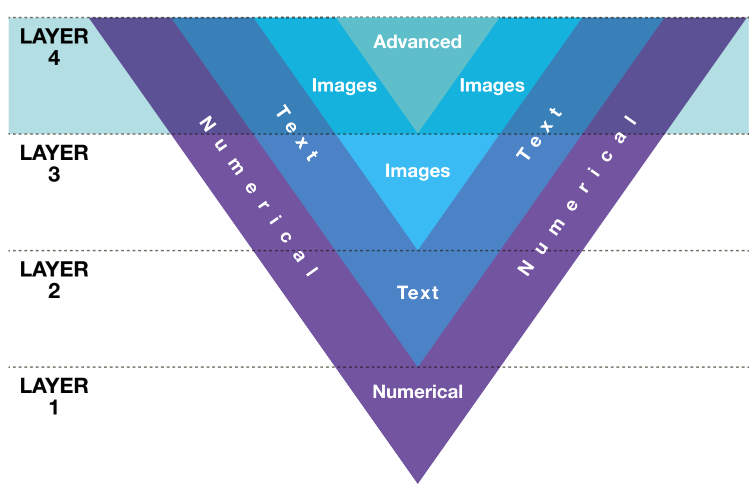
Technique Advanced AI techniques
Reinforcement learning
Bayesian Network Analysis
Video Analytics

Algorithm Advanced
IoT, Reinforcement learning, Bayesian Analysis

Image Processing
Transfer Learning, Convolutional Deep Belief Network, Deep Q-Networks

Text
Natural Language Generation: Language Translation,
Natural Language Understanding: Knowledge Graphs, Semantic Graphs, Word sense disambiguation
Speech Recognition: Text to Speech, Speech to Text

Numerical
Markov Models, Simulation, Simultaneous equations, Stochastic Programming



Source: Authors

FIGURE 10

Layer 4 use cases

USE CASES	EXAMPLES	TYPICAL ALGORITHMS/TOOLS
Advanced a) Connected intelligence b) Auto image tagging, c) Automatic vision-based inspection d) Video analytics	a) • Drones based last mile delivery for packages (vision, geo-location and voice input) • Generating titles for images (image recognition and NLP) b) Automatically tagging objects in images e.g. for use in self-driving cars c) • Identifying defective items e.g. manufacturing parts under production on conveyor belt • Identifying in real-time suspicious activity from security camera feed d) • Auto-indexing video content e.g. capturing brand coverage during sports telecasts • Generating title of the video (e.g. wedding video) based on the contents	IoT, Reinforcement learning, Transfer Learning, Knowledge graphs, IoT, Reinforcement learning, Bayesian analysis, Semantic graphs, Word Sense Disambiguation, Text to Speech, Speech to Text, Markov models, Simulation, Simultaneous equations, Stochastic programming
e) Image to code d) Text to code f) Voice to code	e) Generate bug free UI code from image of an idea depicted on the whiteboard (during brainstorming session). f) Generate bug free code in computer language from a command written in natural language g) Generate bug free code in computer language from a command issued through speech in any natural language	

Source: Authors

preceded by developing the capability to analyze text. This would ensure that the organization is able to capture the AI advantage by using image data to assess and validate any physical loss or damage to freight during shipment.

In a similar vein, it's worth mentioning the availability of enterprise AI solutions (like chatbots, solutions hosted on the marketplaces of Google, Amazon and Microsoft) that can be consumed by organizations after customization. This does not negate the need for the development of in-house cognitive capability. Such off-the-shelf AI solutions require deep customization to meet the idiosyncratic needs of organizations. Customization requires a bare minimum cognitive capability from the organization's perspective. So, our proposed approach is relevant even for those organizations who wish to adopt pre-packaged enterprise AI solutions.

In this article, we have focused only on cognitive technology capabilities. There are other equally important capabilities like organization structure and culture, industry maturity, resource availability, people issue and internal politics, change management and large-scale deployment. For example, deploying a robust and accurate algorithm on a large scale (production) necessitates complex interactions between hardware, Cloud, algorithm running time, API calls, application architecture and time-out issues in the user interface, to name a few. Managing these interactions effectively calls for specific managerial and coordination capabilities. Discussing these additional dimensions is a topic for another article.

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VIEWS ON TWO EMERGING TECHNOLOGIES

5G IS IT A REVOLUTION OR EVOLUTION FOR SUPPLY CHAINS?

The potential of 5G is exciting and revolutionary. The reality is that it may have limited application within supply chain for some time.

BY SYLVIE THOMPSON AND GINA SWEIDAN

Advances in technology and the demand for global connectivity has fueled the proliferation of cellular and IoT devices around the world. As video, IoT connections and mobile data traffic continue to grow, existing networks have become congested, creating significant demand for more capacity, higher speeds, improved reliability and reduced latency.

Think about this: According to Cisco, the projection for global mobile data consumption by 2022 is expected to reach about 80 Exabytes (billion gigabytes) per month compared to 20 exabytes per month in 2018. Additionally, Gartner reports roughly 8.4 billion IoT devices used in 2017, and anticipates this number to grow to 20.4 billion IoT devices by 2020, while Business Insider projects more than 64 billion IoT devices by 2025.

In comes 5G to the rescue. 5G is the 5th generation of mobile technology that will deliver more bandwidth, faster speeds (10 Gbps, or around 10 times faster than 4G) and lower latency (1 ms, or around 50 times lower than 4G), all with greater availability and reliability than 4G. 5G will enable intelligent connectivity between people, devices and machines driving digital transformation and propelling us toward a totally interconnected world.

5G will also create the technology landscape required to support the growing mobile data consumption and the ever-increasing number of connected IoT devices.

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5G is the foundation that will drive new emerging technologies and applications for businesses, industries and supply chain networks. 5G will empower a buzzword rich environment of edge computing, Artificial Intelligence, advanced senor technology, machine learning and so forth.

While that litany of promises and potential applications enabled by 5G sounds exciting and revolutionary, the adoption of these capabilities within supply chain may be limited for businesses for some time. In addition, there are several barriers and challenges that currently exist that make 5G network integration risky and difficult to implement. Yes, it's important for companies to understand the revolutionary potential of 5G, but also to recognize that it will likely occur through an evolutionary timeline.

5G is designed to support three major objectives:

1. Enhanced Mobile Broadband (eMBB) to support the rapid growth of mobile data traffic driven mostly by video streaming, video conferencing and interactive experiences. Enhanced Mobile Broadband is the extension of LTE capability providing higher speeds for applications across a wider coverage area. eMBB will provide the greater capacity necessary to support peak data rates for both large crowds and enhanced end user experiences.

2. Massive Machine-Type Communication (mMTC) to support the massive growth of IoT, particularly machine communications. This will enable wireless connectivity between billions of machines to generate, share and process data to drive use-cases for robotics, automation and remote tracking. Existing cellular standards are often unable to support machine communications. 5G technology will enable ubiquitous connectivity between 10 to 100 times more devices, allowing for hundreds of thousands of connected devices per square kilometer.

3. Ultra-Reliable and Low-Latency Communications (URLLC), also referred to as Critical Machine-Type Communications (cMTC), includes new requirements for latency (1 millisecond) and reliability (99.999%) that will be a major enabler of new applications and services, driving the connection between physical and digital technologies ranging from autonomous vehicles to remote surgery.

Although 5G has the potential to revolutionize the way businesses and industries operate, its challenges, dependencies and the general need for a compelling ROI will limit 5G to an evolutionary role within supply chain. Supply chains will need to fundamentally change in order to capture the potential of 5G, including underlying systems and processes, before they can achieve the business objectives of 5G and create value for organizations. In a field where networks, facilities and systems are designed and built to last years (think 10+), the ability to incorporate the level of change needed to capture the benefits will take time—significant time. Here are a few reasons that we believe evolution—not revolution—is the most likely path for 5G within supply chain.

- 5G network rollouts will be costly, with estimates totaling $2.7 trillion. According to the Ericsson Mobility Report, $1 trillion of this estimate is allocated to 5G telecom network infrastructure and the remaining $1.7 trillion to hardware, software and service investments by businesses to integrate 5G into products, processes and private infrastructure. Such an outlay of capital will require an immediate commercial application to capture revenue. It's no wonder that the initial focus by providers is on commercial consumer applications within select urban centers. If you watched this year's Super Bowl, you witnessed many "firsts" in 5G application.
- 5G will not only require telecom network providers to change their infrastructure, it will also require companies to transform their existing networks. Companies that integrate 5G capabilities will be required to modify their existing IT landscape to become compatible and interoperate with 5G networks. These are inherently complex and will require a high-level of customization for successful deployment. A recent study conducted by Infosys reported that more than half of the reporting firms, including telecom firms, struggled to understand some basic areas of 5G technology including virtualization, software defined networks and core mobile networks.
- Availability of 5G enable devices is also limited. The first iPhone enabled 5G device will not be available until the fall of 2020. Now, think of all of the devices and all of the companies tied to those devices that are required to enable even basic automation in a factory or a warehouse. Robotics, sensors and other forms of automation are not new to supply chain. The automotive industry, for example, has embraced robotics in manufacturing for decades. Other sectors, such as the grocery and retail industry, have only just recently deployed these technologies, particularly in high-density automated warehouses. It takes numerous providers and systems to enable a single facility. Regardless of the use case, and setting aside the ROI question to justify the changeover, conversion to 5G will require an orchestrated effort that will ultimately mean a rebuild for many.

• Security assurance is another concern driven by the sheer increase in the number of connected sensors, devices and assets used to collect, track, transmit and analyze massive amounts of sensitive information. This increased connectivity combined with new network architectures creates the potential for unknown vulnerabilities.

• A shortage of skilled and qualified workers capable of correctly building, implementing, deploying and servicing different elements of 5G technology will also influence the speed of adoption. According to a study conducted by Infosys, a majority of the surveyed companies stated that finding the right talent for 5G technologies is a challenge. Companies will need to invest in filling the skills gaps to ensure employees are able to understand, develop and support 5G technologies.

In addition to the infrastructure cost implications of 5G, businesses have yet to see significant supply chain use cases that will generate positive ROI with supporting quantitative evidence of improvements to entice business leaders. If companies are not able to develop concrete businesses cases with significant benefits to justify early write-downs of existing supply chain investments in order to convert to 5G technologies, it will be extremely difficult to obtain approvals for funding of 5G projects.

To be clear: We recognize the revolutionary potential of 5G, and in some fields, 5G will empower revolutionary change. Healthcare, with a particular focus on wearable devices, is a good use case example. The ability to not only track a person's vitals in real time, but also to respond and intervene during periods of distress could mean the difference between life and death in some cases.

The most compelling use cases are consumer-focused experiences. Indeed, the revenue potential of direct consumer experiences is the underlying driver in the economics of 5G and why telecommunications companies are betting huge dollars on a "build it and they will come" approach to 5G.

When it comes to supply chain, like any new and emerging technology, there is always hype fueled by those who want to make sure they don't miss the new bandwagon. 5G is no exception. Filtering through the hype to understand the true implication of an emerging technology is the hard task. Similar revolution versus evolution comparisons exist within supply chain. We can find them by examining the emergence and adoption patterns of other technologies such as RFID, robotics and Big Data.

• RFID emerged as a technology advancement more than 25 years ago. One of us was personally involved in an RFID proof of concept back in 2000. RFID has had numerous attempts over the years at wide-spread adoption, yet the technology failed to find a compelling business case to unseat existing bar code technology until recently. That use case today is in-store applications that address significant challenges such as in-store inventory accuracy (pre-RFID programs in-store inventory accuracy ranges from 65% to 75% depending on product category). In part, that's because poor inventory accuracy was never considered a problem that needed to be addressed tactically until now. Finally, a compelling case has emerged, which is maximizing revenue through buy-online pick-up in-store and ship from store capabilities.

• Robotics presents another comparable example. The technology has been available for decades and found compelling applications in manufacturing, especially automotive, nearly 30 years ago. However, until the advent of e-commerce fulfillment, robotics was hard pressed to find a compelling use case in warehousing. A high concentration of facilities in regions ideally located for direct to consumer shipping has created a systemic labor shortage that has driven up operating costs and tipped the scales in favor of robotic automation. To the labor challenge, add the high cost of physical square footage associated with the new warehouses going up in dense urban centers to enable next day and same day delivery as another catalyst for highly-automated facilities.

• Finally, consider Big Data and the challenge of capturing information to track, trace and provide real-time visibility. Supply chain control towers and supply chain visibility have also been topics of much discussion, as they are considered critical to smooth operations. The question for firms is: How much data is actually required to achieve productive supply chain visibility? Today, we work with companies that have a tremendous amount of information available. But, in many cases, they have information overload generating distractions rather than focused operations. Do we really need to know where every item and every carton is at every moment? Without laying on other technology solutions like Machine Learning or Artificial Intelligence, how much value will that additional information deliver? And then there is the question: How much is your organization willing to pay to capture, digest and understand that additional information?

The 5G revolution is tantalizing, but we believe that adoption within the supply chain will lag. It will take a slow evolution changeover of networks, infrastructures, facilities and teammates. Moreover, it will take place only when a use case emerges that can be directly tied to revenue generation while at the same time performing a function that cannot be done by any existing and proven technology solution.

THE PHYSICAL INTERNET

A SHARED LOGISTICS MODEL

The Physical Internet initiative promises to revolutionize the way we ship product by mimicking the digital world. But will it catch on?

BY STEVE DENUNZIO

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BOOM! Did you know that every time you send an email, you cause an explosion? Don't worry, we won't tell anyone. Many people don't realize it, but that's the way the internet works.

At some point today, you probably sent an email. The moment you hit "send," your email was broken into numerous packets. Those packets were then routed all over the world separately, probably to diverse interim locations and were ultimately routed to their destination where they were reassembled so that the message could be read by your recipient.

This process is called Transmission Control Protocol/Internet protocol, or "TCP/IP" for short. It really doesn't matter that you're using one internet provider, and the recipient is using another. Nor does it matter that you sent the email through Microsoft Outlook, and they're reading it in Apple iMail. The delivery mechanism and network are agnostic.

If you think about it practically, as the sender, you don't really care that this process has occurred. You just want the intended recipient to receive the email as quickly as possible, and in one piece. Nor does the recipient really care how it got to them; they just want to ensure they don't miss an important message.

Consider also the concept of the Cloud. As a consumer, you may already store your photos, documents and other important information on the Cloud. Apart from customer service considerations, you probably care little that it's Microsoft OneDrive, Dropbox, Apple iCloud or some other service that's providing you this capability. You may even spread your information across all of them. You care exclusively that the data is available when you need it.

Now, let's turn our attention to freight. Ultimately, the end customer cares little how that package arrived, or whether the person delivering it had a blue, brown or yellow uniform. They just want those "Seven Rights of Logistics:"

1. the right product;
2. the right place;
3. the right time;
4. the right price/cost;
5. the right condition;
6. the right quantity; and
7. the right quality.

By contrast, shippers and solutions providers have historically relied on the efficiencies afforded by bulk movement to minimize the total cost of logistics while delivering those Seven Rights. And so, freight is consolidated into trucks, onto rail or onto cargo ships, often without a discrete order being broken. Orders often travel to dedicated distribution or fulfillment facilities, where the orders are processed together. To return to the analogy of email, the message is never broken apart.

However, this bulk movement of freight comes at a cost:

- trucks and ships generate great operational cost and environmental impact;
- the average trailer is 60% full, and often empty (deadhead) upon return; and
- product is shipped to the distribution point in bulk, and then touched and moved again on its last mile journey to the customer.

What if you could mimic the digital world in the physical, with a process whereby shipments could be broken into packets that are shipped across a shared network? That digital model was behind the creation in 2010 of the Physical Internet by Benoit Montreuil, who was then at Université Laval and is now a professor at the Georgia Institute of Technology. In Montreuil's model, freight would move through a network just like those emails through the Internet. The Physical Internet model is based on the following three pillars.

1. Freight, whether it's traveling between nodes in the supply chain, or the last mile to the customer, travels in ***standard-sized containers****. In bulk, this means that smaller (than traditional intermodal) containers carry increasingly discrete cargo, and snap together, almost like Lego-brand plastic blocks. For end-consumers, delivery packages are also denominated in specific, standard sizes to optimize delivery efficiency.*

2. Traditional, vast distribution centers are replaced by more and smaller hubs. These hubs, by nature, are points-of-presence closer to the end consumer. This results in a less expensive last mile and a lower cost of transportation. However, these ***hubs*** *may handle freight for numerous shippers and carriers. They are agnostic to who sent or owns the product. In turn, efficiencies are gained as all senders' freight is delivered using common delivery to everyone's customers.*

3. With these hubs positioned in ***optimal locations*** *in transportation lanes, routes can be optimized for all parties and* ***advanced technology*** *like autonomous trucks can be used to quickly deliver product.*

The benefits of the Physical Internet include speed and efficiency and lower barriers of entry for all participants. Nevertheless, it's fair to highlight some drawbacks of the model, including the following.

- ***Privacy and control.*** Not all businesses will be willing to share proprietary information and surrender a certain level of control.
- ***Standardization.*** The long history of the current intermodal shipping container (see Marc Levinson's "The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger" for a great overview of the story) highlights the time and effort that will be necessary to standardize on new container and parcel dimensions and forms.
- ***Regulation.*** A broad array of regulatory entities will need to agree on the parameters for such a model to be successful.

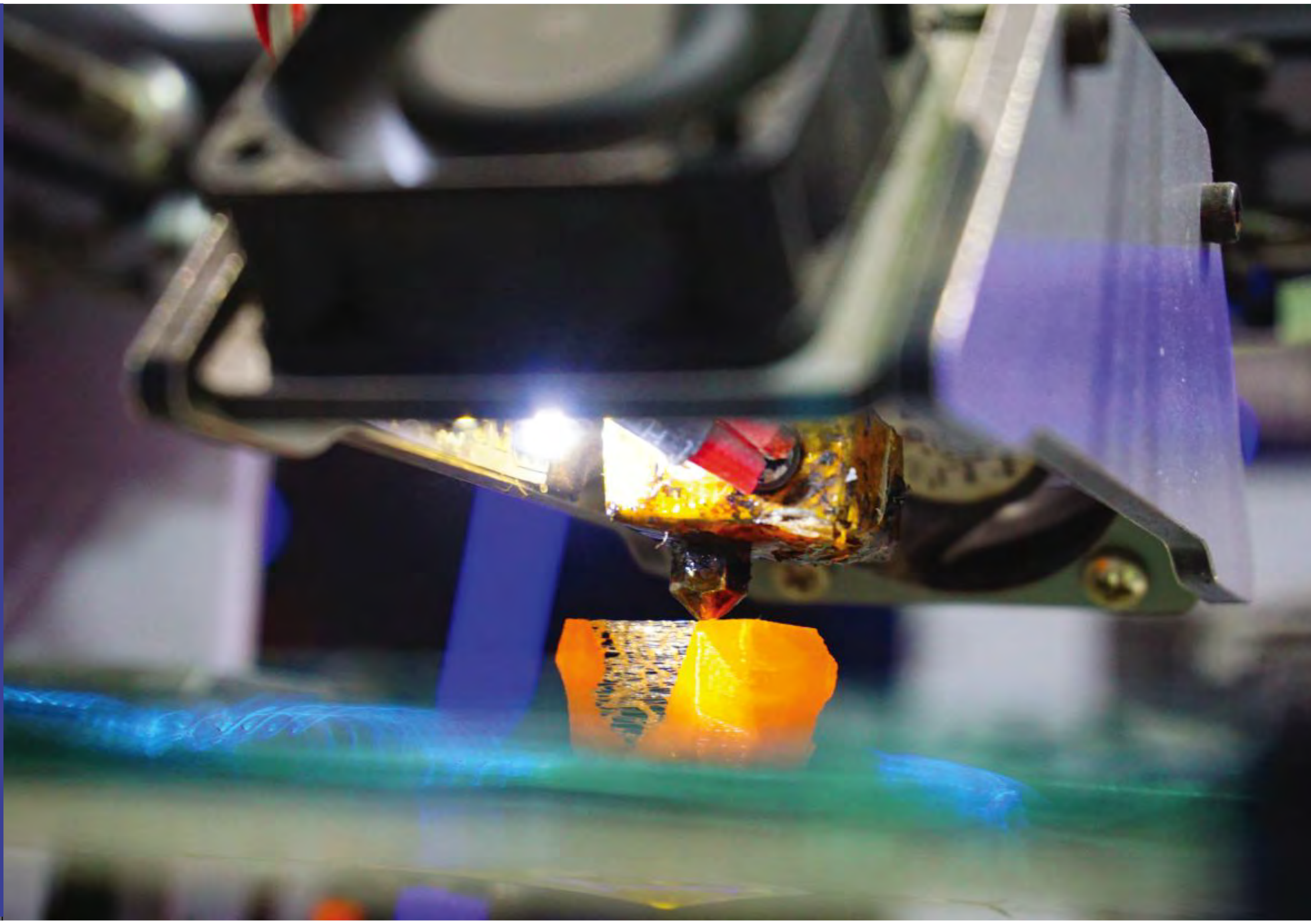
Europe is leading the way when it comes to implementing the Physical Internet. By 2050, the organization The Alliance for Logistics Innovation through Collaboration (ALICE) hopes to have a European Physical Internet in place. Time will tell if the Physical Internet comes to fruition, but it highlights for us all both the impetus and importance of continuous improvement and ongoing analysis of existing processes and models.

PRIME TIME FOR ADDITIVE MANUFACTURING

Once a disruptive technology, 3D printing and additive manufacturing are ready to make the leap from the fringe to mainstream.

BY JAYANTH JAYARAM, ALAN AMLING, ATANU CHAUDHURI AND DAN MCMACKIN

Disruption is the rule in supply chain management and manufacturing today. Although conventional supply chains remain the backbone of global commerce, most observers expect convention to make way for fundamentally new processes such as manufacturing on demand that involve additive manufacturing (AM) and 3D printing. That's certainly our conclusion based on our research for this article, which included field studies of the customers of Fast Radius, a Chicago-based AM solutions company. Utilizing in-depth interviews with key personnel and a review of secondary sources, we've put together a best practices framework along with insights for supply chain managers who are considering AM in the context of their digital supply chains (see sidebar: About our research).



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The story of additive manufacturing is similar to other disruptive innovations that made the leap from the fringe to the mainstream, such as the Internet, electric cars and social sharing platforms like Uber and Airbnb. While AM has a nearly 40 year history, it's now poised to make that transition over the next decade. Capabilities and case studies continue to grow as the drawbacks to AM such as time, cost and material availability, continue to shrink. Forward-thinking companies such as GE, Seimens and Wassara are already reaping the benefits of AM (see sidebar: Putting 3D to work).

Early adopters aside, Industry 4.0 is forcing managers to think differently about where and how goods are manufactured and moved around the world. As a result, their digital offspring, aided by additive manufacturing (AM) and 3D printing, are gaining significant traction in the world of manufacturing and just-in-time fulfillment. Over the last decade, investment in AM research, technology and materials has skyrocketed. According to the 2019 Wohlers Report, the global AM market is expected to hit $15.8 billion in 2020, growing to $35.6 billion in 2024. This is dramatic growth from AM's humble beginnings in the 1980s.

Putting 3D to work

GE, Siemens and the Swedish mining company Wassara are examples of early adopters of 3D printing in the supply chain.

GE was able to combine 855 traditionally manufactured parts for its new Catalyst turboprop engine into five additively manufactured parts. This not only vastly simplified GE's supply chains but enabled a 20% lower fuel burn and 5 percent weight reduction.

Siemens is using AM to produce and repair critical gas turbine components like burner heads and swirlers. In one AM initiative, Siemens combined 13 parts into a single part, resulting in a 25 percent weight reduction. In another, fuel and air pipes that were placed outside the burner in conventional models, could now be routed internally, greatly reducing the risk of damage and leaks. AM also generated savings in fuel consumption, improved efficiency and the performance benefit of a strong cooling effect thanks to improved air flow. This reduced the temperature by up to two-hundred-degrees Celsius, which is noteworthy because a mere 10-degree reduction substantially increases the life span of turbine blades.

Wassara uses high-pressure water to power Down-The-Hole hammers that extract minerals with minimum environmental impact. The complexity of the existing design leads to expensive parts and frequent rejects in production as a result of the joining process. It also lends to failures due to wear and corrosion. Using AM, Wassara redesigned the hammer's sliding case, simplifying complex fabrication steps such as drilling cross-holes that require one end to be blind plugged or welded and chose a new material alloy of maraging steel. The additively manufactured sliding case showed no signs of corrosion and only minimal wear compared to a standard part.

AM adoption

AM represents a fundamental change to the traditional store and ship model. Rather than manufacture and store what a company thinks the consumer wants, goods can be produced and shipped on demand—based on what the consumer is ordering. This allows for customization, and for new designs that are not always possible with traditional manufacturing. Other benefits include parts reduction, efficiency in supply chain management and improvements in product performance metrics, like reduced weight and improved quality. As the quality of products produced through AM increases and the cost of materials and production declines, an increasing number of goods will be produced more often, in lower quantities and closer to the point of consumption. That aligns supply with demand in a way never before possible.

AM also has significant potential to lower the risks involved in the launch of new products. Using AM, companies can very quickly shift from prototype to production to test the market for a new product with zero inventory risk. If needed, changes can be made quickly and in real-time. If it sells on the website, the company can similarly shift into production mode with 3D printing until sales justify a conventional production line.

The early stumbling blocks to the adoption of AM, such as an increase in manufacturing time and the cost and availability of materials, are fading. However, there are still practical challenges that must be considered to make the business case for AM.

For one, a manufacturer must understand the true cost of ownership of its products, including the dynamic stream of life cycle costs. What's more, the benefits of AM are often based on assumptions that must be validated. There is also likely to be resistance to change. In some companies, design personnel may be slow to accept the changeover. In others, it may be production personnel who have to be convinced. For those reasons, implementing AM involves the careful consideration of change management strategies across a variety of stakeholders. These will vary from one company to the next.

Customers may also play a pull or push role in adoption. In some instances, a customer may have a part it wants produced using additive manufacturing, pulling its supplier along. In other instances, a customer may be pushed into accepting 3D printed parts after an AM technology provider educates it on the benefits of additive manufacturing for its product—the push. Of course, pull and push approaches can be combined to offer total customer solutions support.

The new realities of AM

As the technology improves and the market gains experience with additive manufacturing, we have identified several new realities.

Additive manufacturing is more than a printer. The technology got its start in limited runs of consumer products and prototypes. Industrial production is where it's now headed. Consequently, metals showed the strongest growth of any AM material for the fifth straight year, growing nearly 42% in 2018 according to the Wohlers Report. However, industrial scale additive manufacturing is more than just the printer and materials. It represents an integrated ecosystem of processes and services. The same product design, using the same printer and the same material, could have vastly different costs and quality characteristics depending on the manufacturer. More advanced manufacturers have moved upstream to provide design and business planning services to their AM customers, as well as downstream post-production, quality control and logistics support. For this reason, OEMs must not only certify each additive manufacturing partner, but also each product produced by that manufacturer. Consequently, AM marketplaces that merely match customers with AM suppliers may be a poor fit for industrial production, unless the marketplace under consideration certifies the suppliers and assures quality. Some of the more sophisticated service bureaus are trying to make the transition from prototyping to industrial production, but at this point, no service bureau has established a leadership position in industrial production.

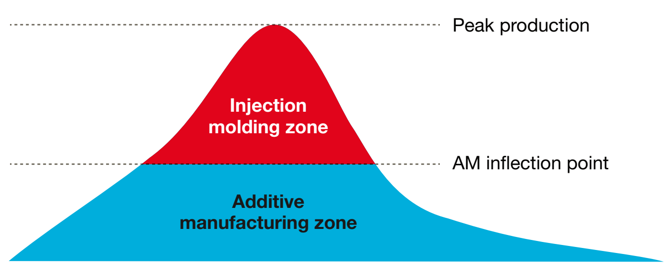
Economies of scale and diseconomies of scale. The improved quality of final parts, along with increased throughput, make 3D printing practical for small and mid-scale manufacturing. In some cases, tens of thousands of units can be produced in a cost-efficient, timely manner compared to the cost of conventional manufacturing. This is enabled in part by the availability of a variety of improved materials. For instance, investment in the use of metal in AM has skyrocketed, with process improvements and new technologies driving down the cost per part. Similarly, there is a high degree of flexibility and versatility in the choice of materials. Today's additive manufacturing systems operate like Swiss Army knives, with a single piece of equipment able to perform dozens of applications. By working with a wide range of materials and switching between them, a single machine is capable of producing parts for many different applications. One of the best examples of this versatility is resin-based polymer 3D printing processes, like stereolithography (SLA). The same compact, desktop SLA 3D printer can produce biocompatible splints and surgical guides in a small dental office, as well as jigs, fixtures and temperature resistant molds for an automotive factory.

Lifecycle approach to additive manufacturing. The decision to employ AM does not need to be an "all-or-nothing" decision. An emerging approach to manufacturing is to use the most appropriate manufacturing method for different points in a product's lifecycle. In the early days of a product's life, that may be using AM for prototyping—some companies are also certifying AM for early production runs of some products when sales volumes are low.

However, as products mature and higher volume production is needed, AM will reach an inflection point where it makes economic sense to switch to traditional manufacturing methods such as injection molding. This inflection point will vary by product and application but is continuing to rise as material costs plummet and AM technologies improve. This concept is reflected in Figure 1 as the "injection molding zone." As the product reaches the end of life and volume drops below the AM inflection point, the most appropriate production method returns to the "additive manufacturing zone." Digital designs of replacement parts can be stored in virtual inventory, to be produced on-demand, improving service levels while dramatically lowering inventory holding costs.

FIGURE 1

AM inflection point



Source: Authors

Fast Radius

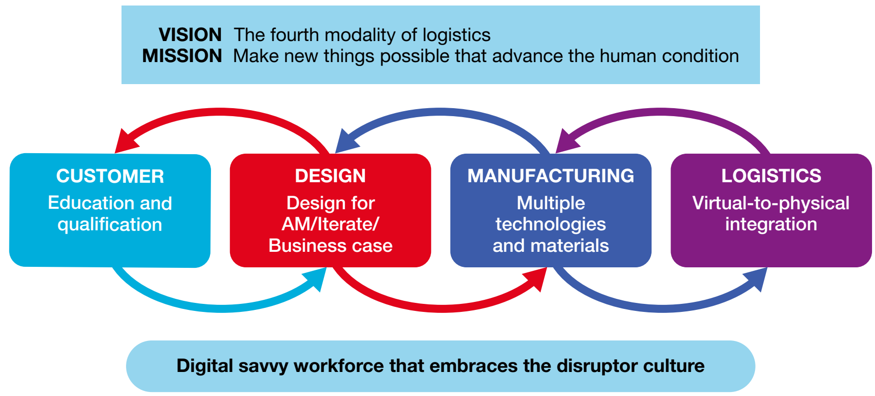
To better understand the state of AM today, we talked with Fast Radius, a Chicago-based contract manufacturer. Fast Radius along with its strategic partner, UPS, were the only North American companies identified by the World Economic Forum as one of the nine best manufacturers in the world implementing the Fourth Industrial Revolution (see sidebar: Fast Radius, a 3D innovator).

In Table 1, we describe six user cases from Fast Radius's customer base. They represent six different industries, ranging from the materials handling industry where Bastian is using 3D printing to manufacture components for its robotic picking arms to the outdoor power products industry where Husqvarna Group is manufacturing parts for its products.

Based on the breadth of industries and customers served by Fast Radius, we've developed the following take-aways on how to build a successful business model around an AM-enabled supply chains. We call this the "anatomy of a disruptor" (Figure 2).

FIGURE 2

Fast Radius: Anatomy of a Disruptor



Source: Authors

The foundation

Fostering a technology disruptor culture. The foundation of this model is built on digitally savvy employees who integrate diverse capabilities along the digital thread, coordinated through a compelling vision and mission. But it's more than that: A key enabler of a successful AM platform is a culture of technology disruption. A dynamic, forward-looking corporate culture helps achieve this disruption mindset by attracting and retaining young and energetic engineers who are technology savvy. These engineers are driven by an opportunity to see real contributions to their client's bottom line and are often extremely motivated and focused on growing their careers along with the growth of the company. These tech-friendly engineers generally strive to be part of a young, ground-breaking company. Many of these employees are "digital natives" and do not need to "unlearn" the design limitations of traditional manufacturing methods.

Fast Radius considers itself to be "technology and material agnostic." Currently, it uses four primary technology providers in its factory (HP 3D Printing, Carbon, Stratasys and Desktop Metal) with dozens of material options. That enables Fast Radius to match the right printer technology and material to each application.

Fast Radius, a 3D innovator

Fast Radius is an additive manufacturing innovation partner based in Chicago. It helps companies discover, design, make and fulfill products that are uniquely enabled by AM or through a combination of manufacturing processes. This enables the company to offer new supply chain solutions through a combination of virtual warehousing and a mass-customization approach geared toward final assembly solutions, or to entirely re-design new products. Once these applications are identified, Fast Radius manufactures and fulfills these products/solutions through global nodes of additive production.

Fast Radius is building an industrial-grade operating system to orchestrate the end-to-end workflow by digitally connecting these nodes. Making repeatable parts at scale with additive manufacturing is often compared to the complexity of semi-conductor and wafer fabrication processes. The Fast Radius OS allows it to deliver consistent, repeatable parts at nodes around the world, which are proximate to the locus of demand.

The top leadership at Fast Radius has referred to this Internet-enabled, distributed manufacturing model as the Fourth Modality of Logistics. According to those we interviewed at the company, AM will transform the Cloud into the Fourth Modality of Logistics, augmenting logistics transport by air, land and sea. Certain goods will be transported by "data over the Internet" to distributed production sites, as compared to a "parts on planes" approach.

TABLE 1

Comparison of case studies using Fast Radius services

COMPANY NAME	INDUSTRY	PROBLEM FACED	AM SOLUTION APPROACH	OUTCOMES
BASTIAN	Material handling	Design and manufacturing of a material handling system that can handle a wide variety of product shapes, sizes, and densities without having to invest additional capital in multiple custom grippers for the picking arms.	By using 3D printing for critical parts (around 50% of BOM), Bastian Solutions can quickly scale the robot arm for its customers' requirements. Once the adjusted design is submitted to Fast Radius' Virtual Warehouse, the customer receives the additive parts in days instead of weeks or months. This helps customers get their new materials handling systems up and running with little interruption to their business. An example of such a part in the system is a proprietary "Shark Fin" adaptive gripper using Carbon® Digital Light Synthesis™ and EPU 40 material. Carbon's material enabled Bastian Solutions to develop a unique set of fingers that are strong but pliable–capable of picking up anything from a laundry detergent bottle to a tube of lip gloss.	Lightweight equipment, improved energy efficiency, rapid manufacturing of custom parts, significant project time and cost savings.
CURTISS	Bike	The complex parts were difficult to produce using CNC machining with long lead times. The new unique bike needed to go into production quickly.	The engineers at Fast Radius worked with Curtiss to make their designs ready for manufacturing. Together, they created parts that could be manufactured while still adhering to Curtiss' high design standard. The Fast Radius team evaluated all of the part requirements and created a hybrid solution that comprised three separate production processes, including legacy and additive methods.	2 days reduction in lead time compared to any other supplier, 95% first-pass yield for the 60 parts produced by Fast Radius.
STEELCASE	Furniture	There was a need to expand the personalization options for the SILQ chair and continue to reimagine the design. Steelcase wanted to explore how additive manufacturing could improve the product development process and differentiate their products in the market, while also greatly reducing the time it took to bring the product to life.	Steelcase™ partnered with Fast Radius and Carbon® to design, engineer, and print a custom arm cap using additive manufacturing processes. Fast Radius designed the additive manufactured arm cap in four zones that provided different attributes based on how someone's arm might interact with the cap. Although each zone was designed separately, Carbon®'s DLS™ technology allowed the entire arm cap to be printed as one cohesive part using EPU 41, a material that is both flexible and conforming. And the use of lattices reduced material usage by up to 70 percent without sacrificing performance.	Streamlined product design and development; Improved and unique aesthetics; Simplified the assembly by consolidating three parts into one; Improved customer experience through mass customization at scale.
COAPT	Medical device	Upgrading production to the next generation of 'complete control' systems required retooling of systems software as well as redesigning hardware components. Speed to meet product release time was vital.	Fast Radius used patented additive processes to print 36 unique designs yielding 195 parts for the customer to evaluate for functional use. Producing at this rate of prototypes quickly helped Coapt get their own finished products faster to the market. It also further tested their testing ability at a fast pace.	Reduction in print time of end-use parts; Increase in print parts per print; Reduction in weight of a part; Increase in the rigidity of a part.
COBALT ROBOTICS	Producing security robots	Finding a cost-effective supplier that could deliver on the exact specifications of the part.	Fast Radius helped on the cosmetic parts of the robot machines. Specifically, they helped manufacture critical parts using urethane casting. They recommended new CNC master patterns that were more accurate compared to Cobalt's original FDM ones that had fitment issues.	Saved 62% on the cost of urethane casting; Saved 33% on the cost of 3D printing; Saved 90% on the cost of painting and finishing; Saved 7% on the overall cost of robot production.
HUSQVARNA GROUP	Outdoor power products	Identify parts that can be made more efficiently and sustainably through AM.	Fast Radius helped screen parts and narrow down parts that could be produced at a larger scale and yet of good quality using AM. Furthermore, they identified the most appropriate AM technologies (in this case, Multijet Fusion (MJF) and Carbon Digital Light Synthesis (DSL)) which are best suited to produce the parts based on price and performance needs.	Reducing carbon footprint through less materials waste; Improving spare parts fill rates; Lowering inventory carrying costs.

Source: Authors

Capabilities

Customer education. Fast Radius has found large gaps in the awareness of AM capabilities within its existing and prospective clientele. These gaps pertain to different AM technologies and equipment. A second key gap is evaluating the business case needed to justify AM.

Gaps in awareness of AM and justifying the ROI through metrics are two of the key factors in AM deployment. Therefore, Fast Radius conducts tailored workshops among a small group of prospective clients. These workshops typically result in clients signing up for dedicated engagements with Fast Radius on AM projects.

Fast Radius helps enterprise clients adopt AM through its proprietary Application Launch Program (ALP). The six-month program helps companies identify applications, validate business cases, develop designs and prototypes, test and certify the applications and prepare to scale.

Building unique qualifying process for AM. This idiosyncratic process gives Fast Radius a competitive edge, and clearly positions it as a better value-added partner compared to service bureau firms whose product/service portfolios are rather limited. The competitive advantage of an idiosyncratic qualifying process is that Fast Radius is able to offer life cycle support and quality assurance of its AM parts and processes. Also, it helps by offering suggestions on new SKU creation and old SKU retirements on a dynamic basis.

Building the business case. As noted earlier, building the business case for AM can be a challenge. To help customers address this challenge, Fast Radius educates them on a process called Total Value of Additive (TVA). The TVA concept is similar to Total Cost of Ownership (TCO) but applied to AM. While the cost of materials remains a primary driver of AM unit cost, TVA includes all costs, such as new product development (NPD), supply chain, re-design costs after launch and carbon footprint reduction. On the revenue side, incremental revenue is considered as well as brand impact, customer experience, capturing otherwise foregone opportunities, compressing NPD cycles and functional improvements (such as deweighting and parts consolidation). Considering the impact on supply chains from minimum order quantities and inventory holding costs for low volume service parts could flip the equation in favor of AM.

Iterative design and material-agnostic solutions. Fast Radius is representative of a new breed of AM manufacturer that understands a customer's needs first and then finds the most appropriate manufacturing method, technology and materials through an iterative design process. It's end-to-end customer-oriented solutions range from digitization all the way up to spare parts delivery on demand to remote locations across the globe. Fast Radius has found that an AM solutions provider must help customers choose an appropriate path of adoption over time. On many occasions, the solution calls for a mix of traditional and AM processes to be used. Fast Radius facilitates both for its customers.

Building data science capability. Through interactions with clients, Fast Radius gathers large amounts of data. These interactions take the form of problem-solving for specific projects identified by clients (the pull approach we discussed earlier). They also prompt new directions for the customer using a push approach. The latter is partly driven by analyzing the huge data set captured through end to end discussions with customers.

As Fast Radius develops recipes to turn CAD drawings into high-quality parts, the information gathered during the design and production phases creates a virtuous circle of information that continually improves those processes. A key challenge in the industrial adoption of AM is an assurance of quality throughout the process. Using data from its printing machines, Fast Radius can predict the failure of a build before it is fully completed, and then rectify the design as a part moves through the production process.

Virtual-to-physical integration. While products can be modified in infinite ways

About our research

Open-ended and guided interviews were conducted with Fast Radius, a leading additive manufacturing company. Interviews included the CEO, COO, chief marketing officer, director of manufacturing and supply chain, chief application engineer, additive/traditional manufacturing solutions manager and the chief designer. Each interview lasted approximately 30 minutes. The topics covered ranged from strategic long-term issues to customer/application-specific strategies, and also included a component of forecasting future trends in AM. These interviews coupled with published customer testimonials (case studies) formed the basis of this work. Further clarifications on themes emerging from the interviews were sought from the company. The resulting and updated best practices framework is reported in this article.

Readers can learn more about the state of additive manufacturing from the following:

"Additive manufacturing revolution for gas turbines," by Niels Anner, siemens.com.

"Co-creation and user innovation: The role of online 3D printing platforms," by Thierry Rayna, Ludmila Striukova and John Darlington, *Journal of Engineering and Technology Management*.

"Digging deep with Wassara," published on Renishaw.com/en.

in the virtual world, we live in a physical world. Optimizing the best of both worlds requires integrated capabilities. AM holds the promise of manufacturing goods in smaller quantities, closer to the point of consumption, allowing dramatic decreases in cost and carbon footprints. AM also allows products to be stored virtually as digital designs that can be printed on demand. All of this requires alignment with physical logistics services. To that end, Fast Radius has worked with global logistics provider UPS on a virtual warehouse solution. The Husqvarna case study in Table 1 is an early example of the virtual warehouse.

Vision for Industry 4.0. Vision is a soft term that is hard to measure, but the successful adoption of additive manufacturing requires top management with a vision and an understanding of how AM fits within Industry 4.0. It's particularly important to track any changes in the vision and to stay aligned with dynamic changes in the environment. For example, the original vision of Fast Radius's co-founders was to provide globally distributed manufacturing, on-demand. However, this original vision evolved into The Fourth Modality of Logistics, an idea that highlights AM's role in the emerging digital supply chain. This evolution encompassed end-to-end manufacturing of industrial parts and products, from design through delivery. This new vision enabled the company to leverage the unique capabilities of AM, including de-weighting designs, combining multiple parts into one and "making the unmakeable." This vision is supported by a mission to "make new things possible that advance the human condition."

The importance of a compelling narrative was supported by a recent article in the *Harvard Business Review* on the top 20 business transformations of the last decade by Scott D. Anthony, Alasdair Trotter and Evan I. Schwartz. The authors found that the common element between all 20 successful transformations was a narrative that infused a higher purpose into the culture and provided clarity to everyday tasks.

Moving AM forward

Fast Radius' efforts to help customers solve manufacturing conundrums utilizing additive manufacturing and 3D printing is an example of technology disrupting long-held processes and their underlying assumptions. More importantly, as more companies like GE, Siemens and Wassara adopt AM, the technology is poised to leap from the fringe into a mainstream. Savvy supply chain leaders will take the time to investigate where 3D printing and AM fit into their futures.

DISTRIBUTION DISRUPTION

Change is coming to traditional distribution—if it's not already here. It's time to get ready.

BY STEVE SCALES

As channels become increasingly integrated and digital consumers' expectations mature, speed and convenience are now table stakes for every retailer. Delivering on that promise, at a lower total cost to serve, will require a radically different distribution center (DC).

Instead of humans continually walking the floor, replenishing locations, picking various items from boxes or crates to fill the constant stream of orders received and then packing them up for delivery to customers, the processes will be handled by machines. Autonomous trucks will pull up at the delivery doors, greeted by various automated handling equipment that unloads the trailers and tends to all movement throughout the facility. They'll be busily picking, packing and sending off completed orders in real time, with no human intervention, save the handful of specialist workers on site who will monitor the machines' performance on a dashboard and tweak them as necessary.

Steve Scales is a managing director at Kurt Salmon, part of Accenture Strategy. He can be reached at steve.scales@kurt-salmon.com.

The future is here

It sounds futuristic, but it's not far off at all. A new study from Accenture Strategy found the majority of retail executives (87%) believe they must leverage Artificial Intelligence (AI) to achieve their growth objectives and further, 68% agree they risk going out of business in five years if they don't scale AI across their organizations. As robotic and AI technologies move from concept to implementation—and retailers push to scale across the organization—planning and distribution processes will require far fewer human interactions.

Walmart, for example, announced plans in 2018 to open its "first high-tech distribution center for fresh and frozen groceries" in Shafter, California. The new facility will process 40% more products than a traditional DC, according to an announcement from Walmart. Walmart also recently announced the expansion of similar robots for use in stores to handle a range of repetitive tasks.

Always at the forefront of the use of new-technology, Amazon recently introduced two new robots, Xanthus and Pegasus. The former is a highly-compact, autonomous driving robot designed to deliver inventory to a picking station, while the latter is capable of sorting and moving individual packages. According to a report in Venture Beat, Brad Porter, head of robotics at Amazon, said that Xanthus and Pegasus won't be confined by traditional warehouse borders and, instead, can "collaborate" with human workers on a variety of tasks. The company also said it rolled out a robotic palletizer this year that has carted more than two billion pounds of totes in total across Amazon's fulfillment centers. The Pegasus sorting system has driven two million miles to date while cutting the number of mis-sorted items in half.

Arguably the most advanced warehouse in the world is the one in Shanghai built by China's second-largest retailer, JD.com, which the company says is the world's first fully automated facility of its kind. Operational as of June 2018, the 430,000-square-foot facility features a team of more than 20 robots that pick, transfer and pack packages, as well as carry goods to and from docks and trucks. Instead of employing 400 to 500 people, which is the typical workforce for a facility of its size, just five people are on site to maintain the machines.[*]

As the development of the technology required for autonomous operations accelerates, these leaders will be joined by other retailers in rethinking how they must run their DCs to grow profitably and increase competitive agility.

What's driving the shift to autonomous operations?

It's clear that retailers have begun deploying the building blocks that will disrupt traditional fulfillment models and make machine-driven DCs a reality. This growing activity is being driven by three key trends that, combined, are making greater warehouse automation not only more accessible, but also a competitive necessity.

***Trend #1: Digital commerce continues to reshape the retail landscape*.**

The speed consumers demand of digital commerce continues to accelerate, yet consumers have demonstrated little willingness to pay for faster delivery. According to Accenture Strategy research and analysis, seven to 10 days was an acceptable delivery time two decades ago, but this continues to be the service promise many retailers cling to today. Now, consumers expect two-to three-day delivery, and nearly half expect that to be free, even during the peak holiday shopping season. If they are open to paying for shipping, consumers often want their orders within hours.

If retailers don't meet these expectations, they risk a customer exodus and lost sales. Research from Global Insights, Metapack shows that 58% of customers shop elsewhere if another online merchant offers more convenient delivery options, and more than one-third of consumers surveyed have abandoned shopping baskets due to slow delivery.

Reseller marketplaces are creating further pressure on retailers' self-funded infrastructure. Aggregators and platform marketplaces, such as Amazon and Alibaba, are dramatically outgrowing direct commerce and make up more than 50% of all online commerce. In some cases, these players enjoy impressive economics that enable them to make significant investments in building last-mile infrastructure—far beyond the resources of most retailers. With such investments, they have a real fulfillment edge over legacy retailers that don't participate in or create their own marketplace models.

The fact is, machine-driven warehouse operations are increasingly necessary to provide the fast, efficient and lower-cost fulfillment that consumers now expect.

Trend #2: Labor is getting more scarce and more costly.
Retailers are increasingly choosing DC locations based on availability of labor as well as proximity to customers. "The most intelligent site selection efforts never lose sight of the fact that labor accounts for more than 20% of total supply chain cost, and up to 75% in final-touch distribution. Its importance can't be overstated," noted Adam Mullen, Americas Leader for CBRE's industrial and logistics business.

Unfortunately, in today's market, labor demand is outpacing supply. As the U.S. unemployment rate continues to fall—3.5% in September 2019, the lowest since December 1969—warehouse and DCs are on track to create 452,000 jobs from 2018 to 2019. Finding those workers will be incredibly difficult given today's employment market.

Complicating matters is the fact that to meet customer expectations for next-day or even same-day delivery, retailers are looking to locate warehouses in or very close to urban areas, where they compete with many other industries and gig-economy employers for similarly skilled labor (and also face higher real-estate costs and less SKU capacity).

High demand and low supply has translated into more expensive workers. Between 2002 and 2014, wages in the warehousing and distribution sector remained stagnant, increasing only 5.5% during that time. Since 2014, hourly wages have increased by 22.6%.

Attrition also contributes to retailers' DC labor challenges. According to Dataexcorp, warehouses and distribution centers experience up to 15% turnover, excluding seasonal and part-time workers, with nearly half of all new hourly warehouse workers abandoning their jobs within the first three months. The direct cost of replacing a warehouse worker can reach 25% of the worker's annual salary. Adding in lost productivity, continually onboarding new warehouse staff, and other indirect costs, attrition can skyrocket to 150% of annual salary.

Retailers will struggle to meet increasingly demanding consumer expectations when they can't find and keep the labor needed to operate their DCs. The "labor crunch" ranked as the highest concern for respondents to *Logistics Management*'s 2018 Warehouse Distribution Survey. Robotics can provide the extra "arms and legs" needed to staff hard-to-fill warehouse jobs.

Trend #3: Robotics are getting more sophisticated and accessible.
Within five years, experts anticipate automated DCs to be standard as development of the required technology accelerates, vendors produce more sophisticated machines and software and the overall cost of automation falls.

The robotics market is growing rapidly, with a compound annual growth rate of 27.1% and an estimated worth of $4.6 billion by 2024. ABI Research estimates that by 2025, more than 4 million commercial robots will be installed in more than 50,000 warehouses, up from 4,000 warehouses using robots in 2018. Helping to drive this growth are compelling new technologies and products that can accomplish more, and more difficult warehouse tasks.

AutoStore, for instance, provides solutions that employ robots for picking that don't need lifts or conveyors to traverse the DC floor and can move inventory to picking stations wherever they are. Another example is Fetch Robotics, whose autonomous mobile robots can move anything from parts to pallets while navigating people, forklifts and other material handling equipment—thus significantly reducing the distances human workers must walk.

Technology companies also continue to make significant advancements in improving the manual dexterity of robots. As opposed to past machines, which were focused on moving large homogenous boxes, we now see robots that can handle granular items—critical in the item-driven DC environment, where the vast majority of orders involve a handful of individual items, each of which could vary dramatically in size, shape, weight and fragility.

Robotics' growing ability to handle many different types of items substantially increases the number of use cases in which robots can be deployed. The robotics company Kindred, for instance, has deployed a robotic arm with immense dexterity at Gap Inc. As the retailer rolls this technology out across its network, the robotic putwall technology is enabling a greater variety and variability of products to be piece-picked from and to totes, which traditionally has been a limiting factor. And, Boston Dynamics, arguably the best-known company in the robotics space, continues to focus its efforts on warehousing applications—robots with the agility to maneuver around complex warehouse spaces and the dexterity to grab and manipulate all types and sizes of items.

The company reportedly plans to sell a commercial version of its famous robot Spot, if it is not doing so already.

Machine learning and AI logic are also making robots smarter. Highly advanced machine learning algorithms that enable unstructured data analysis, such as visual interfaces, will soon make robots sufficiently intelligent, accurate and efficient to make the decisions like people do. Piece picking robots like those from Kindred and RightHand Robotics leverage machine learning to improve item identification and handling requirements through repetitive use. These solutions combine vision systems with advanced AI algorithms to perform complex tasks with human-like intelligence.

Colorado warehouse robotics startup Canvas Technology, recently acquired by Amazon, also provides an example of this type of visual processing technology at work in the distribution environment. Amazon reports that it has already seen significant efficiency gains as a result of its advanced warehouse robotics, including a 20% decrease in operating expenses and a 50% gain in warehouse space.

Importantly, greater use of robotics to automate the warehouse doesn't necessarily equate to capital-intensive initiatives. The option to rent robots—a sort of "robots-as-a-service" arrangement—provides greater flexibility in logistics spending while lowering capital risk. Additionally, many solutions have a modular structure so technology can be applied at much smaller volumes and scaled up over time. Retailers such as Best Buy, have leveraged high degrees of automation in local metro delivery centers to provide exceptionally quick and efficient delivery in major markets.

Where do retailers go from here?

Today, retailers need to review their investment decisions yearly to keep pace with rapid marketplace changes and the growing pressure to be ever-more responsive to the demands of their customers.

Retailers can find help from the robot revolution. Deploying robots across the DC can streamline internal processes, enable the DC to handle far more orders and make fulfillment more efficient. All of this adds up to less time between "order received" and "package delivered," not to mention a lower total cost per order. Robotics makes possible new picking and packing methods that allow orders to be filled from a DC in less than an hour, compared with the day or more that traditional manual, batch methods take. With advanced-logic automated sortation functionality, a product can be injected into last-mile delivery centers without human intervention, enabling retailers to offer a later cut-off time for orders to be delivered the next day.

In fact, with advancements in robotics continuing to accelerate, the reality of the machine-driven DC isn't that far away. But implementing the relevant systems and solutions, not to mention designing and building the new DCs specifically to optimize the use of robots that can drive such a transformation, can be a multi-year process. For that reason, the time to start is now.

For most retailers, the big first step will involve collaborative robots, or cobots. Cobots work side-by-side with humans, and can help eliminate non-value-adding DC activities—such as walking, which typically takes up approximately 60% of workers' time. By pairing visual analytics systems with robotics-human teams, retailers can continuously adapt and optimize their operations to meet specific productivity, quality, safety or other objectives. Cobots will be a boon for retailers struggling with labor shortages. It's realistic to expect that, in the near future, facilities will require half the traditional warehouse workforce compared with traditional fulfillment models. However, DC labor will be made up of both automated and human workers; the higher-level skills required for these human workers to operate within a complex and highly automated facility will likely drive up average hourly wages.

Conventional thinking about warehouse process definitions will also need to evolve to adapt to changing technology. For example, retailers will need to consider using waveless order fulfillment to create a continuous flow of orders, merging pick and pack into one function and shifting to matrix storage from defined aisles and locations.

More than ever, mastering competitive agility in the retail space is centered around the ability to offer the speed and convenience that customers crave while continuing to reduce the cost to serve. The robotics technology on the horizon can play a major role in delivering on that value proposition. Getting started sooner rather than later is critical to avoid being left behind.

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You can view JD.com's automated warehouse on YouTube at: youtube.com/watch?v=RFV8IkY52iY&t=20s

The right pallet is critical to export shipping

Q&A with **Gary Sharon**, executive vice president, Litco International, Inc.

Q. Do exporters have different challenges when it comes to shipping palletized products than domestic shipments.

A: There are at least three issues that exporters need to be aware of. The first is regulatory: Any export pallet must meet the requirements known as IPPC-ISPM 15. This international standard addresses the need to treat wood materials shipped between countries to prevent and to control the introduction and spread of pests from plants and plant products. Second, is the integrity of the delivered unit load. Export-bound palletized shipments go through an extreme amount of handling abuse as they travel through the global supply chain. The pallet is the primary component of a unit load. It protects the product, absorbs the stresses, holds the weight, encounters fork truck impacts and protects the products while traveling through the supply chain. Third, shipping containers are exposed to heat during the day and cooling temperatures at night. A pallet with too high a moisture content will produce humidity and can promote the growth of mold inside the container.

Q. Can the right pallet mitigate these conditions?

A: Absolutely. Manufactured from wood chips and resin, Litco's Engineered Molded Wood pallets are a high-performance, low cost alternative solution to traditional pallets, for both domestic and export one-way shipping. They are ISPM-15 compliant, and because they are molded under high heat and pressure, the manufacturing process drives the moisture content down to about 8%. The drier the pallet, the less likely it is that moisture will build up in the container.

Q. How do I protect the integrity of my load in transit?

A: The stiffness of a pallet ultimately determines how stable the load is and whether it will shift in place during transportation. That's important because the last thing an exporter wants is their customer having to deal with a mess inside a shipping container. Because of their high top-deck stiffness, strength, size and durability, Litco's pallets counteract these kinds of scenarios. In addition, there are no nails or staples that can pop up and cause damage, and our pallets feature a more durable lead edge than conventional pallets. As a bonus, since the empty pallets are nestable, they take up less room in storage.

Q. Are Engineered Molded Wood pallets sustainable?

A: They are certified sustainable as a Cradle to Cradle™ product. Not only do they eliminate the cost of bringing back empty pallets, they can be recycled and don't have to go to the landfill.

Harmonize human and artificial intelligence in global value streams

Q&A with **Philip Vervloesem**, senior vice president, OMP USA

Q: Is it realistic to fully robotize supply chain planning?

A: The level of automation in supply chain planning has tremendously increased and I strongly believe that it will continue to do so, both on the demand and supply side. AI technology is used to achieve this. However, a human touch is still essential. You need to automate the regular routine tasks and provide planners with strong analytics so that they can optimize a closed-loop plan. AI also helps to ensure that all planning levels—from the strategic to the operational—are synchronized, carefully balancing the priorities and concerns of all stakeholders, including business, finance and commercial. At OMP, we call that the Unison Planning™ approach.

Q: How do your customers benefit from AI in managing their global value streams?

A: AI is used to achieve vertical and horizontal integration of the supply chain network and full visibility of the global value streams. This takes people out of their silo-based thinking, for example, by showing the locations of the inventory they need. AI allows you to anticipate, sense demand, limit disruptions and maximize value to outsmart the competition. It allows you to see what demand you should cut or push to maximize your profit. This also proves tremendously useful in dealing with major events such as the COVID-19 crisis. There's an important UX component in this. Unison Planning is not only smart, it deploys AI in such a way that it's easy for stakeholders to present the outcomes. That's because they want to show executives which scenario will give the best market share, profit or growth.

Q: How will this impact the roles of team members?

A: Planners will adopt a different mindset, thinking beyond their role as operations or demand planner for example. They will think more globally, better understand the interdependencies of actions, see the impact of decisions through simulations and have a real end-to-end view on it all. Also, company-wide collaboration becomes more important. You need solid cross-functional processes and real team players to be successful. AI-driven planning will help your teams to reach a consensus.

Q: How does OMP ensure that the technology is optimally used?

A: Unison Planning is not only about technology, it's also about people and about the services we provide. It is no coincidence that advisory and user engagement services are among our fastest growing service areas. Upfront, advisory turns projects in the right direction to maximize value. User engagement includes hands-on coaching to make people smarter and shows them how to be successful.

EXECUTIVE INSIGHTS

Will your supply chain make or break your brand?

Q&A with **Casey Adams**, president, Visible Supply Chain Management

Q: How is supply chain management tied to branding?

A: Your supply chain is your customer experience. A deficiency anywhere in the supply chain — where it's made, where it's initially shipped, who picks it up from there or how the final mile is completed — can lead to your customers not experiencing the brand in the way or the time they expect. That's a poor experience, and a really easy way to lose customers. When you see the supply chain this way, you are essentially entrusting the customer experience to the manager in charge of your dock or your head warehouseman. That experience, in my opinion, is the ultimate factor in success and why it's critical to choose the right supply chain partner.

Q: How does great supply chain management impact my company's growth and bottom line?

A: A poorly designed supply chain can tie up money you could be investing in awareness and driving trial. If you spend more money to ship a package, you have less to market your next product. If you spend more money to purchase packaging, you have less to develop your next product.

We have hard facts and they're clear: Companies with high-performing supply chains achieve better-than-average growth about 80% of the time, while companies with inferior supply chains only achieve better-than-average growth about 8% of the time.

Q: Who's doing supply chain right?

A: I don't want to specifically criticize or exclude anyone but every company has to realize the box-opening experience can - and in many ways must - be a brand experience, like visiting a store. Some great experiences I've recently had include Manscaped, Rockets of Awesome, Versace, Marc Jacobs and FootJoy.

They have all chosen to create an experience around their supply chain. Some have used amazing packaging that opens like a pizza box and gives you a special presenta-tion with their logo printed on the inside and branded paper. Others have focused on amazing time in transit and economics. Ultimately, each company has clearly thought about their supply chain as a method for managing their customers and have brought their brand to the customer's home. Brilliant.

Q: So how do you go about choosing the right partner?

A: You want to choose a partner that can present you with options. One of the mistakes people make is seeking out a supply chain company that will tell them what to do. The best supply chain partners present choices, how they work, what they cost, what you can expect in terms of fulfilment time and how you specifically could work within each framework to deliver a positive experience. They'll tell you about the people behind the options so you can judge the service and whether you are simpatico. Then you should be weighing the pros and cons of each according to the kind of brand experience you want to deliver.

A SPECIAL SUPPLEMENT TO:
SUPPLYCHAIN MANAGEMENT REVIEW

LTL Outlook 2020: Full recovery on the horizon?

A recovering industrial economy, “improving” inventory levels and higher rate forecasts buoy top LTL carrier optimism for 2020.

BY **JOHN D. SCHULZ**, CONTRIBUTING EDITOR

A combination of an improving industrial economy with manufacturers rebuilding lower inventory levels has top executives from the $44 billion less-than-truckload (LTL) market crossing their fingers in hopes of a financial rebound this year.

Indeed, after more than 14 straight months of declining tonnage in the industrial portion of the economy, LTL carriers are hoping for recovery in that sector as international trade worries and overall geopolitical concerns lessen.

“Consumers have done very well in retail, but the industrial side of the economy has not moved as quickly,” says Darren Hawkins, president and CEO of YRC Worldwide. “We rate the manufacturing index as an important leading economic indicator, and with our exposure to industrial, we have a high correlation to that portion of the economy. The lion's share is on the industrial side, and things have settled down in that area and are moving steadily in the right direction."

Even better news for LTL carriers is their newfound pricing discipline. Even with the sudden closure last February of New England Motor Freight (NEMF), which ranked as the 20th-largest LTL carrier with $345 million in revenue, the industry absorbed that capacity without resorting to predatory pricing in order to obtain that NEMF freight.

In fact, there's nothing in the air to signal an LTL price war, especially as carriers continue to enjoy the benefits of a concentrated market. The Top 10 LTL carriers control about 73% market share, according to data from consultancy ShipMatrix, and the Top 25 absorb about 90% of the LTL market.

Analysts say that the LTL market is dominated by three very strong, non-union companies: FedEx Freight, Old Dominion and XPO Logistics. All are formidable competitors to Teamsters-covered YRC Freight and its three regional subsidiaries as well as ABF Freight System, among others. "In addition to being non-union, well-run companies, the top three all have highly developed and sophisticated information technology systems that allow them the information to provide better service at a lower cost," said Donald Broughton, principal of Broughton Consulting.

But an analysis by *Supply Chain Management Review* shows that even the best-run LTL carriers face operational hurdles these days. All are continually competing for fewer qualified

drivers who are demanding higher pay. Costs for equipment and insurance are soaring. And the economy, while good, has been growing at an uneven pace, causing unforeseen spikes and dips in demand.

Let's examine how the best LTL fleets are coping with this ever-changing economic model, and why they're hoping 2020 is a year of economic recovery for them.

Matching capacity to demand

Nothing throws off internal planning sessions at even the best-run LTL carriers more than an uneven economy, up one year and so-so the next. And, that's exactly what happened in the past two years. The market witnessed historic volumes in 2018, while 2019 was labeled by some as an industrial recession.

"LTL demand is not very strong at this point in time," says Chuck Hammel, president of Pitt Ohio, the nation's 17th-largest LTL carrier. "We have moved from up slightly to flat. Last year got progressively soft as the year went on, an so far this year it's the same. However, we're optimistic things will improve."

Raj Subramaniam, president and COO of Fed Ex Corp., parent of the nation's largest LTL carrier, said recently that he was "not pleased" with overall financial performance of many units. At FedEx Freight, its LTL unit, Subramaniam said that it's continuing to focus on yield management, profitable growth, and aligning its cost structure to the lower volumes throughout this fiscal year.

"These efforts have enabled FedEx Freight to significantly offset the impact from softening economic condition," Subramaniam said recently on an earnings call with analysts. "This is yet another example of matching capacity to demand."

The American Trucking Associations' advanced seasonally adjusted (SA) For-Hire Truck Tonnage Index increased 3.3% for all of 2019—that was about half the annual gain in 2018 (6.7%). In December 2019, the ATA SA For-Hire Truck Tonnage Index rose 4% after falling 3.4% in November. That makes planning for equipment, drivers, terminal expansions and freight demand highly risky for 2020, executives say.

"Last year was not a terrible year for the truck tonnage index, but despite the increase at the end of the year, 2019 was very uneven for the industry," said ATA chief economist Bob Costello. "The overall annual gain masks the very choppy freight environment throughout the year, which made the market feel worse for many fleets. In December, strong housing starts helped advance the index forward."

The U.S. Bank National Shipment and Spend Indexes ended 2019 with both metrics falling sequentially and on a year-over-year basis. It said that the indexes reflected that at least parts of the economy, like manufacturing activity, are currently "under pressure." Last year's indexes posted the smallest gains of any year since 2016, U.S. Bank said.

"There is no doubt that 2019 overall was a tough year for motor carriers," U.S. Bank said in its analysis. In fact, shipments contracted 5.9% from 2018, marking the largest annual drop calculated back to 2011. But shippers' spend was up 3.4% from 2018, which U.S. Bank called "remarkable," considering that volumes were off significantly.

For trucking, U.S. Bank said that the falling factory sector is having a significant impact on shipments and spend. Truck sales have exceeded the demand for the added capacity, and freight levels will likely remain "sluggish" into the second quarter. However, it forecast that shipments could start to improve as capacity starts falling with fewer truck purchases as well as carrier closures.

"I think LTL will perform better than truckload this year, and it's not because of the economy or trade wars, it's because of e-commerce," says Satish Jindel, principal of SJ Consulting. "LTL carriers are handling more retail shipments than ever before, and that will continue. LTL carriers must learn how to handle those shipments."

The last-mile conundrum

LTL carriers have been perplexed by the potential of "last-mile" deliveries due to the surge in e-commerce business. The conundrum is this: How much of this business is worth chasing given the sharply higher costs involved in delivering to often rural, out-of-the-way places with no hope of any backhaul traffic.

FedEx Freight recently began its FedEx Freight "Direct Service" that provides freight deliveries right to or through the front door. The company says the new service currently covers 81% of the U.S. population, and is anticipated to cover 90% by July.

FedEx Freight calls this "a market leading value proposition," that includes a two-hour delivery window to your room of choice with full packaging removal. The company says it has "a strong pipeline" and already has prominent retailers lined up for the service. It's all part of a larger FedEx initiative to improve revenue at its Freight and other units.

XPO breakup wild card for rival LTL carriers

There has been no greater success story in the LTL sector than the growth and dominance of XPO Logistics after its purchase of Con-way Freight for $3 billion in 2015.

Since then, XPO's share price has increased more than ten-fold. Yet XPO Chairman and CEO Bradley Jacobs, who engineered the Con-way purchase five years ago, said that his company is trading at "well below the sum of our parts and at a significant discount to our pure-play peers." He claims XPO has been the 7th best-performing stock of the last decade, and he wants to continue such meteoric growth.

So, Jacobs has gone public by saying XPO's board has retained Goldman Sachs & Co. LLC and J.P. Morgan Securities LLC as its financial advisors and Wachtell, Lipton, Rosen & Katz as legal advisor to assist with the review process necessary to find a suitable buyer for any of XPO's major operating groups, with the exception of its LTL unit.

XPO has set no timetable for completion of the review process and has not determined which, if any, business units would be sold or spun off. But the company says it "does not intend to sell or spin off" its North American LTL unit. Last year, XPO ranked as the 4th-largest LTL unit with just under $4 billion in revenue.

Some analysts believe that despite XPO's insistence that the LTL is not for sale, it would be for the right price. "Bradley Jacobs has a great track record as an astute investor," says trucking market analyst Satish Jindel. "If somebody comes along and wants to buy the LTL unit at a nice premium, I wouldn't send them away."

Whatever XPO decides to sell, it says each unit will be offered as a whole entity. Even though XPO says that it's keeping its LTL unit, whatever happens to its brokerage unit, for example, could affect shippers using XPO's LTL operation. That's because analysts and industry insiders estimate as much as 40% of XPO's business comes from "cross-selling"—that is, using its brokerage unit, for example, to fill space in XPO's fleet of LTL trucks.

—John D. Schulz, contributing editor

What LTL carriers have found is that B2B last-mile is preferable to deliveries to home consumers. That's because B2B provides greater density and stronger yields than B2C. So most LTL companies are focusing on commercial traffic. However, the lure of e-commerce is strong because it's growing at an annual rate of more than 15% year over year.

Analysts warn that this isn't an easy market to crack. Truckload giant J.B. Hunt and LTL leader XPO Logistics are already in the last-mile market in a big way along with giant publicly held companies with vast resources such as Ryder and Forward Air.

"My advice is that if you're not in the last-mile market now, it's a little late," adds analyst Jindel. "Everything in last-mile is different—the driver, the trucks, training, the DNA is completely different. It's different bumping up against a dock and delivering freight than delivering to someone's home."

Last-mile operations might make sense for a trucking company with a big presence in retail. Other than that, analysts say, the high fixed costs of last-mile deliveries to homes and remote locations make it a daunting proposition, but one that can pay off handsomely.

"LTL companies should be in last-mile," says Broughton. "The ongoing growth profile and margin potential of last-mile should make it a market segment that's difficult if not impossible to ignore. Those companies that could easily add it to their service portfolios, but don't do so at their own peril."

The rate situation

Pricing for LTL carriers is forecast to rise at a greater rate than for truckload (TL) carriers. One reason is market share concentration. The Top 25 LTL carriers control nearly 80% of the $44 billion or so market. But the Top 25 truckload carriers barely have 10% of the $320 billion TL market.

Until about five years ago, motor carriers had waited about 35 years since the Motor Carrier Act of 1980 deregulated their industry to get a favorable pricing environment. That market is expected to continue to weigh against shippers in the LTL arena, but not so much in the full truckload space.

"Costs continue to increase in trucking mostly around driver and benefit costs and toll roads," says Pitt Ohio's Hammel. "We're still getting increases from our customers, albeit lower than early 2018."

Analyst Jindel is forecasting LTL contract rates to rise 3% to 4% this year, while TL rates should rise maybe half that much. But analysts say shippers can build in a hedge to those price increases by producing more "driver friendly" freight—that is, freight that is accurately weighed, readily available and easily accessed by drivers who increasingly are operating under severe time restraints.

"Simply put, every shipper has the ability to offset that rate increase by improving their operational practices," adds Jindel.

John D. Schulz is a contributing editor to Supply Chain Management Review

5 SUPPLY CHAIN CHALLENGES SOLVED BY GOOD DESIGN

Got challenges? Good network design and technology can solve them. Here's how.

BY BRIDGET McCREA, CONTRIBUTING EDITOR

As the profile of supply chain continues to elevate in organizations and corporate boardrooms, the challenges associated with operating a global network are getting an equal amount of attention. Of particular interest is how organizations structure and manage their supply chains to effectively balance manufacturing costs, inventory and transportation—also known as supply chain design.

Done right, supply chain design boosts efficiency, reduces costs, increases output and improves profitability. It also helps companies overcome challenges like low labor availability, tariffs/trade wars and the rapid pace of business. Here are five challenges that supply chain managers are dealing with that can be solved through a combination of good design and technology.

1. High-cost/low-availability warehouse labor. With the national unemployment rate hovering at 3.5%, and even lower in some areas, labor has become a key driver of supply chain network design. Where several years ago a warehouse operator could afford to hire 200 extra pairs of hands to manage its busy season, that's not always an option in today's labor market. To offset this challenge, Ian Hobkirk, president at Commonwealth Supply Chain Advisors, sees more companies working automation into their supply chain designs. "The ROI for automation is more compelling now that labor costs are high—and just really not available to begin with," says Hobkirk. Particularly compelling for consumer goods-oriented companies that need additional labor to manage their huge fourth-quarter spikes, automation like mobile autonomous robots, Swisslog's AutoStore, OPEX Perfect Pick, pouch sorters and various AS/RS technologies are helping companies tackle these challenges without the need for more human labor. Other strategies include setting up operations in areas where labor is more available and affordable. Rather than opening a DC in California, for instance, companies are serving their West Coast customers from operations in Las Vegas, Reno and Salt Lake City. "They still get very good access to population centers in Southern California," says Hobkirk, "but for somewhat lower operating costs. That's definitely a trend that we're seeing, and one that is in no small part driven by California's high labor costs."

2. Tariffs and trade wars. When the trade wars started to heat up in 2019, there was suddenly an intense focus on the downsides associated with global diversification. This immediately affected supply chains across numerous industries, with automotive, electronics and consumer goods all feeling the earliest impact of the trade wars. "Companies with supply chains that were running like clockwork were suddenly asking themselves how the tariffs would affect them, what their new cost structures were going to look like and whether they needed to look for new sources of supply," says Matt Tichon, vice president of industry strategy at Llamasoft." The tariff situation appeared to be easing up slightly as we moved into 2020, but companies are still on edge about the future impacts. "The trade wars were the catalyst for the executive suite to look at how it was quantifying risk, what its exposures were across different geographies and whether it was dual-sourced on certain items," says Tichon. "That led to an increased focus on the overall theme of supply chain agility." It also sent companies back to the drawing board, knowing that the supply chains they'd implemented years or even decades ago were largely static and asset-centric in nature. "The focus now is on supply chains that can quickly respond and shift to the changing needs of the market," he adds, "and all in the name of having a more nimble network that isn't as exposed to geopolitical changes that can happen quickly."

3. Y2K legacy systems that don't "talk" to one another. It has been two decades since the world's computer systems successfully endured the "Y2K" threat that was expected to wreak havoc as the year changed from 1999 to 2000—which of course never happened. Technology has advanced rapidly since then, but some companies are still using their Y2K-era systems to run their global supply chains. "A lot of systems that are in place either date back to Y2K or have been put together in a piecemeal fashion," says Jon Chorley, vice president of SCM strategy at Oracle. These systems can't keep up with the business and market shifts, nor do they "talk" to one another. This has created a largely siloed structure that doesn't support a modern day supply chain network. Knowing this, companies are now reevaluating their supply chain platforms and looking for ways to progress down the path of digital transformation. As part of this push, they want to be more connected, flexible and responsive to new opportunities and challenges. For example, Chorley says IoT-enabled systems that provide visibility into real-time data sit high on most supply chain managers' must-have lists right now. "We're seeing an interest in systems that are easy to use, have low barriers to entry and can accommodate workforce shifts," Chorley says. "They want help managing the movement away from tribal knowledge and over to more system supported decision-making."

4. Geopolitical instability and global uncertainty. Tariffs aren't the only global issue taxing the world's supply chains right now. The threat of war with Iran, the ongoing debate over Brexit, unpredictable terrorist attacks, fluctuating currency exchange rates, the coronavirus and overall political instability are also weighing on these networks. "We're in a market where some very fast and unpredictable changes are emerging," says Milena Janjevic, a research scientist at the MIT Megacity Lab. "These sources of uncertainty are becoming an increasingly important aspect of supply chain design. If you don't somehow incorporate these issues into your design process, you'll end up with a supply chain that's not robust to those changes." To make sure this doesn't happen, Janjevic says companies need to incorporate flexibility into their supply chain design, all with an eye on creating networks that can be more "adaptive to those eventual changes." By seeking out more diverse sources of supply, for example, supply chain managers can better respond to geopolitical events as they emerge. "This can help make supply chains less prone to disruption," says Janjevic.

5. Company-specific requirements. As the director of the MIT Humanitarian Logistics Lab, Jarrod Goentzel works with companies of all sizes and across numerous industries. Because each brings its own unique logistics requirements to the table, there's no one-size-fits-all answer to the supply chain network design problem, nor is there a single software package that can address every company's top challenges. "The companies that we're meeting with and talking to all have very diverse requirements," Goentzel explains. For example, some of the organizations want to know where they should locate their warehouses and DCs, knowing that some pockets of the country have better (and more affordable) labor availability than others. A different company may be focused on getting as close as possible to its customers in an effort to shorten delivery lead times. Particularly in urban areas, that need must be balanced against the cost and availability of warehouse space. Another organization might be focused on connecting its supply chain strategy with the quality of its outside sales force, knowing that integrating these two components can result in higher profitability. "The questions are always very specific, and require a good understanding of the most impactful industry and market-specific elements," says Goentzel. "From there, it's about finding a way to integrate those elements into the supply chain planning process."

Setting realistic expectations

With the busy 2019-2020 holiday season now squarely in the rear-view mirror, this is the time for companies to regroup and reevaluate their supply chain networks. "With e-commerce continuing to grow rapidly, supply chain managers are saying: 'We can't go through another fourth-quarter like that,'" says Hobkirk, "'next year has to be different.'"

But global supply chains don't just turn on the dime. "You need a good two years for major changes to take hold—from the time of conception until they're actually live and stable," says Hobkirk, who tells organizations to be realistic with their timelines. Fixing e-commerce throughput issues isn't going to happen overnight.

"There are some incremental things you can do in the interim to take a bite out of the problem," Hobkirk concludes, "but in light of manufacturing lead times and the need to test and debut systems, there's always going to be a two-year cycle before companies start to see real improvements in their supply chain networks."

What's really slowing your digital transformation?

To fast-track digital supply chain, focus on foundational engineering.

By Neal Walters, Jeff Hewitt and Mike Piccarreta

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Digital transformation has the potential to deliver staggering improvements in operational performance. Companies clearly understand this. The IDC Spending Guide predicts that global investments in digital transformation will reach $2.3 trillion in 2023. A substantial portion of those investments will be devoted to building digital supply chains.

At this point, most supply chain organizations have evaluated an array of available technologies including advanced robotics, 3D printing, AR/VR and advanced data science. Many have hired top digital talent, crafted ambitious digital supply chain strategies and launched multiple pilots.

Why, then, does real progress remain so elusive? In truth, many supply chain leaders seem dissatisfied with the pace and impact of their digital transformations, as mounting investments are stubbornly slow to yield breakthroughs in supply chain performance.

The problem is not with the technology, which often proves effective in pilots. The big challenge is successfully scaling up. Pilots that succeed in a single location create tremendous initial excitement, then fail to prove out the projected value across the broader enterprise. Such failures breed skepticism and drain precious momentum from the transformation effort.

Not all companies are struggling. Those that are achieving major supply chain performance gains, at scale, share certain traits in common. Particularly within manufacturing, we find that effective scaling of digital innovation arises from a sustained focus on foundational engineering capabilities (i.e., process characterization and reliability engineering). Here, briefly stated, are the key things we see leading manufacturing organizations doing right, with clear implications for supply chains as a whole.

Avoid the technology trap. First, they avoid the trap of becoming overly enamored with new technologies. Companies making real headway in digital supply chain begin with a fundamental business case that specifies what business issues need to be addressed. Starting with the business case helps you identify which technologies should make the biggest difference in supply chain performance, so you can pinpoint a short list of the most promising technologies to pilot.

Master the basics. Second, leading companies take the somewhat counterintuitive step of focusing on the timeless basics of supply chain performance, recognizing that mastery of those basics is a vital prerequisite to getting full and lasting value from digitalization. Manufacturing organizations best prepared to apply digital technologies can answer questions such as:

- What are the key variables that determine whether each process is in control?
- What is the right data to collect and archive to ensure that control algorithms learn over time?
- What variables are predictive of an upcoming problem?
- What are the specific remediating actions for the different conditions that signal a process is out of control?

Objectively assess readiness. Third, they are honest about their state of readiness and choose their path forward on that basis, avoiding the temptation to blindly pursue an inspiring, but ultimately unattainable vision. We've found that manufacturing organizations striving to apply digital technologies are currently in one of the four states of readiness depicted in Figure 1.

Focus on foundational engineering. Finally, leading manufacturing organizations recognize that process engineers (although not "digital experts") are essential to fully and effectively applying digital technologies for supply chain performance. In light of this understanding, these companies:

- objectively assess whether they have the right foundational engineering talent in place;
- stay closely attuned to how their process engineers spend their time;
- differentiate between low-value and high-value activities; and
- avoid burdening this key cadre of technical talent with low-value work.

FIGURE 1

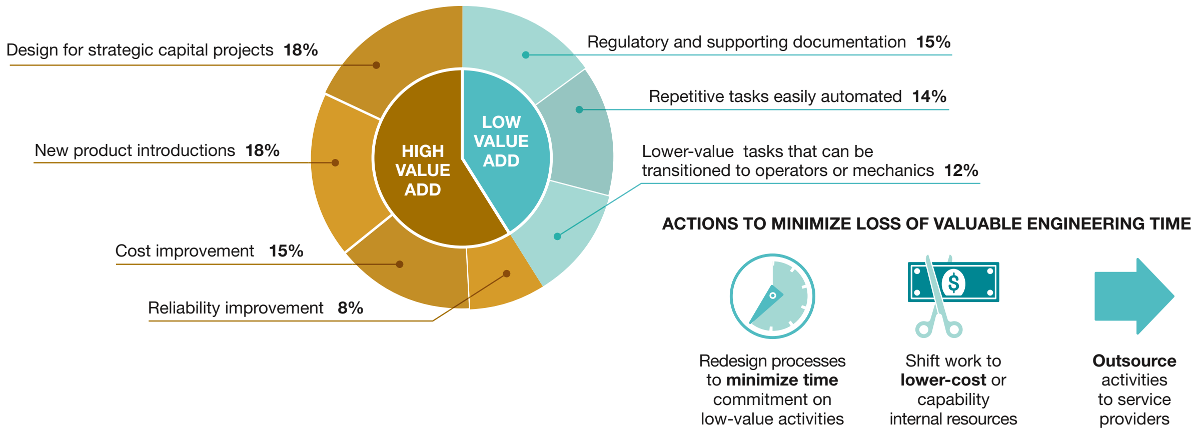
Digital manufacturing readiness

	BUILDING THE FOUNDATION	SETTING THE DIRECTION	PREPARING THE WORKFORCE	SCALING
Readiness description	Many processes are not fully characterized, in control, and stable Causes of non-conformance, downtime (or bottlenecks), and throughput losses are not fully understood	Most processes are characterized and stable, but the company is unsure which digital technologies will generate the most value	Value proposition of various digital initiatives is known and the most relevant have been selected for initial focus The road map and specific skills and capabilities required to scale digital innovation across the organization is unknown	Direction has been established and initial pilots have been successful Scaling innovation is recognized to be a significant undertaking, but leadership is unclear on how to fund or redeploy resources
Implications	Expecting digitization to compensate for a lack of foundational engineering excellence will most likely result in waste in both capital and human resources	Making decisions solely on a technology basis will most likely lead to a number of disparate pilots that are difficult to both scale and confirm value	Hiring Silicon Valley talent may help but will not provide full readiness—base business resources (for example, engineers, technicians) will not be prepared to utilize the technology to deliver the value or sustain capabilities	Shifting resources around or supplementing with external hires will not be enough to scale and sustain without structure changes to operating model, organization, and training programs

Source: Kearney analysis

FIGURE 2

Process engineer activity allocation



Source: Kearney analysis

Figure 2 shares the findings of an activity analysis we conducted for one manufacturing company to uncover existing inefficiencies within its engineering organization. To accelerate digital transformation, companies should apply a range of focused talent analyses to inform detailed scale-up plans that pinpoint resource requirements for each site and technology combination. This provides a clear picture of the technical talent required to effectively apply technology for improved supply chain performance. One company we served found gaps in dozens of full-time equivalents (FTEs) across a number of crucial skill sets. With this knowledge, transformation leaders were able to put together a comprehensive resource plan—blending upskilling, hiring and outsourcing—to ensure they had the full skill mix needed to execute their strategy.

Of course, even as you pursue a technology transformation, your organization must continue to meet everyday requirements and expectations. Such competing priorities will inevitably pull your key resources in different directions, and "firefighting" will remain part of the mix. Yet with conscious and persistent effort, it is possible to minimize the time key resources spend executing low-value tasks. Specifics steps you might take to minimize waste of valuable engineering capacity include these:

- identify tasks that can be automated, moved to less vital resources or outsourced;
- redesign processes to minimize time spent on low-value activities; and
- assign qualified employees in your company to work closely with your Silicon Valley experts, to rapidly build their knowledge of the business and the operational (versus technical) keys to superior supply chain performance.

Right now, digital technologies are forging a fourth industrial revolution and ushering in the factory of the future. The changes unfolding in your world are vast and the implications are staggering. The challenge is to see the big picture without being blinded by it.

After all, digitization remains a means to an end. You pursue digital transformation to make your operations significantly faster, more capable, more reliable and more cost effective. It is vitally important to recognize that these outcomes cannot be driven by technology alone.

When companies struggle to build digital supply chains, it is rarely because they lack understanding of digital technologies. Rather, it is because they underestimate the range of technical expertise required to extract meaningful value from those technologies. Successful companies recognize that—even in this age of digital wonders—foundational engineering remains the cornerstone of superior supply chain performance.

Bending to supply chain circularity

By Alexis Bateman and Ken Cottrill

The path to sustainable supply chains may be ill-defined, but chances are it's circular. Companies are coming under increasing pressure to reduce waste by redesigning, recycling or repurposing end-of-life products, processes that are core to circular supply chains. However, embracing circularity across supply chains designed primarily to move product forward in a linear fashion is a massive undertaking that entails changing deeply ingrained practices. How can companies engineer this course change without undermining the performance levels they have worked so hard to achieve in the linear world?

Such a change requires much innovation. In December 2019, some 40 companies from various industries gathered at the MIT Center for Transportation & Logistics' (MIT CTL) *Towards Circularity in the Supply Chain Roundtable* to discuss the innovative approaches companies need to create closed-loop supply chains.

Mapping a circular route

The Ellen Macarthur Foundation defines a circular economy as "a framework for an economy that is restorative and regenerative by design." The model is based on three principles: design out waste and pollution, keep products and materials in use and regenerate natural systems. Supply chain management is fundamental to achieving the first two principles.

There are countless ways companies can put these principles into practice within their supply chains. However, choosing the right approaches and implementing them systematically is a difficult challenge. Here are some pointers learned from the roundtable and ongoing research at MIT Sustainable Supply Chains (MIT SSC) that might help enterprises make smarter choices on their journey to circularity in the supply chain.

Understand the drivers. Companies need no reminding that consumers are paying more attention to the amount of recycled materials used in a product and the extent to which it is designed for end-of-life. However, research suggests that consumer pressure is just one of many drivers of circularity. Other examples that have equal or greater weight are the concerns of employees who want to work for responsible firms and investors who expect to be more informed about corporate responsibility. These pressures can be harnessed to drive circularity.

For example, a leading apparel company described how a project to use scrap material to make a limited-edition product provided an opportunity for employees to learn about the process. The exercise also motivated the

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INNoVATION STRATeGIES

employees to tackle bigger and more challenging opportunities to reduce and reuse scrap and waste materials. Another market leader in the apparel industry created a new business that utilizes end-of-life items or scrap material and turns it into new, profitable products. The company sells the material to other manufacturers, such as makers of surfaces for sports arenas. The inspiration for the venture came from employees concerned about the volume of waste the company was generating.

Cost often drives innovation, but it's not the primary driver when it comes to circularity. Other arguments can get leadership engaged, such as using circular opportunities to improve risk management and build resilience. For example, recovering or extending the life of materials that are subject to extreme price fluctuations, scarcities or supply uncertainties can reduce risk. Companies can also find value in boosting their reputations by minimizing waste and increasing the use of recycled materials.

Redefine ingrained ways of thinking. A leading hardware manufacturer at the roundtable explained how it had changed the way the organization perceives sold product. "We look at our equipment out there as an asset that we want to take back." The company has made a special effort to reframe what is meant by waste and to use the change in mindset to support a more ambitious effort to embrace circularity both internally and externally. The manufacturer has reframed its corporate mission to include circularity because it feels that this objective is fundamental to the future of the enterprise.

Developing a more holistic view of product flows is also part of the company's attitudinal shift. A broad study of manufacturing operations found their inter-plant packing was the biggest culprit in terms of waste. Also, the company is revamping its established approach to inventory management to give the organization better control over product usage. "We are starting to assign product to inventory but not move it right away so a department can access it when they need it," said the company representative at the roundtable. Also, an integrated financial model that the enterprise is developing identifies more clearly the cost of returns, who within the enterprise bears that cost and how to change budgets and incentives to reflect the cost burdens and benefits. This approach reshapes the dialogue and budgeting around returns and recharacterizes used product as a source of value.

Look for partners in innovation. A consumer electronics company at the roundtable explained how a charity organization became a channel for product returns. The charity's outlets accept donations of clothes and household goods—and used electronic devices that the manufacturer collects for recycling and refurbishment. Another win-win is a partnership with a supplier that re-grinds plastic from used devices and sends the material to the manufacturer for reuse in new product.

Circularity can only work—especially at scale—if companies are willing and able to form partnerships. However, it's essential to keep in mind that successful, circularity-building partnerships take commitment, patience and in some cases years to get right.

These marriages of opportunity require some out-of-the-box thinking. For instance, an organic food manufacturer wanted to find a substitute for the outer flexible film packaging on its boxes. Flexible film is extremely challenging to replace and changing it was the last step in a broader program to eliminate single-use plastic packaging from the company's products. The enterprise started an industry group to make the new material more attractive to suppliers from a volume perspective. After some five years of hit-and-miss development work and trials, the team chose a plant-based biodegradable material that can be composted at the end of life and used by farmers. The group found a commercial composter to work on the project. The effort has enabled the company to minimize waste, boost its reputation and get closer to the organization's sustainability goals.

The food company's travails point to another strong reason for collaborating on circularity—the need to address a lack of standards for materials. The standard digestion period for the biodegradable material is 83 days, but commercial composters want a 45-day digestion period to make the operation economically viable. The group of food companies must find a way to bridge this gap.

A lack of standards was one of the most common issues cited by the companies at the roundtable. For example, a difficult problem for the apparel company that recycles used shoes is not knowing what materials other manufacturers use in their products. A formidable challenge is recycling items made of various materials that are difficult to separate. Standards on restricted materials would reduce the risk of toxins appearing in waste streams and boost product reuse and recycling.

There is an urgent need for more collaboration between companies—including competitors—to develop standard specifications for the materials they use.

Participants also explored how they can learn from other industries. For example, plastics recyclers are trying to solve the problem of de-inking end-of-life product, an issue that paper companies addressed some time ago to increase recyclability. Similarly, glass recycling has reached a tipping point in terms of scale in that industry, suggested an attendee and other sectors could learn from their experience.

More cross-industry and cross-company collaboration is essential to the future viability of circular supply chains.

The future looks circular

There were many other challenges highlighted by the roundtable, and participants also looked at the future of circularity.

Several companies talked about the creation of something akin to a "materials passport" that would provide information on the materials in a product as it moves through supply chains and guide recovery processes. Such a record would also support the creation of symbiotic relationships where one enterprise uses the waste of another as a feedstock without the worry of negative inputs.

If circular supply chains are to go mainstream, future products will have to be designed differently. "Once a material has been made, most of the environmental damage has been done," pointed out one attendee. Perhaps even the concept of "circular" will be revised. It was suggested that a future representation of a product flow could be more like a conveyor belt than a circle, where companies reuse the components and materials derived from a product that are most suitable for their individual needs, and the remainder stays on the conveyor for other organizations to use.

While such ideas may or may not become reality, one thing seems inevitable: Companies will come under increasing pressure to move toward circularity as a fundamental business imperative and opportunity.

The outcry over ocean-clogging plastic waste and the refusal by countries such as China, and more recently Malaysia, to accept trash from wealthy western nations, have added to the pressure on companies to cut the volumes of waste they produce. Leading companies such as Coca-Cola, Starbucks, AB InBev and Unilever have publicly proclaimed their intentions to reduce their waste outputs and redesign products for circularity. Colgate-Palmolive has released the first recyclable toothpaste tube, open-sourced its design and is now exploring with MIT SSC how to utilize e-commerce networks for take-back.

These types of initiatives will be increasingly common as companies seek to achieve their sustainability goals and design truly circular supply chains working within and outside of existing systems.

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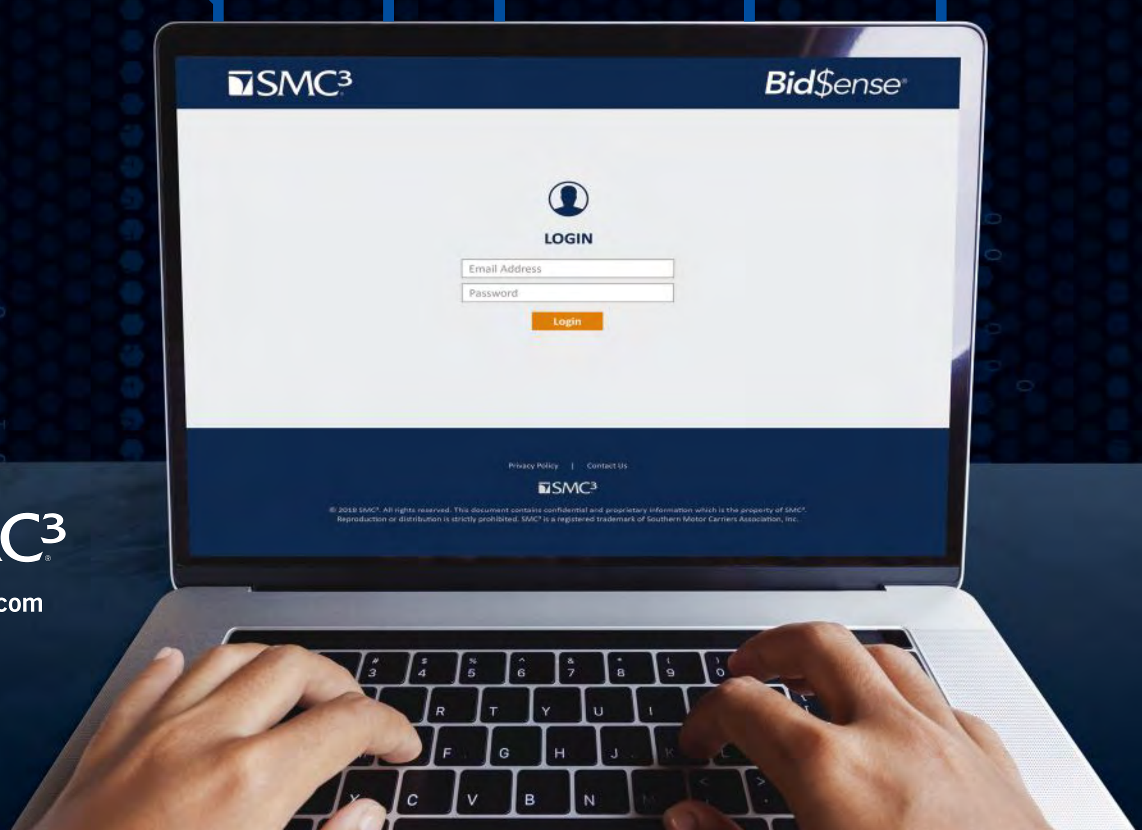

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