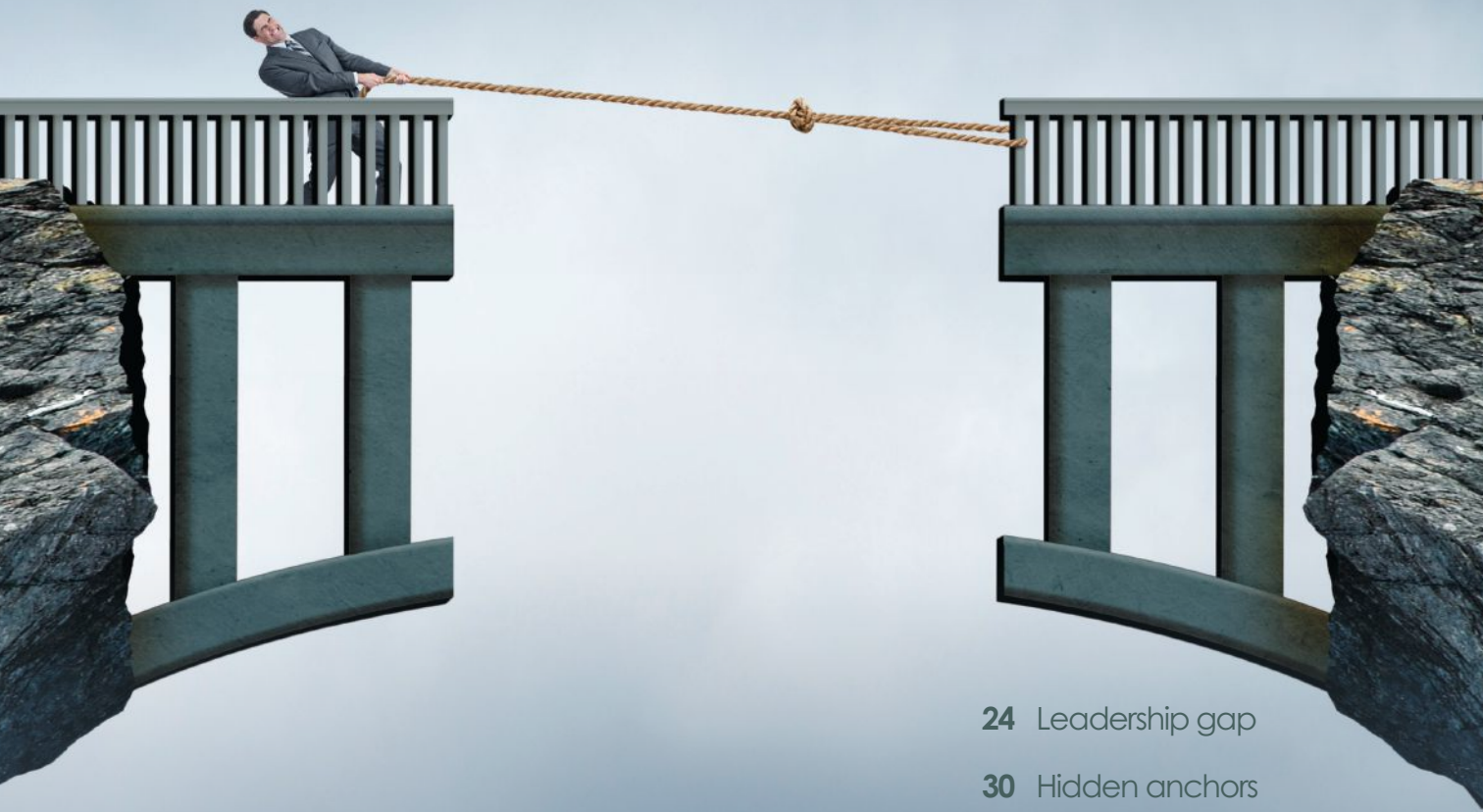


SUPPLYCHAIN

July/August 2026 MANAGEMENT REVIEW

Workforce reboot

PAGE 16



24 Leadership gap

30 Hidden anchors

36 Real-world options

DigitalExtra

EXCLUSIVE BONUS CONTENT

The economics
of lead time
Exclusive to digital subscribers



scmr.com

Do You Know how to turn

insights

into results?



Turning data into actionable insights shouldn't be guesswork. At Odyssey Logistics, we combine smart technology, proven processes, and industry expertise to help streamline operations and boost performance. From route planning to warehouse optimization, we uncover efficiencies and deliver measurable results. **Let's get there together.**



odysseylogistics.com



© 2026 Odyssey Logistics & Technology Corporation



Technology isn't strategy

The rush to implement AI, robotics, and other automation solutions isn't the key to success; it is a holistic approach to solving your pain points.

EDITORIAL OFFICES

50 Speen St., Suite 302
Framingham, MA 01701-2000
1-508-663-1590

BRIAN STRAIGHT

Editor in Chief
bstraight@peerlessmedia.com

BOB TREBILCOCK

Editorial Advisor
btrebilcock@peerlessmedia.com

FRANK QUINN

Editorial Advisor

SARAH PETRIE

Executive Managing Editor
spetrie@peerlessmedia.com

GARY FORGER

Contributing Editor - scmr.com
gforger@peerlessmedia.com

JEFF BERMAN

Online News Editor
jberman@peerlessmedia.com

POLLY CHEVALIER

Art Director
pchevalier@peerlessmedia.com

WENDY DELCAMPO

Art Director
wdelcampo@peerlessmedia.com

KELLY JONES

Production Director
kjones@peerlessmedia.com

BRIAN CERAULO

President and CEO
bceraulo@peerlessmedia.com
Peerless Media LLC

SUPPLYCHAIN
MANAGEMENT REVIEW



For the past several years, supply chain conversations on artificial intelligence, robotics, and other automation solutions have been dominated by the technology itself. Yet after dozens of conversations with supply chain leaders, software providers, consultants, and practitioners over the past year, I've come to realize that many organizations see the technology itself as the solution to their supply chain pain points. It is not.

The companies seeing the greatest success right now with AI aren't necessarily deploying the most advanced tools. They are the ones that start with a business problem and work backward. Two recent conversations helped reinforce that point. Amazon Web Services' Petra Schindler-Carter and JBF Consulting's Tony Wayda both told me that companies looking at the entire problem, and bringing in other departments such as finance, marketing, etc., are having the greatest successes.

It turns out that technology alone is not the answer, but a holistic approach to the problem is. That is not some groundbreaking thought, but too many organizations have lost sight of that. Too often, organizations begin with a declaration that they need AI, a digital twin, a transportation management system, or the latest automation platform. What frequently comes next is a lengthy implementation effort that never fully delivers the expected return because the organization never clearly defined the operational problem it was trying to solve, or integrated the partners necessary to make it work.

The challenge becomes even greater with AI because success depends on far more than the technology itself. Data governance, change

management, process design, and training all matters. Those require cross-functional alignment.

Supply chain leaders cannot deploy AI in isolation and expect transformational results. Finance needs to be involved to establish business objectives and measure outcomes. Operations must help define workflows and decision-making processes. IT and security teams must ensure governance, integration, and scalability. Human resources may need to rethink skills development and organizational readiness.

In other words, AI is not a supply chain initiative; it is a business initiative.

NextGen Supply Chain Conference

We are deep into the planning and marketing stage for our 2026 NextGen Supply Chain Conference. This year's event will take place Oct. 21-23, 2026, at the W Nashville hotel in downtown Nashville. We will have Keynote addresses from Tractor Supply, Wayfair and Eli Lilly. Speakers will include senior supply chain leaders from companies like Amazon, Fanatics, Mars, Target, Evonik, Johnson & Johnson, Dr. Reddy's Laboratories, Evonik, GXO Logistics, Penske Logistics and DP World to name just a few. More speakers are being added regularly.

Early bird registration is ongoing. We still have a few slots available for sponsors, if you are a technology or solution provider interested in participating. More information, including registration, is available on our conference website at nextgensupplychainconference.com.

I hope to see you there.

Brian Straight

THE FUTURE DOESN'T WAIT.

Supply chains don't stand still.

Markets shift. Technology advances. Customer expectations evolve.
Disruptions emerge without warning.

And every day, supply chain leaders are expected to
make the right decisions.

EDGE 2026 HAS THE KEYNOTES THAT MATTER

At EDGE, you'll hear directly from the leaders shaping the future of
supply chain—executives who have navigated disruption, driven
transformation, and delivered results when it mattered most.

These sessions go beyond big ideas to reveal what's actually working today.
Discover how organizations are building resilience, embracing innovation,
improving performance, and preparing for what's next.

Whether you lead planning, procurement, transportation, logistics, operations, or
strategy, EDGE keynotes deliver the perspective and practical insights you need
to move forward with confidence.

Fresh perspectives. Real-world lessons. Actionable takeaways.

No matter your role in the supply chain, **you belong at EDGE.**

EDGE™

Expertise • Development • Globalization • Execution
October 4–7, 2026 | Nashville, Tennessee



Scan to Register

Keynote Lineup



Stuart Whiting
SVP Logistics,
Planning & Services
Global Supply Chain
Schneider Electric



Jo Marini
Chief Executive Officer
& Co-Founder
Mothership Materials



Roberto Canevari
EVP, Chief Value Chain Officer
The Estée Lauder Companies



Peter Larsen
Vice President
Amazon Supply Chain Services



SPECIAL REPORTS

54

The certification question

58

The Top 50 3PLs

COMMENTARY

4

Insights

Chokepoints need the 'Theory of Constraints'

8

Innovation Strategies

From rules of origin to rules of resilience

12

Global Links

The AI-empowered supply chain leader

44

Operations Advantage

Risk sharing is the new advantage in capital project delivery

48

Benchmarks

Managing human and AI teams across the supply chain

16 THE VALUE PROPOSITION: BRIDGING THE SKILLS GAP BETWEEN THE SCM DEGREE AND THE WORKPLACE

As AI, geopolitical volatility, and sustainability mandates rapidly reshape supply chain operations, universities and industry partners face growing pressure to redesign SCM education around applied digital fluency, resilience, and real-world execution skills that better prepare graduates for the modern workplace.

24 DEVELOPING THE NEXT GENERATION OF SUPPLY CHAIN LEADERS. IS HIGHER EDUCATION SERVING THE NEEDS OF THE MARKETPLACE?

As supply chain management evolves into a broader value chain leadership discipline, universities face growing pressure to redesign curriculum around risk, resilience, finance, geopolitics, technology, and hands-on leadership development to better prepare graduates for the realities of a rapidly changing global marketplace.



30 NEXUS SUPPLIERS: HIDDEN ANCHORS OF RESILIENCE IN DECENTRALIZED SUPPLY CHAINS

As supply chains become more decentralized and fragmented, resilience increasingly depends not on the number of suppliers in the network, but on "nexus suppliers" whose embedded relationships, informal influence, and cross-network coordination quietly stabilize operations during disruption.



36 WHAT OPTIONS DO YOU REALLY HAVE? SHAPING THE SUPPLY CHAIN RESILIENCE FUNNEL

Before investing in resilience, map your real option space—then decide what is feasible, useful, and usable under pressure.



TO SUBSCRIBE: Subscribe or renew online at scmr.com/subscribe. Contact customer service at scmr.com/customer-service. **MAIL:** *Supply Chain Management Review*, PO Box 677, Northbrook, IL 60065-0677. Make checks payable to "Peerless Media" for all subscriptions.

LICENSING AND REUSE OF CONTENT: Contact our official content licensing agency, Wright's Media, about available usages, license fees, and award seal artwork at peerless@wrightsmedia.com. Please note that Wright's Media is the only authorized company that can provide Peerless Media brand materials.

AUTHOR'S GUIDELINES: Interested in writing an article for possible publication in *Supply Chain Management Review*? See our guidelines for authors on scmr.com.

PLUS+

PLUS subscribers: Access this issue, all archives and more at scmr.com/plus

SUPPLYCHAIN
MANAGEMENT REVIEW

changes to: Supply Chain Management Review, PO Box 677, Northbrook, IL 60065-0677. Reproduction of this magazine in whole or part without written permission of the publisher is prohibited. All rights reserved. ©2026 Peerless Media.

Dr. Lapide is a lecturer at the University of Massachusetts; Lowell and formerly an MIT Research Affiliate. He has extensive experience in industry, consulting, business research, and academia as well as a broad range of forecasting, planning, and supply chain experiences.

He was an industry forecaster for many years, led supply chain consulting projects for clients across a variety of industries, and has researched supply chain and forecasting software as an analyst. He is the recipient of the inaugural Lifetime Achievement in Business Forecasting & Planning Award from the IBF. He welcomes comments on his columns at Lawrence_Lapide@uml.edu.

Chokepoints need the ‘Theory of Constraints’

As geopolitical tensions expose vulnerabilities in global trade routes, supply chain leaders can apply the “Theory of Constraints” to identify chokepoints, build strategic buffers, and design more resilient networks capable of absorbing disruption before it becomes a crisis.

By Larry Lapide

With all the hubbub about the Strait of Hormuz being a chokepoint these days, I’ve begun to wonder whether supply chain managers have been thinking hard enough about bottlenecks in their global supply chains. When I was an analyst at AMR Research (now part of the Gartner Group)—focused on Advance Planning and Scheduling (APS) software—I learned a bit about “The Theory of Constraints”(TOC). It is “an overall management philosophy introduced by Eliyahu M. Goldratt in his 1984 book *The Goal* that [is] geared to help organizations continually achieve their goals. It describes a case study in operations management, focusing on the ‘Theory of Constraints’ and bottlenecks in addition to how to alleviate them,” according to a Wikipedia entry describing it.

Because a chokepoint appears to be a bottleneck that has been shut down for an indefinite amount of time, I wondered what are ways in which a global supply chain might be designed to temper the impact of a random chokepoint popping up in one’s supply chain.

Design irrespective of possible future supply happenings

Fourteen years ago in my Insights column, “Don’t Forget Supply-Side Risk” (July/August 2012), I cautioned managers against assuming that only the demand side of their business has risks and uncertainties

associated with it. The subtitle stated that: “As the global environment becomes more uncertain, managers need to pay greater attention to risks on the supply side.”

In it, I stated that supply chain managers have always been reconciled to the fact that customers are fickle. They understand that demand is uncertain, thus forecasts and plans are invariably inaccurate. They’ve become adept at coping with demand uncertainty and risk by using various buffering strategies, including the deployment of inventory safety stock. However, when it comes to understanding and managing uncertainty and risk on the supply side, they are typically far less accomplished or even concerned.

Back in the day, I debated a seasoned and accomplished supply chain manager on the topic. He agreed with my view that demand-side uncertainty might increase significantly because of a financial crunch (i.e., the Great Recession that had happened at that time). However, he refused to accept that the same could happen on the supply side. He could not envision any supply-side uncertainties that he couldn’t manage around—and the audience wholeheartedly agreed with him.

Supply disruptions became more prevalent

In my column, I mentioned several examples of this supply-side uncertainty and risk. The Japanese tsunami and the Thai floods, back then, disrupted the high-tech and automobile supply chains for quite some time. The Arab Spring caused the disruption of supply chains in some Middle East countries. Several Latin American countries such as Venezuela, Argentina

and Bolivia were more inclined to nationalize businesses. Also, pirates disrupted supply lines off the coast of Somalia. Lastly, politicians around the world were expressing concern about the unemployment of domestic workers, putting outsourcing and offshoring programs at risk.

Since then, the world experienced the COVID-19 pandemic that rendered both demand and supply more uncertain and riskier for quite some time. For example, there were serious shortages of vital medical masks and baby formula—primarily due to the outsourcing of production to remote outsourcers—and the lockdowns that kept people from going to work.

Chokepoint: A Strait of Hormuz lesson

As a result of the recent war with the U.S., Iran created an oil supply chain chokepoint in the Strait of Hormuz in which a significant percentage of the world’s oil passes. It drove up energy prices at high economic costs to the world in order to put pressure on the U.S. during ceasefire negotiations. Since modern economies rely heavily on, and are actually addicted to fossil fuels, the higher energy costs and inflation are a significant concern among economists.

At one point, around 600 tankers were stuck in the strait. To my simple mind, this is unbelievable. Why did transportation managers and executives allow it to reach this crisis level? Did any of them ever take a detour in their car to avoid a severe traffic jam—especially a potentially deadly one for their sailing teams?

Coincidentally, a timely book from Edward Fisher, titled *Chokepoints: American Power in the Age of Economic Warfare*, was recently published. According to Amazon.com it is:

- The epic story of how America turned the world economy into a weapon, upending decades of globalization to confront a new authoritarian axis—Russia, China, and Iran. (*The New York Times*)
- Chokepoints provides a thrilling account of one of the most transformative developments of our time, demystifying how the U.S. government harnesses the power of Wall Street, Silicon Valley, and Big Oil against America’s enemies. At the center of the narrative are the trailblazing diplomats, lawyers, and financial whizzes who have masterminded America’s escalating economic wars against Russia, China, and Iran.

The book extends the idea of geographic chokepoints—including the Bosphorus and the Strait of Hormuz—that are critical domains of the global economy dominated by the United States and its allies. Fishman argues that these chokepoints give Washington extraordinary leverage, while cautioning that their exploitation is driving U.S. adversaries to construct alternatives (Wikipedia).

In a news article, “In This War, Chokepoints Beat Tariffs” (*WSJ*, April 15, 2026), a reporter states that: “Neither Iran nor even China possess anything like the economic sway the U.S. does. What they control are ‘chokepoints’—China produces 94% of rare-earth magnets and 20% of the world’s oil passes through the Strait of Hormuz.” Also, “as finance and supply chains have globalized, potential economic chokepoints have multiplied, as have the efforts to weaponize them.”

Also, “Fishman notes that once a chokepoint has been weaponized, vulnerable nations will go to great lengths to neutralize it.” For example, in an article, “Trucks Circumvent Hormuz Barrier” (*WSJ*, May 13, 2026), the subtitle states that “With strait jammed, overland shipping is next best option, a logistical lifeline. Highways, railroads, and ports in Saudi Arabia, the United Arab Emirates, and Oman have been transformed into an emergency logistics lifeline circumventing the Strait of Hormuz waterway.”

The Theory of Constraints (TOC) might be useful

“The Theory of Constraints [TOC] is a management paradigm that views any manageable system as being limited in achieving more of its goals by a very small number of constraints. There is always at least one constraint, and TOC uses a focusing process to identify the constraint and restructure the rest of the organization around it. TOC adopts the common idiom that ‘a chain is no stronger than its weakest link.’ That means that organizations and processes are vulnerable because the weakest person or part can always damage or break them, or at least adversely affect the outcome,” according to Wikipedia.

Use buffering to mitigate bottleneck risk

TOC deals with bottlenecks. According to Wiktionary.com, two of the definitions of bottleneck (with chokepoint being synonymous) are: 1) “In traffic, any narrowing of the road, especially resulting in a delay,” and 2) “The part of a process that is too slow or cumbersome.”

Thus, in looking at a global supply chain involving multiple tiers of upstream suppliers to downstream sellers, troubled bottlenecks can significantly impede the flow of goods. In TOC nomenclature, bottlenecks are termed constraints. Buffers are used around a severe bottleneck to protect it against upstream (supply) and downstream (demand) vagaries. The Insights column “How Buffers Can Mitigate Risk” (April 2008), discussed one important solution to coping with uncertainties is to plan with them in mind, and put in place more efficient ways of coping with them. Leveraging risk management during planning is a way to build in the appropriate levels of agility, adaptability, flexibility, and responsiveness.

Variability Buffering Law

One of the laws found most useful for enabling risk management in supply chains is called the “Variability Buffering Law.” It states that “variability in a production system will be buffered by some combination of inventory, capacity, and time.” The law helps identify methods for adding buffers needed for sustaining performance that also mitigate against future uncertainties. Here are some examples:

- **Inventory.** Inventory is the most prevalent buffering method. The concept of safety stocks is well understood among supply

chain managers. In addition, formal techniques exist for setting safety stocks based on uncertain supply lead times and demand uncertainties to achieve customer service-related performance goals. To ensure maximum use of bottlenecked assets, TOC prescribes using inventory buffers in front (e.g., the upstream side) of these assets based on the uncertainties of supply activities. As well as often buffering behind (e.g., the downstream side) to mitigate against the risk of significant vagaries in demand.

- **Capacity.** The concept of not using 100% of capacity is intuitively unappealing. However, when things do not go according to plan in a system running at 100%, havoc can ensue. Should there be any upticks in demand or supply glitches, inordinate delays will occur. Thus, from a practical standpoint, operations are utilized significantly below their theoretical maximum. Leveraging the Variability Buffering Law, for example, running two shifts with a capability to run a third is one way to buffer against supply shortages or upticks in demand. Building redundancy in a system can also effectively buffer via capacity. For example, designing a plant with the capability to switch production among multiple products, or multi-task workers, or use multiple suppliers for a component, effectively increases capacity by providing options to apply additional supply resources to products experiencing higher-than-expected demand relative to others.

- **Time.** Allowing extra time to take action, make a decision, or service a customer are ways to buffer against variability. For example, manufacturing postponement buffers against demand risk by delaying the defining steps in the manufacturing process of a product until demand is better known. Delaying distribution by holding inventory upstream until absolutely necessary or re-directing goods in-transit are better ways to match variability in demand geographically. “Service window management” schemes also leverage time buffers. These involve padding the delivery time quoted to customers so that more time is available to service them should glitches occur during order fulfillment. For example, many parcel carriers quote a delivery time range, such as within five days. Other companies quote an order delivery by adding days or weeks to their average fulfillment times to account for uncertainty in supply operations.

The Hormuz chokepoint evolved to a disaster waiting to happen

Research for the MIT Supply Chain 2020 project I managed the launch of in 2005 included the profiling of supply chains in a variety of industries. In the auto industry, GM was picked as a topic for a graduate student’s thesis. In a draft of it, the company’s sponsor saw that one of the best practices that was profiled was “state-side” inventory.

This was holding inventory of cars in the U.S. to buffer against the vagaries of the ocean shipping of cars manufactured overseas. The student was told to take it out of the published thesis because the supply chain managers had instituted the policy without running it by executive management. Often focused on return-on-assets, the executives wanted to run a lean, just-in-time (JIT) supply chain, holding minimal inventory, especially in the United States.

TOC might have helped mitigate the chokepoint

Middle East oil producers appear to have evolved to a lean, JIT oil supply chain. With (apparently) little thought to using inventory, capacity, and time buffers to mitigate against various vagaries in supply and demand. For example, producers held all their oil inventory in-country, assuming that the Strait would always be wide open for order fulfillment. More inventory should have been held nearer to downstream customers in other geographic areas of the world (think about GM’s state-side inventory example). Also, there was insufficient excess pipeline ‘capacity’ in their country to move oil without using the Strait. Lastly, they should have promised customers longer and more flexible (e.g., extended) lead times just in case tankers needed to be detoured, rather than (too-often) directed into the closed and dangerous Strait of Hormuz.

Bottom line: Apparently, too little oil inventory was in-transit and not stored outside the Middle East. In retrospect, wouldn’t it have been better to have up to 60 days or more of oil demand on tankers and in storage elsewhere so that customers would be served for at least 60 days, while the producers figured out detours away from the Strait? •

From rules of origin to rules of resilience

Gastón Cedillo, Ph.D., is a Radcliffe Killam Distinguished Faculty Member at Texas A&M International University, a Physical Internet Ambassador (EU), and the founder and inaugural technical director of the National Laboratory for Transportation Systems and Logistics (Mexico). He can be reached at miguel.cedillo@tamiu.edu.

Chris Mejía-Argueta, Ph.D., is the founder and director of the Emerging Market Economies Logistics Lab (EMeL), formerly named the Food and Retail Operations Lab, and the director of the SCALE network for Latin America and the Caribbean at the MIT Center for Transportation and Logistics. He can be reached at cmejia@mit.edu.

Developing the next frontier of North American competitive advantage.

By Gastón Cedillo, Ph.D. and Chris Mejía-Argueta, Ph.D.

For decades, trade agreements have focused on fundamental components: product or service features, markets, regulatory standards, investment protections, and dispute resolution. In North America, this logic is embedded in the United States–Mexico–Canada Agreement (USMCA) through rules of origin and regional value content requirements. These provisions determine whether a product or service qualifies for preferential tariff treatment based on the percentage of content sourced or manufactured within the region.

Recent supply chain disruptions have exposed a critical weakness: knowing where a product was manufactured, where it will be sold, or which regulatory or legal conditions apply provide no actionable insight into whether it can move reliably, securely, and sustainably across borders.

The next competitive frontier for North American supply chains is not siloed initiatives or traditional maquila approaches; it is the logistics value that resiliency delivers. For three decades,

North American trade rules have certified one stage: where a good was made. The next generation must certify the next crucial stage: the resilience of the movement of goods. Supply chain resilience belongs alongside origin in tariff treatment, not below it.

For practitioners and entrepreneurs, negotiations over the North American Trade Agreement extend far beyond government-to-government talks. Business and policy leaders need an actionable agenda to ensure supply

chains continue driving value in volatile environments through better planning, scenario analysis, and stakeholder alignment.

The new bottleneck is a moving target

During the Golden Age of low-vulnerability perception, firms invested heavily in optimizing production networks.

Manufacturers reduced costs, increased specialization, and expanded cross-border sourcing in search of standardization and cheaper labor.

Today, however, the greatest risks often occur after production is complete, and they vary in severity, frequency, spread, likelihood, and duration. Most of these risks stem from supply chain breaches across diverse stakeholders, decision-making levels, and business units.

Border closures, cargo theft, cyber-enabled freight fraud, infrastructure congestion, labor disruptions, power outages, geopolitical tensions, and environmental regulations increasingly determine whether products arrive on time and at the expected cost. A component that meets every regulatory requirement still loses value if it is delayed at a crossing, diverted through fraud, stranded due to infrastructure failure, or mishandled due to poorly skilled labor. In turn, resilience has become a competitive differentiator.

Organizations that can predict disruptions, recover faster, make informed decisions, and maintain service continuity

gain advantages in customer satisfaction, working capital efficiency, inventory management, and risk mitigation. Yet resilience remains largely absent from trade policy discussions and is often treated as a cost center rather than a strategic, value-generating capability.

Four dimensions for the next frontier in competitiveness

Building long-term sustainable capabilities for the U.S., Mexico, and Canada has been challenging. However, four measurable dimensions of supply chain resilience should be addressed to facilitate integration, gain visibility, and enhance competitiveness in the region.

The first is *reliability*, defined as the predictability of transit times and logistics performance. Since businesses plan around expectations rather than average values, a shipment that consistently arrives in five days is often more valuable than one that averages four days but fluctuates wildly between two and 10 days. Predictability reduces inventory buffers, improves production scheduling, increases service performance and speed, and decreases unexpected costs.

The second dimension is *security*. Cargo theft and freight fraud have evolved dramatically in recent years, becoming increasingly sophisticated and digital-forward. Criminal activity now extends beyond physical theft to include identity spoofing, double-brokering, and fraudulent load-diversion schemes. As supply

chains become more connected, security is inseparable from operational performance.

The third dimension is *redundancy*.

While efficiency initiatives often eliminate redundancy, recent disruptions have underscored the importance of maintaining alternative routes, transportation modes, suppliers, and border crossings. Organizations with options recover faster from disruptions, particularly when single-sourcing is present.

The fourth dimension is *governance*. The other three dimensions measure what happens to goods, whereas governance measures whether the authorities responsible can set the stage for this system to work and stay prepared when something fails. USMCA corridors cross three customs regimes, dozens of state and provincial transport agencies, and bridge and port authorities whose mutual recognition protocols remain only partially aligned.

Regulatory pressure, customer expectations, and investor scrutiny are making performance expectations too complex for a single entity to manage. A potential board of practitioners, policymakers, and academics should create a master plan for regional development, logistics, and integration to influence market access and competitiveness, particularly in global trade corridors connected to other global regions.

Together, these four dimensions provide a practical lens for assessing resilience in ways that executives can measure and manage.

Turning resilience into a tradable asset

Measuring resilience is feasible and economically valuable. A Logistics Resilience Credit Score may reward organizations as a corridor-level rating that converts measured resilience into a small, additive tariff credit against the Regional Value Content obligation. A shipment moving through a corridor that

meets jurisdiction-agreed thresholds for travel-time variability, cargo-loss incidence, emissions intensity, and route redundancy earns a credit calibrated to be small enough to preserve origin requirements yet large enough to mobilize interest in updated telematics, security technology, and clean-fleet conversion. Leading organizations are already moving in this direction through resilience dashboards, control towers, risk-scoring platforms, and company-centric observatories. However, building strategic decision-support systems that translate resilience and scenario planning into common language across governments, carriers, manufacturers, insurers, and logistics providers remains largely underdeveloped.

The rise of digital trust

To cope with the rapidly evolving digital world, supply chain stakeholders should develop a mechanism to document and verify the resilience profile of individual shipments, thereby increasing traceability, visibility, and data sharing among organizations. Therefore, a *Digital Certificate of Resilience* would convert a shipment's measured resilience profile into a verifiable trade-policy instrument. Exporters could attach a certificate to each shipment that shows its measured profile across the four dimensions. The certificate does for logistics what the certificate of origin does for content: it makes a private operational record auditable.

As supply chains become more digital, the ability to verify shipment conditions, route integrity, security compliance, and sustainability performance becomes increasingly valuable. Organizations that can demonstrate trusted performance may gain advantages in customs processing, insurance pricing, customer relationships, and regulatory compliance.

The future of industry and policy leaders

Building resilient trade corridors will require more than new policies and digital infrastructure; it will require a new generation of supply chain leaders capable of operating at the intersection of logistics, technology, public policy, and risk management. As artificial intelligence becomes increasingly embedded into transportation planning, customs operations, cargo-security monitoring, and disruption forecasting, organizations must invest in developing the skills needed to deploy these tools responsibly and effectively. Universities, executive education programs, and corporate training initiatives therefore play a critical role in preparing industry and policy leaders to manage resilient, data-driven supply chains across North America.

Why this matters for U.S. leaders

During this significant realignment of manufacturing and sourcing strategies, success depends on more than production capacity. Now, growth requires integrated physical and digital infrastructure, including resilient logistics corridors, strategic decision-support systems with a scenario perspective, and a skilled workforce that creates value rather than merely reducing costs.

Executives evaluating investments in North America should pay close attention to border infrastructure, transportation security, corridor performance, customs modernization, and data-sharing capabilities. These factors increasingly determine economic viability, structural adaptability, and alignment of regional supply chains across industries.

A practical roadmap for the region

Enhanced carrier verification processes, stronger freight security protocols, greater use of visibility technologies, improved data-sharing practices, and corridor-level performance monitoring are all within reach for current supply chain organizations.

Executives do not need a sophisticated treaty amendment to begin measuring reliability. However, the public agencies in the region need to act in coordination to become enablers of the next logistics ecosystem, ensure proper infrastructure development to build trust, drive competitiveness to the next level, and provide a platform for connecting with other regions.

The Bottom line: The non-local isolation

Supply chains have entered a new era. Competitive advantage increasingly depends on the ability to anticipate disruptions, maintain continuity, and recover quickly from failures. Resilience deserves to be the central piece of a new scheme, measured, managed, and rewarded alongside traditional trade metrics.

For years, trade policy has focused on where products are made. The next generation of supply chain leadership will focus equally on how products move. However, organizations that embrace that shift today will be better positioned to compete tomorrow through orchestrated efforts to increase fluidity in our regional supply chain ecosystems. •

References

- Cedillo-Campos, M., Piña-Barcenas, J., Pérez-González, C. & Mora-Vargas, J. (2022). *How to measure and monitor the contribution of transportation infrastructure to the logistics value of supply chains?* Transport Policy, Volume 120, May 2022, Pages 120-129. <https://doi.org/10.1016/j.tranpol.2022.03.001>
- Montoya-Torres, J. R., Muñoz-Villamizar, A., & Mejía-Argueta, C. (2023). *Mapping research in logistics and supply chain management during the COVID-19 pandemic*. International Journal of Logistics Research and Applications, 26(4), 421-441. <https://doi.org/10.1080/13675567.2021.1958768>

*Anne G. Robinson, Ph.D.,
is the founder and CEO
of Robinson Insights, an
analytics and supply chain
advisory service. She is a
past president and fellow of
INFORMS, a partner with
the Masters of Supply Chain,
and a mentor for the
Creative Destruction
Lab Supply Chain stream.
She can be reached at
arobinson
@robinsoninsights.com*

The AI-empowered supply chain leader

AI isn't replacing supply chain leaders. It is redefining what leadership demands. Are you ready?

By Anne G. Robinson, Ph.D.

If you believe the headlines, AI is about to put global supply chains on autopilot, quietly sidelining planners, buyers, and logistics managers. That may make for great clickbait, but it's not the story unfolding inside leading supply chain organizations. AI is not replacing supply chain professionals. It is changing the work they do, the decisions they influence, and the capabilities leaders must build to stay relevant.

The more urgent question is no longer whether AI will eliminate supply chain roles. It is where in the supply chain should AI be applied, what decisions should remain human-led, and which leadership skills become more valuable as AI becomes ubiquitously embedded across operations. For supply chain leaders, this is a skill-building moment. The organizations that benefit most from AI will not simply have better tools. They will have leaders who know how to frame the right problems, govern the risks, interpret the outputs, and turn AI-enabled insight into better decisions. Here are five key dimensions to consider to ensure you and your team are not left behind.

1. Increase your AI fluency

As a supply chain leader, you need to understand AI. With the landscape changing on a seemingly daily basis, it's not critical to understand the inner workings of every AI analytics model. However, it is important to get a grasp of how they work and where they apply. AI fluency for supply chain leaders is about knowing where AI can consistently elevate supply chain performance, not just experimenting with LLMs and agents. It involves being able to identify and frame the problems and opportunities that are best suited for AI, validate the inputs, and interpret outputs with a critical, operations-aware lens, turning insights into action.

At its best, AI fluency transforms AI into a collaborative teammate for real-time decisions while leaders retain accountability for the final call. It also requires a comprehensive understanding of the total costs, data requirements, and organizational implications of AI, so that investment is directed toward high-impact, measurable use cases and capabilities rather than a collection of disconnected pilots or experiments.

2. Adopt an entrepreneurial mindset

Thinking like an entrepreneur is becoming a core leadership skill in the age of AI. AI has empowered supply chain teams to create their own capabilities without always needing to code. This reopens the classic build-versus-buy decision every time a new need or opportunity appears. Leaders now have to weigh not only traditional legacy providers, but also a wave of startups offering targeted capabilities faster and often at lower entry costs, as well as the option

to build internal tools on top of AI platforms to augment existing capabilities. The real question becomes: Is this the moment to build in-house, to place a bet on a new venture, or to double down on a legacy platform that is steadily augmenting its AI features?

Adopting a venture capitalist mindset helps structure those choices. Leaders evaluate whether a startup is well funded, whether the team has genuine supply chain expertise, and whether the product can scale to enterprise-grade performance, security, and support. At the same time, they assess internal readiness: Do we have the data, talent, and capacity to build and sustain this ourselves? This entrepreneurial lens turns technology selection from a defensive IT decision into a strategic portfolio choice, balancing risk and reward, diversifying bets across planning horizons, and ensuring that each AI investment is aligned with long-term supply chain and organizational strategy.

3. Recognize ethics and governance are table stakes

The biggest risks with AI in supply chains are no longer just technical; they're ethical and governance failures. Analysts now point to real-world cases where opaque models and their outputs have amplified bias, compromised data security, or propagated poor or incorrect policy creating lawsuits, regulatory exposure, and reputational damage for the companies using them.

Ethical responsibilities in supply chain teams begin at the individual level: building trustworthiness starts with each person's choices and actions. Ethical AI is not

a nice-to-have; it is essential and foundational for innovation that respects human dignity, safeguards stakeholders, and protects the organization's long-term reputation and license to operate.

Established ethical frameworks such as the NIST AI Risk Management Framework provide a strategic compass for supply chain professionals to champion fairness, transparency, and accountability in every AI and analytics initiative they influence, aligning technology decisions with corporate values, regulatory expectations, and business objectives.

AI governance is not only about risk avoidance. It is also about value realization. Without a clear governance model, AI spreads in disconnected pockets; experiments in planning, ad-hoc copilots in procurement, and home-grown logistics models that may not be visible, scalable, or aligned. Shadow AI is the new shadow IT. Supply chain leaders need aligned governance that turns pilots and proofs of concept into repeatable capabilities, with clear ownership, decision rights, guardrails, and business measures aligned with strategy.

4. Elevate domain expertise—it still matters

Supply chain excellence is a strategic differentiator, not a back-office function. As such, supply chain leaders must have a depth of understanding on how strategy, planning, inventory, and operations intertwine and directly affect profitability, sustainability, and customer experience. In a recent Masters of Supply Chain podcast, the CEO of an emerging supply chain technology vendor, commented “Supply chain is a very specific sport. You need people who know the math and the materials flow.” In fact, as supply chain roles shift from “spreadsheet jockey” to “model steward,” “exception manager,” and “scenario strategist,” the demand for experienced

professionals increases. For instance, instead of a planner manually stitching together reports from ERP, TMS, and a couple of spreadsheets, an AI-enabled planning system can aggregate those signals, flag anomalies, and propose a ranked list of actions. The planner's job doesn't disappear; it becomes more strategic, validating the assumptions behind inputs and recommendations, managing exceptions, and weighing business implications. AI takes over the heavy lifting of pattern recognition and simple decision automation, not decision accountability. These types of shifts are giving way from larger traditional operator teams to smaller teams of highly skilled professionals who supervise multiple capabilities, decide how to handle edge cases and exceptions, and ensure supply chain objectives are aligned with corporate direction.

5. Keep the human in the loop

Human judgment is what keeps AI-led supply chains both effective and humane. AI can surface crowd-sourced expertise on demand, automate decisions within defined boundaries, and dramatically increase the scale at which these smaller teams can operate, but the human perspective in the loop remains essential.

A recent study from the University of Melbourne's Center for Business Analytics revealed that, despite the hype and the abundance of AI frameworks, a large majority of analytics and AI projects still fail. These failures typically stem from organizations underestimating project complexities, setting unrealistic expectations, or overlooking the human and organizational work required to make these AI capabilities truly useful and delivering value. In that context, humans cannot simply act as box-tickers validating algorithmic outputs; they must bring empathy, practical experience, and change-savvy communication.

This in turn resets expectations, explains new workflows, and builds trust in AI-augmented ways of working. As industry thought leaders like Polly Guthrie have stated, AI systems lack three critical human capabilities: context, collaboration, and conscience, the very qualities that people contribute when they stay actively engaged in the loop. Human judgment, in that sense, supplies the “soul” of the system, ensuring that AI acts as a powerful decision partner rather than an unexamined authority, and that its recommendations stay grounded in real customers, real context, and real-world operations.

This is the moment for supply chain leaders to act. Start with deliberate, practical steps: build AI fluency across your leadership team, not just in technical roles; target a few

high-value decisions where AI can materially improve speed, quality, or consistency; establish clear governance, guardrails, and accountability before you scale; elevate domain expertise so AI outputs stay grounded in operational reality; and keep humans actively in the loop for context, collaboration, and conscience.

AI is not going away. It is rapidly becoming part of the operating fabric of modern supply chains. The leaders who create the most value will not be the ones who delegate AI to IT or chase every new tool, but those who build the organizational muscle to use it responsibly, practically, and at scale with the potential of unlocking a new level of performance. AI is rewriting the supply chain leadership playbook; the differentiator will be leaders curious and confident enough to harness it for sustained supply chain advantage. •

ULINE

QUALITY HAS A NAME

ORDER BY 6 PM FOR SAME DAY SHIPPING

ULINE TUBES

ULINE INDUSTRIAL TAPE

ULINE MINI-WRAP

ULINE AIR IN A CAN

ULINE BUBBLE MAILERS

ULINE ROLL TOWELS

ULINE TOILET TISSUE

COMPLETE CATALOG 1-800-295-5510 uline.com

THE VALUE PROPOSITION:

Bridging the skills gap between the SCM degree and the workplace

By David Widdifield, DBA and Misty Blessley, Ph.D.

As AI, geopolitical volatility, and sustainability mandates rapidly reshape supply chain operations, universities and industry partners face growing pressure to redesign SCM education around applied digital fluency, resilience, and real-world execution skills that better prepare graduates for the modern workplace.



David Widdifield, DBA, is a clinical associate professor and vice chair of the Department of Marketing & Logistics at the Fisher College of Business at The Ohio State University. He can be reached at widdifield.2@osu.edu.

Misty Blessley, Ph.D., is an associate professor in the Department of Information Systems and Supply Chain Management at the John Chambers College of Business and Economics at West Virginia University. She can be reached at misty.blessley@mail.wvu.edu.

“If you always do what you’ve always done, you’ll always get what you’ve always got.”

~ Henry Ford

For graduates walking across the stage with a degree in supply chain management (SCM), it may feel like receiving a key to the engine room of the global economy. An investment of four years at tens of thousands of dollars in tuition seems like a fair trade for the engine room key, but that comes with expectations.

A few months into the first “real-world” role brings this into focus. The sophisticated ERP systems discussed in textbooks have been replaced by a fragmented series of legacy spreadsheets or systems held together by tribal knowledge. The strategic sourcing strategies practiced in case studies, which always turned out, are not relevant as they are sidelined by the immediate, chaotic necessity of finding a single missing container on a rail siding in Omaha. After just one year, so much has changed that you are now behind if you have not already begun to upgrade your SCM skills for the role.

Reality sets in: Utility-to-effort dissonance

As this new SCM professional looks at their first student loan statement, a quiet but persistent dissonance begins to set in—was all this worth it? There may be a growing frustration that the “effort-to-utility” ratio used to evaluate the value of the degree is skewed. Typically, degrees are assigned a level of utility (value) based on a scale of values for assessing their worth in the marketplace (Mosteller & Nogee, 1951). Degrees in SCM must combine “science” with application in a work setting if young professionals are to be adequately equipped for the operational and

strategic requirements defining their day-to-day roles.

The harsh reality facing new employees and their employers today is the “half-life” period of the SCM degree has accelerated at an alarming rate. This is a sobering metric for a new graduate as they face an ever-changing environment. In the context of today’s workspace, the shelf life of the technical and tactical skills acquired during a four-year SCM program has reached an all-time low. While a degree provides a permanent credential, the utility of the specific technical skills within that degree now follows a rapid decay curve.

Current industry data suggests that the half-life of technical skills in business and technology fields—including SCM—is now approximately 2.5 to 5 years (Morson Group, n.d.) In highly digitalized areas of supply chain operations like AI-driven forecasting, robotic process automation (RPA), and real-time logistics tracking, the half-life can be as short as 18 to 24 months. By the time a graduate celebrates their third work anniversary, nearly 50% of the specific software tools, tactical methodologies, and technical frameworks they learned in their SCM degree program are either obsolete or have been significantly superseded by AI-augmented

systems (World Economic Forum, 2025). This creates a gap between the skills required in the workplace today versus those that students were taught in academia just a few years prior (see Table 1 below).

- procurement;
- project management; and
- supplier relationship management.

The goal is to ensure SCM program graduates are

TABLE 1

Skills gap

SKILL CATEGORY	HALF-LIFE EXPECTANCY	WORKPLACE REALITY
Tactical/Tools (AI ERP, Excel, SQL, WMS)	< 2 years	AI now writes the code and automates the data cleaning that graduates spent years mastering.
Strategic/Functional (Procurement, S&OP, network design)	3 to 5 years	Geopolitical volatility and regulatory compliance are constantly changing supply chain strategies.
Foundational (Customer relations, demand management, inventory management)	15+ years	These remain the “science.” They are the only part of the degree that does not rapidly decay.

Source: Authors

How did we get here?

As greater access to college education increased the number of degree holders over the decades, the four-year SCM degree has emerged as a primary mechanism for developing work-ready supply chain talent. In the past decade alone, universities witnessed more than a 105% increase with an average of 16,000 SCM degrees being awarded annually (National Center for Education Statistics, 2023). The growth in this field can be partly attributed to the rise of importance of the supply chain function in firms. The SCM major provides graduates with structured exposure to operationally critical skills such as:

- customer relationship management;
- demand management;
- economic order/production quantity;
- inventory management;

adequately trained with the basic skillset needed to tackle the challenges of the workspace. Industry is seeking entry-level hires to be “operationally bilingual” who can handle new and highly complex market environments. Young SCM professionals need to speak the language of high-level SCM concepts as well as be able to apply this knowledge in the successful execution of operations in the firm today.

To further strengthen SCM graduates’ skills and overall competitiveness, universities established formal partnerships with industry leaders to couple the delivery of critical SCM knowledge with experiential opportunities such as case studies, in-class assignments, internships, projects, etc., to apply conceptual theory in a practical work setting.

Unfortunately, these partnerships frequently result in predictable or “sanitized” learning experiences because

of the use of basic assignments using normalized data. Often done for cost and expediency reasons, students gain little hands-on opportunity in the development of applying SCM in the very real-world scenario they will face in industry. Here we have what is fast becoming an obsolete model for talent acquisition, despite the academic/industry partnership.

Adding to the talent development challenges are ever-changing global pressures. Firms are facing these changes at unprecedented levels, requiring the development of new “must-have” skills for a successful entry-level SCM professional (see Table 2).

In this section we take a deeper look at each of these pressures, as well as the new “must-have” skills

exceptions (Sudirman, A., et al., 2026). These are the messy, non-mathematical problems like a port strike, a warehouse fire, or a sudden labor shortage.

Must-have skill: Exception management & AI literacy.

- The workplace reality: New graduates are expected to be equipped with operational AI competence to audit supply chain performance to determine AI’s optimal suggestion using real-world scenarios.
- Success metric: Can you look at an AI-generated delivery route, recognize a localized weather event the system missed, and manually override it to save the client relationship?

TABLE 2
“Must have” skills

INDUSTRY PRESSURE	THE “OLD” EXPECTED SKILL	THE 2026 “MUST-HAVE”
AI integration initiative	Data entry/Reporting	Operational AI competence
Geopolitical volatility	Basic procurement	Total cost of ownership (TCO) analysis
Transparency mandate	Ethics awareness	Multi-tier data traceability

Source: Authors

if entry-level SCM professionals are to bring value to firms. To ensure SCM professionals are ready for the workspace, forward-thinking firms and universities MUST rethink their traditional partnerships.

1. The AI integration initiative. Due to the rapidity of changing workspace skill needs and previously discussed half-life value of the SCM degree, AI now handles the easy stuff (routine forecasting and replenishment). This has created a pressure-cooker environment where the only tasks left for humans are the

2. Geopolitical volatility. Firms are currently trapped in a cycle of rapid-fire geopolitical shifts. Supply chains are suddenly facing unprecedented global upheaval events related to geoeconomic confrontation, state-based armed conflict, and societal polarization, changing the cost of doing business almost weekly. Companies are under immense pressure to keep relationships profitable even as landed costs jump by nearly 11% (World Economic Forum, 2026).

Emerging must-have skills: Financial & sourcing literacy

- The workplace reality: New graduates must be able to perform total cost of ownership (TCO) analysis on changing supply chain environments “on the fly.”
- Success metric: Can you explain to a manager how a 10% tariff increase on a Tier 2 supplier in Asia ripples through the entire margin of a finished product?

3. The transparency mandate. Sustainability compliance is now a legal requirement of the supply chain landscape (EY, 2026). New regulations such as the International Ethics Standards for Sustainability Assurance or International Standard on Sustainability Assurance 5000 now require firms to stay up to date with global sustainability standards to meet changing compliance and transparency requirements. Non-compliance issues can result in monetary fines, product seizure, along with loss of brand reputation.

Emerging must-have skill: Digital traceability & data auditing

- The workplace reality: New graduates must be able to clean messy supply chain data by providing the firm with supply chain multi-tier data traceability. Firms need professionals who can navigate Blockchain or Digital Product Passports to verify compliance.
- Success metric: Can you audit a supplier’s ESG data and flag a “red zone” risk before the shipment hits customs?

What can we (academia and industry) do?

In response to growing global pressures we, academia and industry, have identified three critical SCM program enhancements. Incorporating these enhancements into the SCM curriculum will better arm young professionals with the requisite value and skills firms demand.

1. Applied digital fluency and AI integration

SCM programs must teach digital fluency by designing curricula that move beyond basic data management toward applied technology, where students are trained to be “techno-strategists” (Attaran et al., 2023).

- Generative AI & machine learning: Programs are

integrating AI to improve forecasting accuracy and operational efficiency (He et al., 2024).

- Digital twins: Digital twins (DT) are used in simulating entire supply chains. This allows students to stress-test scenarios, model different nodes, and uncover abnormalities before they manifest in real-world settings (Attaran et al., 2023).
- Data-driven decision making: Schools are embedding big data analytics and real-time information sharing into core modules to develop data literacy and analytical reasoning (Industry 4.0 in Logistics Higher Education, 2026).

2. Strategic resilience and risk management

Disruptive global events have shifted the focus from just-in-time efficiency to just-in-case supply chain resilience (Jiang, B., Rigobon, D. E., & Rigobon, R., 2021), necessitating supply chain resiliency as a core competency.

- Scenario planning: Curricula now emphasize using predictive analytics to assist in forecasting future difficulties and shifting market demands.
- Cybersecurity & data governance: As networks become more interconnected via the internet of things (IoT), graduates are viewing data security and ethical data governance as a means of protecting the integrity of the supply chain (Industry 4.0 in Logistics Higher Education, 2026).
- Agility: Educational models are incorporating immersive environments, such as AR/VR, to help students develop cognitive agility when responding to complex disruptions.

3. Supply chain sustainability and circular economy metrics

The shift toward sustainable supply chain management (SSCM) is no longer a peripheral concern but a fundamental component of modern business strategy, incorporating economic, environmental, and social dimensions to ensure long-term viability (Esan et al., 2024). Industry leaders expect SCM graduates to have the skill set necessary to lead this transition toward sustainable supply chain networks design incorporating circular economy metrics.

- **ESG integration:** Curricula are being adjusted to teach students how to integrate environmental, social, and governance (ESG) metrics into traditional finance and operations frameworks (Abdel Magid et al., 2023; Beyond Greenwashing, 2026).
- **Circular metrics:** Programs are introducing objective evaluations of resource efficiency, such as circular material use rate (CMUR) and lifecycle carbon intensity, to move beyond greenwashing (Beyond Greenwashing, 2026).
- **SDG alignment:** HEIs are increasingly aligning their logistics modules with sustainable development goals (SDGs), focusing on renewable resource management and ethical sourcing (Sustainability-Oriented Higher Education Activities, 2026).

Expected employment growth and outcomes for skilled SC professionals

The U.S. economy is projected to grow employment for all sectors of industry by 3.1% CAGR from 2024 to 2034, according to the U.S. Bureau of Labor Statistics (BLS, 2025). However, employment of SCM professionals is projected to grow to 17% CAGR for the same period. Annually, the supply chain will generate over 26,000 openings for SCM professionals over the next decade.

Globalization and technological advancements are driving demand for graduates possessing the skill set discussed in this article, emphasizing AI integration and fluency, data analytics, risk management, and sustainability.

In its recent 2025 supply chain salary survey, the Association for Supply Chain Management (ASCM) found supply chain professionals holding a bachelor's degree have a median salary of \$92,000. Of the supply chain professions participating in the survey, individuals reported:

- 81% higher job satisfaction levels than their peers;
- 85% express pride in their roles as industry professionals and value contribution; and
- 83% enthusiastically recommend supply chain to those seeking a change or students charting their professional futures.

A similar positive outlook is demonstrated in

graduate outcomes for top-tier supply chain management programs. Programs report exceptional employment placement rates of approximately 82% (on graduation) and 93% ninety days following graduation (*Note: data represents the aggregation of employment results from top 10 SCM programs listed in article references.*) Based on the growth and outcomes in the supply chain profession, the answer to whether to partnership or not in alignment of SCM program curriculum is a resounding 'yes' for firms and institutions.

Moving forward

Supply chain pioneering legend Bernard (Bud) LaLonde (2001) stated that upon graduation SC professionals will "need to spend 20% of the time investing in new skills so as not to become obsolete." This applies not only to professionals but their employers and universities responsible for their training.

For those who choose to move forward with the strategy outlined here, making a collaborative and concentrated effort in the development talent a habit is a win-win for employers, employees, students and of course universities. This effort starts at the entry of students into the SCM program and continues as the graduate walks across the stage and moving into the "engine room" of the global economy.

In adopting the suggested enhancements outlined in this article, SCM programs can ensure their graduates' degrees have a longer functional half-life and that graduates enter the workforce with the requisite value firms are demanding. Achieving these ends, however, is not a one-time collaboration. Industry leaders and universities with forward-thinking programs must establish deeper and ongoing partnerships to ensure SCM program curricula incorporates the three critical SCM program enhancements discussed above.

Many top SCM programs across the country are taking deliberate actions to ensure program curriculum consistently develops capabilities mapping directly to modern supply chain requirements. Graduates of these programs easily demonstrate proficiency in quantitative analysis, data interpretation, process mapping, and cross-functional communication when entering the workspace, but graduating is only the first step on a new path.

They are trained by SCM program curriculum to frame ambiguous problems, evaluate tradeoffs, and support recommendations with conceptual, financial, and operational reasoning. These new SCM skills reflect the interdisciplinary nature of supply chain management, its growing importance in industry and society, and prepare graduates to operate interdependently within complex corporate systems, rather than executing disconnected tasks in corporate and/or market isolation.

Well-prepared SCM professionals can help their firms reap improvements (i.e., performance, productivity, and profit) that compound quickly. Possessing the ability to make informed operational enhancements such as forecast accuracy improvements, reduced premium freight, or safety stock adjustments, generate disproportionately higher financial returns for the firm.

Enhanced supply chain capabilities directly influence overall revenue growth and operating cost savings. An efficient supply chain minimizes waste from excess inventory and reduces logistics-related opportunity costs, which typically account for a substantial portion of a firm's total expenditures (He et al., 2024).

Not only will these actions result in operational cost savings and performance, SCM professionals graduating from such programs described in this article compress the employee investment payback period measured in weeks rather than years. Accompanying this is improvement of employee fit culturally and managerially. Industry firms actively partnering with innovative universities to design-redesign SCM curricula to meet market needs experience lowered replacement costs for entry-level employees. These replacement expenses include activities related to employee recruiting, onboarding, and lost productivity which represents 20% to 30% of an annual salary (Warner, 2025).

In closing, graduates with SCM degrees obtained through universities' programs with the characteristics discussed in this article provide early-career success representing a

substantial, though often hidden, source of return on degree-aligned hiring decisions for industry and universities alike. It is the authors' hope this paper is a call for deeper conversation and collaboration between academia and business partners to create a winning outcome for everyone. •

**Note: article grammar, clarity, spelling, and structure was enhanced via AI (Gemini)*

References:

- Arizona State University. (2025). *W. P. Carey School of Business undergraduate career outcomes report: Class of 2025*. [https://career.wpcarey.asu.edu/Association for Supply Chain Management. \(2025\). 2025 supply chain salary and career report. https://www.ascm.org/making-an-impact/research/salary-survey/](https://career.wpcarey.asu.edu/Association%20for%20Supply%20Chain%20Management.%20(2025).%202025%20supply%20chain%20salary%20and%20career%20report.%20https://www.ascm.org/making-an-impact/research/salary-survey/)
- Abdel Magid, A., Hussainey, K., De Andrés, J., & Lorca, P. (2023). *The moderating role of online social media in the relationship between corporate social responsibility disclosure and investment decisions: Evidence from Egypt*. *International Journal of Financial Studies*, 11(2), 60. <https://doi.org/10.3390/ijfs11020060>
- Attaran, M., Attaran, S., & Celik, B. G. (2023). *The impact of digital twins on the evolution of intelligent manufacturing and Industry 4.0*. *Advances in Computational Intelligence*, 3. <https://doi.org/10.1007/s43674-023-00058-y>
- Beyond greenwashing: how circular economy metrics could revolutionize ESG investing. (2026). *Frontiers in Sustainability*. <https://doi.org/10.3389/frsus.2025.1588374/full>
- Esan, O., Ajayi, F. A., & Olawale, O. (2024). *Supply chain integrating sustainability and ethics: Strategies for modern supply chain management*. *World Journal of Advanced Research and Reviews*, 22(1), 1930-1953.
- EY. (2026, March 17). *What do shifting sustainability regulations mean for business?* https://www.ey.com/en_gl/insights/climate-change-sustainability-services/what-do-shifting-sustainability-regulations-mean-for-business

- Georgia Institute of Technology. (2025). Scheller College of Business undergraduate employment profile: Class of 2025. <https://www.scheller.gatech.edu/career-services/undergraduate/index.html>
- He, J., Fan, M., & Fan, Y. (2024). Digital transformation and supply chain efficiency improvement: An empirical study from a-share listed companies in China. *PLOS ONE*, 19, e0302133. <https://doi.org/10.1371/journal.pone.0302133>
- Industry 4.0 in Logistics Higher Education. (2026). *IntechOpen*. <https://www.intechopen.com/online-first/1233793>
- Jiang, B., Rigobon, D. E., & Rigobon, R. (2021). From Just in Time, to Just in Case, to Just in Worst-Case: Simple models of a Global Supply Chain under Uncertain Aggregate Shocks (No. w29345). National Bureau of Economic Research.
- Michigan State University. (2025). Eli Broad College of Business: 2025 undergraduate program employment report. <https://broad.msu.edu/career-management/outcomes/>
- Morson Group. (n.d.). The technical half-life: What skill decay means for productivity. <https://morson-group.com/news/technical-half-life-skills-decay/>
- Mosteller, F., & Nogee, P. (1951). An experimental measurement of utility. *Journal of political economy*, 59(5), 371-404.
- National Center for Education Statistics. (2023). Table 322.10. Bachelor's degrees conferred by postsecondary institutions, by field of study: Selected academic years, 1970-71 through 2021-22. *Digest of Education Statistics*. https://nces.ed.gov/programs/digest/d23/tables/dt23_322.10.asp
- The Ohio State University. (2025). Fisher College of Business: 2024-2025 undergraduate salary and outcome data. <https://fisher.osu.edu/careers-recruiting/salary-outcome-data>
- Pennsylvania State University. (2025). Smeal College of Business: Undergraduate career statistics class of 2025. <https://ugstudents.smeal.psu.edu/career-connections/statistics>
- Purdue University. (2025). Mitch Daniels School of Business: Undergraduate career success and outcomes 2025. <https://business.purdue.edu/undergraduate/career-success/>
- Rutgers University. (2025). Rutgers Business School: Undergraduate placement and salary report 2025. <https://www.business.rutgers.edu/career-management/undergraduate-outcomes>
- Sudirman, A., et al. (2026). Procurement 4.0: A three-pillar framework for ethical AI adoption in small businesses. *Journal of Small Business Strategy*, 36(1). <https://jsbs.scholasticahq.com/article/157792>
- Sustainability-Oriented Higher Education Activities: Insights from Institutional Isomorphism Perspective. (2026). MDPI. <https://www.mdpi.com/2071-1050/17/24/11034>
- Texas A&M University. (2025). Mays Business School: 2025 undergraduate employment statistics. <https://mays.tamu.edu/career-management-center/statistics/>
- University of Arkansas. (2025). Sam M. Walton College of Business: 2024-2025 undergraduate employment outcomes. <https://walton.uark.edu/career/employment-outcomes.php>
- U.S. Bureau of Labor Statistics. (2024, August 29). Logisticians. *Occupational outlook handbook*. <https://www.bls.gov/ooh/business-and-financial/logisticians.htm>
- University of Tennessee, Knoxville. (2025). Haslam College of Business: Supply chain management career outcomes report 2025. <https://haslam.utk.edu/career-management/outcomes/>
- Warner, C. (2025, April 23). The real cost of employee turnover now. *HRMorning*. <https://www.hrmorning.com/articles/real-cost-employee-turnover/>
- World Economic Forum. (2026). The global risks report 2026 (21st ed.). <https://www.weforum.org/publications/global-risks-report-2026/in-full/>

DEVELOPING THE NEXT GENERATION OF SUPPLY CHAIN LEADERS:

Is higher education serving the needs of the marketplace?

By Sumantra Sengupta

As supply chain management has evolved into a broader value chain leadership discipline, universities face growing pressure to redesign curriculum around risk, resilience, finance, geopolitics, technology, and hands-on leadership development to better prepare graduates for the realities of a rapidly changing global marketplace.



Higher education faces mounting pressure from declining enrollment, the demographic cliff, and increased scrutiny of learning outcomes. At the same time, demand for supply chain professionals is growing globally at double-digit rates, creating an opportunity for universities to align curricula with workforce needs. Since its emergence in the 1980s, supply chain management has evolved from a siloed operational discipline to a strategic value chain perspective. While academic programs have expanded rapidly, future curricula must further adapt by shifting to a value chain management framework, emphasizing risk, sustainability, and geopolitics, and including the development of leadership capabilities. Institutions that successfully evolve their programs will better prepare graduates for leadership in an increasingly complex global value chain environment.

The evolution

Many higher education institutions are at a crossroads. Declining student enrollment, increased scrutiny on student learning outcomes, post-graduation ability to repay debt coupled with the advent of mega companies claiming that college degrees are not a prerequisite for employment all add up to an environment that is under a lot of pressure. These facts are in addition to the often discussed “demographic cliff” which relates to the sharp decline in U.S. high school graduates beginning this year and continuing well into the next decade.

In the general high-pressure environment, the growth in supply chain-oriented jobs over the next decade according to the latest Bureau of Labor Statistics (BLS) report shows growth rates in the double digits (17%+). EU and APAC show robust growth rates as well in the double digits. This bodes well for higher education to provide training and

formal curriculum to support job market growth. We will acknowledge that the growth in the jobs does cover both the vocational and non-vocational aspects of supply chain management so trade schools/trade-related programs will also benefit from this job market trend.

To understand what the current state of higher education (degree granting only and does not include trade schools) is and where it should head, it is imperative to understand the evolution of the field of study.

The year was 1982 the first time the term supply chain management was mentioned in the press—Financial Times, June 4 to be specific. Keith Oliver, a partner with Booz Allen Hamilton, was the originator of the term, although that has been debated by Dr. Wolfgang Partsch, who was also a member of the same team as Keith. I have had the pleasure of being associated many years later with both during my respective tenure at Ernst and

Sumantra Sengupta, Ph.D., CTP, is a veteran practitioner in the field of global supply chain/operations management as well as managing risk and resilience. He currently serves as the founding dean of Rio Grande College of Business, at Sul Ross State University in Texas (a member of the Texas State University System). He pivoted to academic management after a 26-year professional career including serving as partner/SVP with several general management consulting firms and consumer products companies as well as group president of a multinational food and feed security company with global operations. He has been a contributor to Supply Chain Management Review since 1998 and the opinions in this article are based on his own experiences.

Young LLP and Booz Allen Hamilton (now Strategy &). Both individuals were and are true pioneers in driving the integration of the once siloed fields of planning, procurement, operations, transportation, and customer service.

I began my own practitioner journey into the siloed field via work in lean manufacturing and then strategic sourcing and operations management starting in the year 1993. Prior to that, my formal training in the field was comprised of heavy analytics (mathematics, statistics, data structures /algorithm design and programming), operations research and management, inventory optimization and other tangential areas within the business school. However, I had to take courses in 3 different schools and colleges within the same university to create an educational journey that matched my professional goals.

During the past 33 years of my professional journey (private sector and academia), I have had the pleasure of working in many parts of the world including NA, MENA, EU and APAC. I have recruited colleagues from universities in the regions mentioned above and have enjoyed watching the shift in the capabilities that displayed evolution and not revolution. The analytical skills changed gears from training in fundamental concepts to more applications and presentations. More emphasis was placed on project and program management and team dynamics. Integrative constructs that showed the evolution of supply chains to being value chains was emphasized and the adoption of technology in the various segments of the silo was given very high importance.

I have wondered whether we emphasize the basics as much as we used to. I still remember working inventory calculations using the core formulae, doing simplex calculations on a piece of paper and looking at lane by lane LTL and TL rates as well as the fundamentals of ABC analysis during my studies or shortly thereafter. I personally benefited from that type of fundamentals training—also known as first principals; but do understand that we were starting the journey when computing power became cheaper and more ubiquitous.

The field of study also broadened from within the factory, DCs and retail walls to become omnichannel

(the internet revolution). It soon included all aspects of customer service (SCOR model) as well as product design and development and led to an expansion that now includes the various tiers of suppliers and customers (I coined the term Extended Value Community in my book *The New Rules* (2001).

Executives such as Apple's Tim Cook, GM's Mary Barra, Land O'Lakes' Beth Ford, Walmart's Doug McMillan, Flex's Revathi Advaiti and Coca-Cola's Henrique Braun are among those that have risen to the CEO via the supply chain ranks. These career progressions have continued to place SCM in the very heart of boardrooms. There are many VC and PE funds that focus on supply chain startups and rollups to deliver significant returns of value to their investors.

In the 1990s, fewer than 20 universities in the U.S. offered formal training or courses in the field of supply chain management across all degree levels (associate's, bachelor's and master's). That number today is closer to 500, representing a staggering 25 times growth in formal training. This does not include the various certificates that exist in the broader non-education marketplace. The worldwide trend in formal curriculum growth shows similar trends of growth and expansion over the past three decades.

In the next section we will do a deeper dive into the formal educational journey across select parts of the globe that exists today.

Journey until now

The suite of educational programs in the U.S. are oriented toward successful attainment of the various levels of advanced CSCP, CPSM, SCP pro certification(s) and the current needs of the professional industry, including management consulting.

Most of the leading programs have a strong foundational curriculum in topics that cover the fundamentals in the following areas.

- 1) Operational excellence which includes operations planning, and international management
- 2) Logistics and procurement strategies and processes
- 3) Analytics and usage of technology to enable and optimize supply chains
- 4) An introduction to some elements of risk and sustainability

5) A Capstone course/project that showcases experiential learning

European programs tend to follow a similar path; however, there is a much deeper dive in the areas of sustainability and digitization that reflect the EU's somewhat strong commitment to sustainability (until the November 2025 session of EU parliament that significantly wound back the ESG policies).

Additionally, there are some program options tailored by sector (e.g., automotive, energy, healthcare), reflecting broad SCM roles and practical applications.

Many APAC master's programs combine business, engineering, analytics, and operations with a key emphasis such as logistics, operations, procurement, sustainability, and digital tools, all grounded in current business practices.

Given the logistics and manufacturing-heavy regional economies, the programs tend to emphasize stronger industry exposure and skills training with the programs often aligned with cross border and global trade/compliance

To qualitatively enhance the content and test some of my hypothesis, I discussed the evolution of the supply chain/value chain higher education with several industry executives and practitioners. The executives were based in North America, the EU and APAC. One of the executives had significant prior work experience in the MENA region as well. The executives each held advanced degrees from R1 universities in the U.S. and India, with one holding a Ph.D. in business from a leading Swiss university. One of them had secured the CSCP certification and the five of them have combined work experience of 120 years across the globe and have been active in hiring in their fields.

The discussions centered on a few main themes: adequacy of the current state of formal training provided by degree-granting institutions; gaps that they perceived and what they would expect from the next generation of leaders.

The question on adequacy centered around a choice of ranking from 1–5 with a score of 1 being “did not meet,” 2 being “met many,” 3 being “met and exceeded some,” 4 and 5 being “ready to go for the next decade.” The average score based on the simple survey was 2.8 with an interesting caveat. Most of the executives

surveyed felt that the score would have been higher if they had been asked the same question about two to three ago. They would have scored the current state slightly higher and noted that the rapid changes in the global landscape over the past two to three years have shown that the programs need more overhaul to remain relevant. The ranking was not directed toward any specific programs or types of universities, but largely based on the graduates that these executives either worked with, interviewed or consulted for. Given their experience span and breadth of the executives (see end note), there is no bias that would be built into the scores. An additional point (mainly EU centric) was based on the rank being for degreed candidates and not vocational schools. The consensus was that the field was shifting very rapidly and that the needs of the market/industry was outpacing the innovation and change that was exhibited by being taught at many universities.

The executives pointed to four areas they felt was impacting the ability of new graduates to have a greater impact in today's hyper-connected and competitive world. The areas were as follows (given the business implications of the perspectives, we will not delve into the details but provide resolutions and suggestions in curriculum and structure sense in the next section).

1. Some erosion in teaching the fundamentals to accommodate new topics that were “in vogue” without truly embedding them into existing coursework.
2. Lack of preparedness to rapidly gain executive presence that is necessary even for entry-level analyst/project management personnel.
3. Lack of a high degree of hands-on experience with solving difficult and cross departmental / cross divisional problems that are par for the course in today's supply / value chains.
4. Missing knowledge and insight into linkages that have enabled the evolution of SCM to VCM, as well as the evolution from being viewed as a cost center to a source of competitive advantage.

Where should we go next?

Higher education will need to continue to pivot,

transform and adapt to serve the future needs (some of the broad indications that led to hypotheses were enumerated above). Degree-granting universities/institutions are faced with a U.S. market acceptance of 30-credit-hour master's degree plans and UG concentrations that range from four to five deep-dive courses in the field. The degree plans and requirements may vary a bit outside the U.S. but are within a 10% variation upward. So, pivoting implies shifting the degree plans, creating new courses, and in the end, also finding faculty members to teach the content effectively.

Pivots anywhere are difficult and especially so in higher education. This is largely driven by traditional aspects inherent in the operating model—namely, the lack of urgency to innovate, established faculty roles and performance measurements that support volumetric outcomes and a lack of incentives to motivate disruptive curriculum development and adoption. The adage of “why change if I don’t have to or need to” is largely applicable and hence it takes a high degree of organizational resilience and self-motivated desire to be on the leading edge to drive transformations. However, in my past decade serving the higher education sector, I have found that innovation is much easier to implement and faculty embrace change more openly.

As we look to the future evolution of curriculum to support the growing needs as outlined above, here are the main areas that will need to be addressed to meet the needs for the next decade.

The major themes for pivots/augmentations fall under the following seven categories.

1. Continue the move from a supply chain-only focus to include value chains.
2. Augment and deepen focus on the extended community fundamentals.
3. Provide greater focus on risk and resilience, coupled with analyzing the impacts of geopolitics and policy making.
4. Demonstrate closer alignment with finance and the financial implications of supply chain decision making.
5. Promote and educate students on the adoption of the usage of intelligent technology for AI, automation and optimization by modifying the core curriculum.
6. Incorporate deeper learning on topics in organizational behavior and leadership across the

extended ecosystem.

7. Reimagine delivery pedagogy to be closer to allow for hands on lab-like learning via experienced faculty.

Let’s elaborate on the themes to provide some additional clarity.

1. The main difference between supply chain management and value chain management is that even today the primary focus of SCM in a higher education setting is primarily operational and VCM is fundamentally strategic. As an example, the field of SCM asks: “How do we deliver the right product, at the right time, at the lowest cost?” VCM asks: “How do we design the enterprise and its ecosystem to create durable value?”

This shift includes the introduction of broader topics of innovation, product imagining, product development and registrations, quality control, product registrations and trade policies as well as the proactive design of the span and scope of the end-to-end delivery chain, i.e. potential JVs and M&A options, into the core curriculum.

2. Augment and deepen the curriculum on extended community fundamentals is par for the course. The fundamentals include a curriculum that covers all aspects of the SCOR model, the SCOR DS model (ASCM ownership) as well as the Extended Value Chain (EVC) construct (written by author in 2001). Adding curriculum on negotiations, large-scale program capture and management, and pivot the teaching to case-basis and more experiential learning-based as opposed to textbook teaching. Additionally, compromising on content from the core to include buzzword-centric courses will not bode well for student learning outcomes.

3. Quoting/paraphrasing the words of several individuals (see end of article note), the field of supply chain management has moved from being deterministic to being much more stochastic. This is driven by the need to focus on risk and resilience in all aspects of the supply chain (see articles by the author in SCMR December 2024 and November 2025), including curriculum that deals with managing geopolitics and influencing policies. Geopolitics and influencing policies have typically been taught in political science or public administration curriculum (if at all) and the cross-pollination between the disciplines.

4. Value chain management/supply chain management is steeped in finance and financial implications that

arise from the inherent cost structures. However, curriculum in corporate finance, mergers and acquisitions, and tax efficiencies are not generally part of the standard coursework in many degree-granting programs that focus exclusively on the topic (exclude the MBA in SCM since the MBA portion will cover some of the financial aspects). This gap between financial management of VCMs/SCMs should be bridged.

5. Technology, automation, optimization, and digitization efforts are at all-time highs and will continue to dominate discussions. The rapid advent of AI (all variations generative and agentic) will accelerate the process (probably in similar vein to the dot-com era of 1999–2001 that added omnichannel management forever into the Design to Delivery processes). This is coupled with the advanced usage of analytics and big data management. Curriculum that provides pragmatic applications of all topics must be woven into each course and not be taught just as a standalone topic.

6. The age-old construct of people, process, and technology remains in the field and when we factor in the EVC (ecosystem) management that is needed in today's hyper-connected world—the people aspect becomes even more crucial. However, with managing people comes the importance of managing and designing organizations for steady state as well as crisis times. Having managed global multinational companies in my past, the need for effective organizational behavior, design, leadership and knowing how to tap into the EQ (emotional quotient) becomes key for the next generation of leaders. Can all this be taught? The answer is “no”—however, introducing the need to maintain focus on all the topics should be included in the curriculum so that we don't become a footnote in the famous book by Mark McCormack, *What they DON'T not teach you at Harvard Business School?*

7. I pivoted to higher education almost a decade back. During my time, we had to manage the COVID pandemic and the acceleration of all aspects of online teaching pedagogy (it can be a bit of an alphabet soup—online asynch, online anytime, only synch, online hybrid, online competency-based, and on and

on) and now the rapid advancements in AI. The fact that higher education has embraced online is yesterday's news. The fact that online pedagogy is required to serve the non-traditional workforce is also in the rearview mirror. However, several STEM fields have maintained the usage of laboratory work (hands-on training) or practicum hours as part of their programs. Our opinion is that the effective usage of lab work in the curriculum would behoove for a better prepared student. Lab work can be in the form of practicums, live cases, actual simulations and even field work. This work must be coupled by faculty who blend scholarly output with deep expertise as practitioners. Many universities will advertise the fact that “live cases” are part of curriculum, but when you really dig deeper, you will find that maybe one course had a live case as part of the students' learning outcomes. We position that every course should embrace elements of a lab so that the traditional (full time) and non-traditional students benefit from more exposure to scenarios. This can be augmented also by incorporating current work that non-traditional students are doing in their profession / companies as competencies that can be credited toward their learning journey (especially for competency-based learning).

The above listed facets are meant to serve as some guidelines and not the panacea for higher education efforts to serve the workforce development needs. I am sure that many of the leading programs across the globe have taken steps to incorporate variations of these topics into their programs. However, I am also just as confident that there are many institutions that have not embraced the need to evolve and change the curriculum to match the needs for the next decade (and beyond). The field does not have a standard (unlike CPA) curriculum that can be used as a baseline measure, and neither do we have continuing education requirements. The best part of this field is that it is a) in high demand, b) evolving and c) had increased in position and prominence in the various industry sectors globally.

Sincere thanks go to the following executives and long-time colleagues: Nishad Gadgil, Shaun Harris, Toly Novik, Deep Parekh, Ph.D., and Budaja Thamrin for their points of view on the current situation and futuristic thinking on the gaps. •

NEXUS SUPPLIERS:
Hidden anchors
of resilience in
decentralized
supply chains

By Obie Byrum, MBA, Ph.D.

Obie (Paul) Byrum, MBA, Ph.D., is a professor of practice in the Department of Management and Supply Chain at East Tennessee State University. He can be reached at ByrumO@etsu.edu.

As supply chains become more decentralized and fragmented, resilience increasingly depends not on the number of suppliers in the network, but on “nexus suppliers” whose embedded relationships, informal influence, and cross-network coordination quietly stabilize operations during disruption.

Executives often assume that decentralizing supply chains makes them more resilient. In practice, it often makes them more fragile.

Over the past decade, many firms—particularly in global consumer goods and textiles—have diversified sourcing away from concentrated production bases. The logic is familiar: spread risk, increase flexibility, and reduce dependence on any single country or supplier. Yet as networks expand, visibility declines. Standards fragment. Coordination weakens. What appears diversified on a sourcing map often operates as fragmentation in execution.

When disruption hits, resilience does not come from the number of suppliers in the network. It comes from how the network holds together—and from which suppliers quietly do the work of holding it together.

Concept introduction

In decentralized supply chains, resilience does not reside evenly across suppliers, nor does it track reliably with spend, scale, or contractual importance. Instead, it is often anchored by a small number of suppliers whose positions and behaviors

allow them to stabilize the network when disruptions occur. We refer to these firms as nexus suppliers.

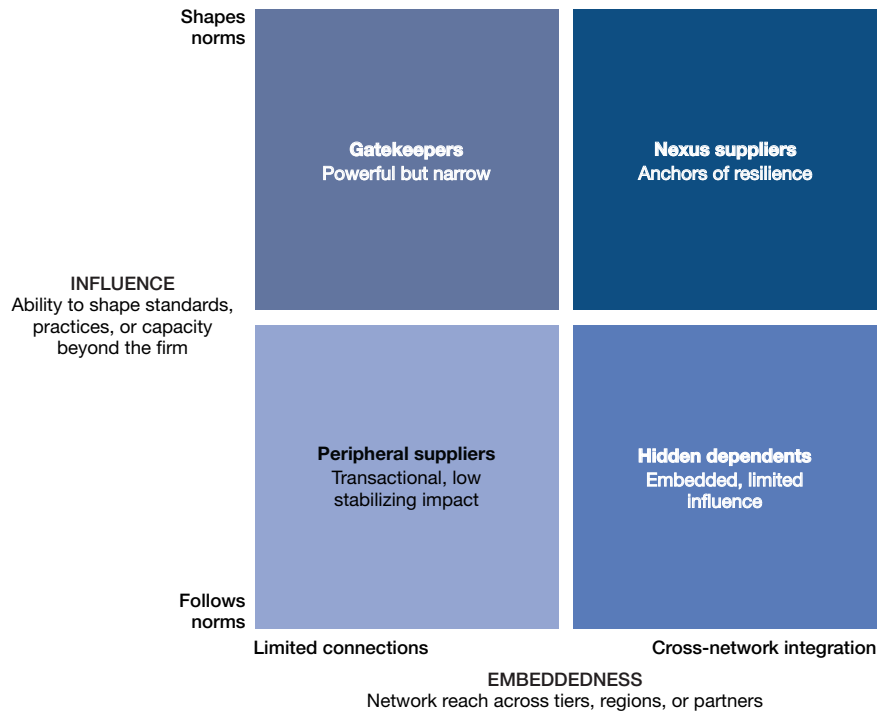
Nexus suppliers are characterized by two defining features. First, they are deeply embedded across the supply network, maintaining connections that span multiple tiers, regions, or partner firms. Second, they exert influence beyond the focal firm, shaping standards, practices, or capacity in ways that affect how other suppliers respond to stress. Importantly, these characteristics are revealed through observed behavior during disruption, not through formal authority or size.

This definition is intended for executive use. It does not rely on formal measurement, maturity scoring, or retrospective performance metrics. Instead, it provides a practical lens for recognizing suppliers whose actions disproportionately affect how decentralized supply chains hold together under pressure.

FIGURE 1

Supplier resilience matrix

Identifying suppliers that anchor resilience—beyond spend and scale



The matrix differentiates suppliers by embeddedness across the supply network and influence beyond the firm, highlighting nexus suppliers that play a disproportionate role in stabilizing decentralized supply chains.

Source: Author

As shown in Figure 1, nexus suppliers represent one of four distinct supplier roles, differentiated by levels of embeddedness and influence within decentralized supply chains.

Four roles: Behavioral patterns that anchor resilience

The Supplier Resilience Matrix highlights four distinct supplier roles based on levels of embeddedness and influence. Within and across these roles, our research identifies a set of recurring behavioral patterns that explain how resilience is actually anchored in decentralized supply chains. These behaviors are not evenly distributed. While they can appear in different quadrants, they are most consistently and reliably

observed among nexus suppliers, whose network positions allow these behaviors to scale beyond individual firm boundaries.

Knowledge brokers

Knowledge brokering refers to the ability to transfer technical know-how, process improvements, or problem-solving practices across suppliers and tiers. In decentralized networks, this behavior helps prevent localized disruptions from becoming systemic failures. While some suppliers may broker knowledge episodically, it is most effective when performed by suppliers with broad embeddedness and cross-network visibility. When present, knowledge brokering accelerates recovery by aligning responses across otherwise disconnected partners.

Executive takeaway: Resilience improves when suppliers that see across the network actively share operational knowledge, rather than treating learning as firm-specific.

Standard enforcers

Some suppliers play a critical role in translating, reinforcing, or extending standards related to quality, compliance, or operational practices. This behavior reduces ambiguity during disruption by clarifying expectations and stabilizing execution across the network. Although standard-setting authority may originate with focal firms or regulators, suppliers with influence beyond the firm often operationalize those standards in practice.

Executive takeaway: Suppliers that help enforce and normalize standards can stabilize decentralized networks more effectively than formal controls alone.

Capacity balancers

Capacity balancing involves reallocating work, smoothing bottlenecks, or coordinating production shifts when disruptions strain specific nodes in the supply chain. This behavior limits cascading failures by absorbing shocks before they propagate. While many suppliers manage their own capacity, those with embedded network positions are better able to rebalance capacity across partners, not just within their own operations.

Executive takeaway: Suppliers that can flex capacity across the network reduce the amplification of disruption during periods of stress.

Influence multipliers

In decentralized supply chains, some suppliers shape responses not through contracts or formal power, but through credibility, experience, and trusted relationships. This influence guides how other suppliers prioritize actions during disruption, often accelerating coordination when time and information are limited. Although influence can exist in multiple roles, it is most consequential when exercised by suppliers connected across tiers and regions.

Executive takeaway: Informal influence—when held by well-embedded suppliers—often matters more than contractual leverage in moments of disruption.

These behavioral patterns should not be mistaken for quadrant roles themselves. Rather, they explain why certain roles—particularly nexus suppliers—anchor resilience more effectively than others. Peripheral suppliers may exhibit one or more behaviors in limited contexts, while hidden dependents and gatekeepers may perform them within narrower scopes. Nexus suppliers stand out because they combine multiple behaviors with positions that allow those behaviors to stabilize the broader network.

The Supplier Resilience Matrix

Executives often struggle to distinguish between suppliers that simply deliver inputs and those that actually stabilize the supply chain during disruption. Traditional approaches—ranking suppliers by spend, volume, or contractual importance—offer limited insight in decentralized networks, where risk and coordination are widely dispersed. To address this gap, our research points to a simple diagnostic tool: the Supplier Resilience Matrix.

The matrix differentiates suppliers along two dimensions that matter most under stress: embeddedness and influence. Embeddedness reflects how deeply a supplier is connected across tiers, regions, or partner networks. Influence captures a supplier's ability to shape behavior beyond its own operations—by enforcing standards, transferring knowledge, or stabilizing capacity when disruptions occur. Placement in the matrix is not based on size or spend, but on observed behavior during disruption.

Viewed through this lens, four distinct supplier roles emerge. Peripheral suppliers are transactional and contribute little to network stability. Hidden dependents are deeply embedded but lack the influence needed to stabilize others, making them quiet points of fragility. Gatekeepers exert strong influence within narrow scopes, often creating chokepoints that require careful management. Nexus suppliers combine broad embeddedness with the ability to shape practices, knowledge flows, and capacity across the network.

For executives, the matrix is not a scoring model or a prescription to rebalance spend. It is a sensemaking tool that clarifies where resilience actually resides. By identifying which suppliers anchor stability—and which merely appear important—leaders can move beyond reactive risk management and make more deliberate decisions about partnership, visibility, and investment in decentralized supply chains.

How to spot a nexus supplier

Executives often assume their most resilient suppliers are the largest by spend or volume. Our research suggests otherwise. To identify suppliers that actually anchor resilience in decentralized supply chains, ask the following questions:

1. Who connects the network? Which suppliers interact across multiple partners, tiers, or regions—especially when issues arise?

2. Who sets or enforces standards? Which suppliers help translate, enforce, or extend compliance, quality, or certification requirements beyond their own operations?

3. Where does knowledge flow through? Which suppliers share technical know-how, process improvements, or quality practices that others rely on?

4. Who stabilizes capacity during disruption? When disruptions occur, which suppliers help rebalance workloads, shift production, or prevent bottlenecks from cascading?

5. Who do others listen to under pressure? Which suppliers influence how partners respond during disruptions, even without formal authority or large contract values?

Interpretation

Suppliers that consistently surface across multiple questions—particularly those combining broad network connections with the ability to shape behavior—are likely nexus suppliers. These firms often carry outsized responsibility for stabilizing decentralized supply chains and should be

managed as strategic resilience partners rather than transactional vendors.

Mini-case: A supplier that made the difference

This mini-case vignette reinforces the nexus supplier concept through observed behavior during disruption. It is intentionally anonymized and narrowly scoped to illustrate how resilience concentrates around specific supplier actions rather than spend, size, or formal authority.

In one decentralized textile supply network in Southeast Asia, a mid-sized supplier in Vietnam played a central coordinating role during a period of prolonged disruption. Although not among the largest suppliers by spend or volume, the firm maintained working relationships across multiple tiers and regions, allowing it to see emerging issues before they escalated. When upstream capacity constraints and compliance concerns surfaced simultaneously, this supplier became an informal point of coordination for several partners.

Rather than waiting for direction from the focal firm, the supplier proactively shared process adjustments, clarified quality expectations, and facilitated communication between upstream and downstream partners. Other suppliers adapted their responses based on this guidance, even in the absence of formal authority or contractual mandates. Over time, these actions helped prevent localized failures from cascading across the network.

In Figure 1 terms, this supplier functioned as a nexus supplier—combining high embeddedness with influence that extended beyond the focal firm.

The implication is straightforward. Resilience in decentralized supply chains does not always flow through the most visible or highest-spend suppliers. Instead, it often depends on firms whose network positions and behaviors quietly stabilize coordination when formal controls are insufficient.

Conclusion

Resilience in decentralized supply chains is not evenly distributed. As firms extend their networks across regions, tiers, and partners, stability increasingly depends on a small number of suppliers whose positions and behaviors allow them to hold the network together under stress.

As illustrated in Figure 1, resilience concentrates in suppliers that combine embedded network positions with influence beyond the focal firm. These suppliers do not simply execute transactions. They shape how information flows, how standards are interpreted, and how capacity is stabilized when formal controls break down.

For executives, the implication is not to optimize supplier portfolios based solely on spend or scale, but to recognize and manage the roles suppliers actually play in sustaining coordination. If you don't know who your nexus suppliers are, you don't know how resilient your supply chain really is. •

WHAT OPTIONS DO YOU REALLY HAVE?

Shaping the supply chain resilience funnel

By Kirstin Scholten, Dirk Pieter van Donk,
and Stefania Boscari



Before investing in resilience, map your real option space—
then decide what is feasible, useful, and usable under pressure.

Black swans are not rare anymore—they have become a recurring operating condition. Ever since COVID-19 highlighted to the world the dependence of our daily lives on supply chains, resilience is at the forefront of managers' minds. As a clear illustration, today, 45.4% of companies have a dedicated person responsible for overseeing the running of a resilience program who reports directly to the board, according to the Business Continuity Institute's 2025 Supply Chain Resilience Report. This board-level attention reflects a simple reality: supply chain disruptions are widely considered inevitable. According to the same institute's 2024 report, every year, almost 80% of companies experience at least one significant disruption stemming from tier 1 suppliers (50%), tier 2 (23.4%) or even beyond that (9.6%), with many of those having significant financial impact.

One important reason is that organizations and their supply chains are dispersed, complex and global. A local disruption can cascade across regions, affecting supply, production and customer service far from where the original event occurred. At the same time, global chains typically rely on longer and more complex transportation and distribution networks which add vulnerability through longer and less predictable lead times. In short, both suppliers and logistics networks are exposed to a wider range of risks and, increasingly, several of these risks hit at once, causing simultaneous disruptions due to macro phenomena such as global warming, tariffs, and geopolitical tensions.

Over the past two decades, both academic and practitioner literature have

increasingly advised organizations to invest heavily in supply chain resilience. Much of that advice implicitly reads like a checklist: pursue every possible activity that might increase resilience. Many resilience frameworks implicitly suggest that firms should “do everything,” preferably to a high degree. Findings from our study, *What Options Do We Have? The Supply Chain Resilience Funnel* (Scholten, K., van Donk, D.P. & Boscari, S. (2025) *What Options Do We Have? The Supply Chain Resilience Funnel. Journal of Supply Chain Management*, 61, 74-105. <https://doi.org/10.1111/jscm.12342>) and summarized in the following paragraphs, shows that aiming for resilience is not a generic “more is better” goal. Our research shows you cannot and even should not

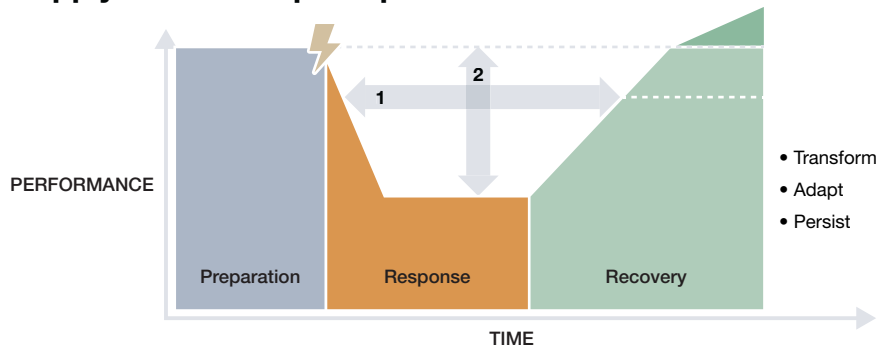
Kirstin Scholten is a professor and chair in supply chain management at the University of Dusseldorf. She can be reached at kirstin.scholten@hhu.de
Dirk Pieter van Donk is a professor in the Department of Operations at the University of Groningen.
Stefania Boscari is an assistant professor in the Department of Operations at the University of Groningen.

aim for everything, because the resilience options you can realistically build and activate are constrained by your product–process–supply chain (PPS) configuration and by your operating context. When we say that resilience options are constrained by PPS configuration, we simply mean this: the options a firm has in a disruption depend on how its products are designed (e.g., technical specifications and packaging choices), how production is set up (e.g., decisions related to make-to-stock versus make-to-order, equipment, or production

Surprisingly, although seemingly every manager is talking about and striving for supply chain resilience, it is still ill understood what supply chain resilience actually means. This is illustrated by the words of a service continuity & resilience lead (utilities, UK) in the Supply Chain Resilience Report in 2025, p.13: “Resilience means 100 different things to 100 different people.” These differences relate conceptually to differences in an organization’s reality in terms of its product, process, supply chain and context. As a result, managers often struggle to translate resilience into what it

FIGURE 1

Supply chain disruption profile



Source: Authors

footprint), and how the supply chain is configured (e.g., sourcing choices, contractual relationships with suppliers and customers, and network design). In fact, pushing options that are not feasible in the specific organizational context can waste money, and in the worst-case scenario, striving for resilience can become a risk in itself when, for example, the wrong investment options are chosen. In other words, asking the natural question “how do we become resilient?” is not so key, as the question “what options do we really have?”

should mean for their own organizational situation.

Taken the above together, managers experience ambiguity and confusion around three interrelated themes:

1. *What is resilience and how can it be measured?*
2. *How do you know when a supply chain is resilient?*
3. *When is resilience beneficial for a company or situation?*

In the following, we address these three questions in turn.

What is supply chain resilience and how can we measure it?

At the core of resilience is the idea that organizations need to accept that disruptions will happen and that they might be affected in terms of a performance decline. Figure 1 provides a simplified disruption profile showing how a disruption can affect an organization's performance, and it illustrates what we mean by resilience during a disruption. The figure plots performance over time: a disruption creates a drop below the pre-disruption baseline performance, followed by a recovery trajectory back toward the original or to a new level of performance. In addition, this visualization helps to distinguish three ways managers typically think about resilience and its measures. First, managers consider the duration. Here, time-based metrics capture how long the system is affected (e.g., disruption duration, time to recovery, and—if used—time to survive). Second, managers consider the size of the impact. Here, performance-based metrics capture how severe the impact is in operational or customer terms (e.g., amount of performance loss, decline in service level/fill rate, or unfulfilled demand). Third, managers consider overall consequences. In that vein, financial metrics

translate the combined time-and-performance impact into economic outcomes (e.g., lost profit during recovery or net present value of lost profit). Finally, the same profile also connects measurement to outcomes: depending on the disruption and the options available in preparation and response, a supply chain may persist (absorb the shock), adapt (recover through changes), or transform (move to a fundamental redesign) when constraints make recovery unrealistic. PPS configuration matters because it shapes which levers are feasible quickly—and therefore which of these outcomes is realistic.

The above might still make resilience somewhat abstract, therefore, Table 1 provides insights into some common ways to concretely measure supply chain resilience (see e.g., Behzadi et al., 2020). Notably, some preparedness measures may prevent visible performance loss altogether; in that case, resilience is experienced as robustness or simply as “no impact on customer deliveries.” Taken together, these approaches are complementary: duration and magnitude jointly shape the total impact, but each lens highlights something different. Finally, none of the measures captures all effects on its own, which is why Table 1 also highlights typical limitations.

TABLE 1

Supply chain resilience metrics

METRIC	WHAT IT CAPTURES	TYPICAL MEASURES	MANAGERIAL USE	LIMITATIONS
Time-based metrics	How long does the disruption effect last?	• Disruption duration • Time to recovery	• Continuity targets • Recovery planning	• No magnitude/impact depth • Depends on “recovery” definition
Performance-metrics	How much performance is lost?	• Service level • Fill rate • Unfulfilled demand %/rate	• Service/customer impact assessment • Scenario comparison	• Needs baseline + clear “performance” definition (OTIF, output, fill rate, etc.) • Misses duration
Financial metrics	What is the economic consequence?	• Lost profit during recovery • Incremental cost during recovery (e.g., expediting) • Net present value of lost profit	• Business-case justification • Trade-off decisions • Prioritization/resource allocation	• Assumptions heavy (margins, substitution, recovery trajectory) • Sensitive to model choices

Source: Authors

How do you know when a supply chain is resilient?

Based on the metrics introduced in Table 1, this question seems to be easy to answer, but it actually is not, because these measures only reveal how resilient a supply chain is after a disruption has occurred. It would be preferable to know upfront whether a supply chain is resilient or not. Even more ideal would be (almost) sure that we are able to deal with a disruption without any visible drop in performance. In essence, this requires taking stock of the available options and the potential the organization has in (quickly) launching and orchestrating remedial activities across functions and partners. Hence, we need proxies that allow us to assess resilience potential before a disruption happens. The following are proxies (known and reported under various labels) that are commonly discussed in the supply chain literature:

Flexibility: What changes can we make?

Flexibility is about having real alternatives available (not just planned). Typical actions include safeguarding availability of alternative suppliers, routings, or raw materials as well as creating flexibility in product specifications, capacity, or alternative logistics modes. For example, when the main packaging supplier of a company we talked to could not ramp up volumes (cardboard demand spike), the firm redesigned its packaging from a four-color to a three-color design to double supplier capacity

(single production run). Additionally, they also temporarily used unprinted cardboard boxes to avoid empty shelves. This is flexibility because the firm created a viable alternative through product/packaging design change, rather than relying only on new sourcing.

Agility: How quickly do we observe a disruption and can we react? Agility is about speed of sensing and responding. Typically, it involves activities such as detecting early warnings, rapid decision-making, using escalation paths, and the ability to re-plan quickly when assumptions break. For example, in our study, a firm detected pallet shortages early through supplier-shared forecasts that indicated a significant risk and then reacted quickly by shifting volumes across its main pallet suppliers. This is a typical example of agility as it combines early sensing with rapid reconfiguration under time pressure.

Redundancy: How much backup do we have? Redundancy is about purposeful slack beyond normal operations. It relates to holding inventory buffers, spare capacity, backup suppliers, dual tooling, or pre-qualified substitutes. Despite a multi-week transport delay, one of the firms we talked to avoided stockouts because its safety stock buffers were sufficient to bridge the disruption window. This is redundancy working as intended: buffering a short-to-medium disruption without requiring redesign of product or process.

Collaboration: How do we work with whom?

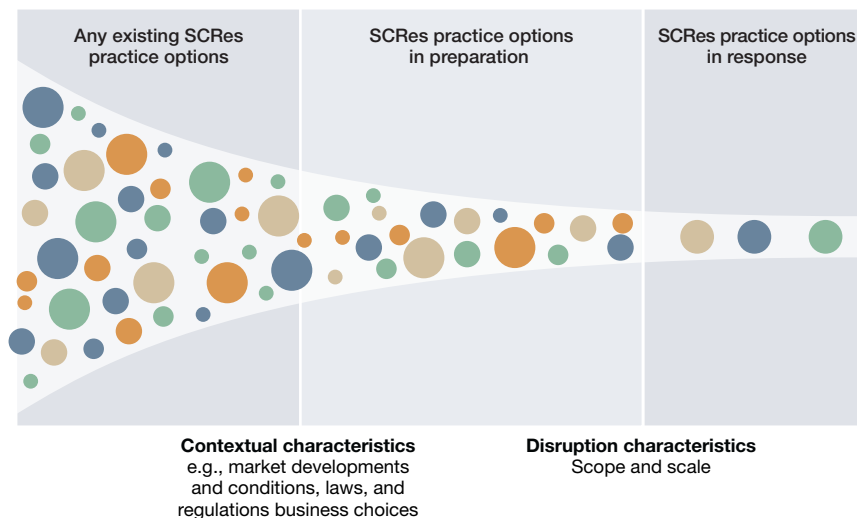
Collaboration is about coordinated action within and across firms and tiers. It involves information sharing, joint planning, supplier development, and aligning incentives and contracts so that working along the supply chain is rational rather than optional. Collaboration often determines whether flexibility, agility, and redundancy can be activated quickly in practice. For example, one firm told us that it relied on a close supplier relationship (including priority treatment through a just-in-time partnership) and integrated its supplier's constraints directly into production planning and prioritization decisions (e.g., prioritizing A-brands when supply was tight). This is a clear example of collaboration because resilience here depends on joint planning and aligned actions across firm boundaries, not just internal measures.

When is resilience beneficial? The supply chain resilience funnel

As explained above, each proxy (flexibility, agility, redundancy, collaboration) can be supported by multiple resilience practices. It might be tempting to activate all of them “just in case,” but this is often overly expensive and, in some contexts, not even feasible. The key point is that resilience options are not equally available to all firms. They depend on contextual characteristics such as industry and regulatory environments, market conditions, and a firm's own strategic choices. For example, in a declining market, it would make little sense to invest in new production capacity to increase flexibility or redundancy. Likewise, a company offering perishable products might not want to invest in large inventories. Finally, legislation can put specific demands on product specifications (e.g., only approved sources in pharmaceuticals) and storage facilities (e.g., dangerous goods), which can strongly limit flexibility and storage options.

FIGURE 2

The supply chain resilience



Source: Authors

This logic is captured in the supply chain resilience funnel (Figure 2). It depicts that, in principle, an organization has many potential options to build resilience by taking actions across the four proxies in product, process, and supply chain design. In reality, however, the number of feasible options is reduced in two steps.

First, context narrows what is feasible and sensible before any disruption even hits. Second, once a disruption emerges, options narrow further because time pressure, capacity constraints, and the disruption's scope and scale limit what can actually be implemented. In other words, the funnel is a practical way to move from "do everything" advice to a more realistic question: what options do we really have, given our PPS configuration, operating context, legal restrictions, and prior strategic choices? This also helps explain why "best practices" in resilience do not transfer cleanly across companies, industries, and disruptions. At the same time, the funnel highlights why preparation matters. Companies should implement as broad a set of feasible and useful SCRes practice options as possible in advance, within their constraints, because once a disruption happens, it will only restrict the available option set further. In other words, the goal is not 'everything,' but the best option set you can realistically build and afford, given your PPS configuration and context. Our research indicates that particularly global and long-term disruptions require the development of flexibility options. If such options do not exist in advance, they often cannot be built under pressure. By contrast, when disruptions are short-term and localized, flexibility and redundancy that are prepared in advance can be

very effective because the time span that needs to be bridged is relatively short.

Developing options is, in general, a good thing. However, as the funnel explains, options developed should also be usable in situations a firm is likely to face. Otherwise, aiming for resilience can actually become a risk. If a context does not allow for flexibility, a company might be better off trying to avoid disruptions where possible and to develop specific responses for specific risks, as traditional risk management suggests. In such contexts, redundancy in preparation for disruption becomes important, and sometimes it is the only realistic lever. Importantly, redundancy is not only inventory; it can also include alternative supply chain strategies, alternative processes, and alternative product configurations.

Referring back to Figure 1, three final outcomes were depicted: persist, adapt or transform. The funnel helps clarify each of these three outcomes.

Persisting through a disruption can happen if an organization had prepared options that enabled it to respond to a disruption without, or almost without, a drop in performance. For example, a rather short disruption can easily be handled with inventories or changes in production schedules.

Adaptation might happen for more extensive disruptions that require the search and finding of new suppliers, a change of product specification or new markets. This can also result in the organization somewhat changing its context, but in essence, the result will be a return (or almost) to the earlier performance level after an initial drop in performance.

Finally, transformation becomes relevant if a disruption is long, global, or fundamentally

changes constraints. Adapt or persist will be impossible and in terms of the resilience funnel, the existing contextual characteristics with the scale and scope of the disruption together narrow down the funnel such that there are no options remaining. In other words, “recovering” to the previous state may be unrealistic. In those situations, an organization needs to fundamentally change or transform to a new situation with new products, processes, and/or supply chain. It might be clear that this will be uncomfortable and costly but it might be the only viable path.

So far, this is the logic captured in Figure 2. However, the cases in our study also revealed an additional insight that the funnel does not explicitly depict: where organizations tend to look first for options across product, process, and supply chain. This matters because “having options” is not only about how many options exist, but also where those options sit in the PPS system and how quickly they can be activated. Our findings suggest that the funnel has a PPS direction. Resilience options are not only narrowed by context and by the disruption characteristics; they are also distributed across the product–process–supply chain system. In preparation, organizations typically build resilience primarily in the supply chain, for example, through buffers and supplier-side measures, while keeping process and product configurations relatively stable.

When disruption hits, organizations then tend to activate supply chain options first and try to protect core processes and product choices. That is because process and product are often harder to change quickly, are tightly constrained (e.g., by specifications or

regulation), or are central to competitive advantage. However, we also noticed that options in product and process are less considered in preparation for disruptions. Only when supply chain measures are insufficient, especially in long-term or global disruptions, do organizations escalate from supply chain adjustments to process changes, and then to product adjustments, with transformation as the last resort.

This PPS direction also clarifies why disruption characteristics matter. In shorter and more local disruptions, redundancy and supply chain workarounds may be sufficient to persist without visible customer impact. However, particularly global and long-term disruptions reduce supply chain options over time and force organizations to develop new ones. In those situations, flexibility becomes critical because it is often the only way to create options that did not exist before—through changes in routing, sourcing, internal processes, or, eventually, product and packaging requirements. Ultimately, if resilience is about options, then the managerial task is option management: knowing what options exist given a specific context, where they sit in PPS, and which ones survive different disruption scenarios. The funnel offers a simple way to do that. Map the feasible option set in advance, stress-test it against short/ local versus long/ global disruptions, and decide where redundancy is sufficient and where flexibility must be created. That is the main recommendation from our research which turns resilience from a buzzword into a capability. •

Reference:

Behzadi, G., O’Sullivan, M. J., & Olsen, T. L. (2020). On metrics for supply chain resilience. European Journal of Operational Research, 287(1), 145–158.

Risk sharing is the new advantage in capital project delivery

Neal Walters is a Kearney partner focused on large-scale manufacturing transformations and can be reached at Neal.Walters@kearney.com.

Bill Duffy is a Kearney partner focused on performance transformation and value creation in the oil and gas industry and can be reached at Bill.Duffy@kearney.com.

As labor shortages, capacity constraints, and record infrastructure spending reshape capital markets, leading organizations are turning to risk-sharing contracts to improve execution, accelerate decision-making, and gain a competitive advantage in project delivery.

By Neal Walters and Bill Duffy

The fate of a capital project is often sealed long before the biggest problem appears on site. The outcome is driven in large part by the delivery model, where incentives, decision rights, and commercial pressure determine how the team responds when conditions shift. Traditional contracts often load risk onto one party, which can be effective where scope is stable and execution risk is low.

In less predictable environments, that structure can strain coordination and slow recovery. With capital spending at record highs, companies need contracts that share risk, reward, and accountability between both parties.

Capital project delivery faces unprecedented capacity constraints

A wave of capital investment is straining engineering, construction, and equipment markets across industries. In North America alone, data center spending is projected to approach \$3 trillion by 2029, with power, grid, manufacturing, and logistics investments rising as well (see Figure 1).

Delivery capacity has not kept pace. Companies that once counted on top-tier engineering and construction teams now compete for the same limited resources. Even when staffing targets are met, expertise is often uneven,

and turnover is high. Companies can no longer assume they will get the same depth of talent from engineering, procurement, and construction management (EPCM partners) that they relied on for decades.

How risk allocation shapes owner-contractor collaboration

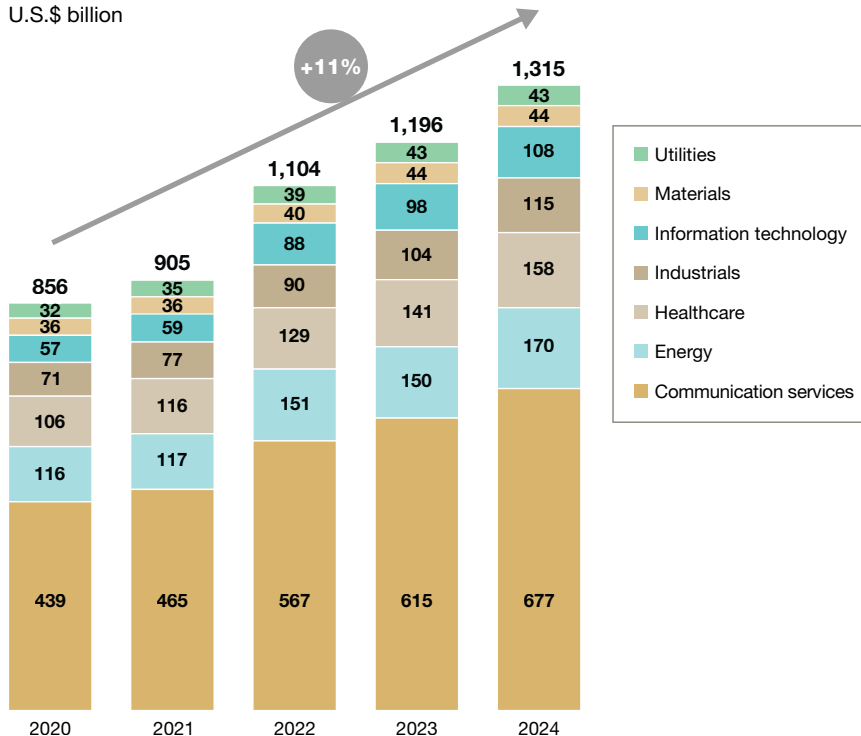
More than 80% of large capital projects run materially over budget. Most do not fail because of bad luck. They fail because planning is weak, governance falters, and execution breaks down.

Traditional contracts often make that worse by placing too much risk, sometimes all of it, on one side of the deal (see Figure 2). Under fixed-price and not-to-exceed (NTE) contracts, contractors absorb that risk, and, under time-and-materials (T&M) contracts, owners do. That split can erode the shared incentives that complex projects require, causing manageable issues to sit unresolved until they become formal escalations. At that point, attention often shifts from solving the problem to assigning blame. This cycle is corrosive, especially when alignment matters most.

FIGURE 1

Large U.S. companies are investing significantly more in capital projects and assets

U.S.\$ billion



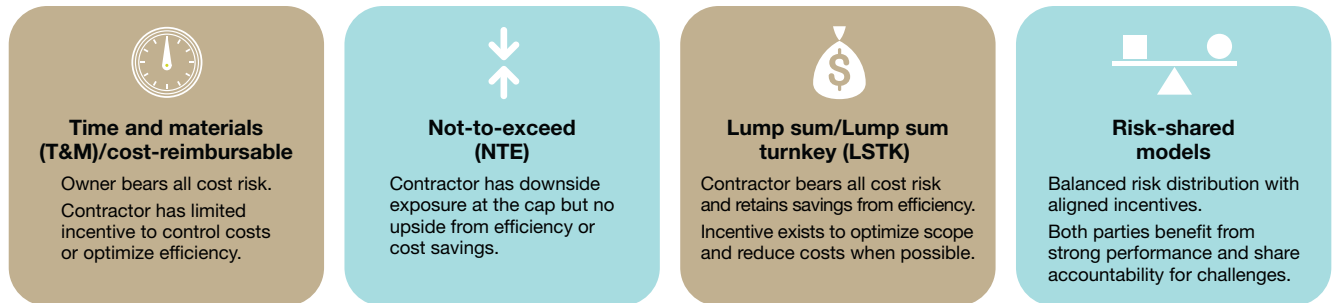
Note: Capital expenditure analysis is based on a fixed peer set comprising the top 25 U.S.-listed companies by market capitalization within each GICS sector. The same company universe is applied consistently across all historical years to ensure comparability.

Source: S&P Capital IQ, company financials. Kearney analysis

FIGURE 2

Traditional contracting structures assign risk too heavily (or entirely) to one party

Contract structures and risk (not exhaustive)



Source: Kearney analysis

How much this hurts depends on the project. In repeatable settings, with mature designs, proven technology, experienced contractors, and stable supply markets, traditional contracts can still deliver predictable results.

But uncertainty changes everything. New technology, unfamiliar locations, first-time contractor relationships, tight supply markets, and compressed schedules all make coordination harder and leave less time to respond. In those conditions, project performance depends not just on the contract but on how risk is shared and how information moves during execution.

From risk transfer to shared outcomes

Risk-sharing contracts bind owners and contractors to the same outcome from early planning to final delivery. Instead of pushing risk across a contractual line, they spread both risk and reward across the table. That changes not just who is accountable, but how the work gets done.

The point is not only to limit downside. It is to improve execution. In a tight market, the projects that move first, secure capacity, attract talent, and work through supply bottlenecks gain an edge. Better execution lifts contractor profits and improves owner returns. It rewards speed, judgment, and capability, not just caution.

But the model works only if both sides commit early. Risk-sharing is most effective when contractors come in during feasibility and concept development, while important technical choices are still in play. That is when incentives can still shape outcomes. Early involvement also helps build the habits of collaboration that strong execution requires.

These contracts ask more of both sides upfront. Teams spend more time aligning on design readiness, sequencing, and market exposure before commitments are locked in. They identify risks earlier because the incentives favor candor over concealment.

They can also help solve a growing talent problem. When incentives and accountability are aligned, contractors have more reason to preserve continuity, rethink retention, and reduce the need for long relocations. Some roles can move to the owner after completion, creating career paths that help attract scarce specialists. In a market where expertise is limited and unevenly spread, that continuity matters.

The results are tangible. Across more than 300 risk-shared infrastructure and industrial projects, representing about \$60 billion in capital spending, failure rates stayed low and project outcomes improved by several percentage points. Much of that lift came from resolving issues

earlier and speeding up shared decisions before they disrupted delivery.

Contracting strategy is now a value lever

Traditional contracts still work when the basics are in place: mature designs, proven technology, ample supply, and manageable schedules. Even then, the best model depends on the job. Fixed-price contracts suit capable contractors, while cost-based models fit owners who need close control or bring critical expertise. In more mixed conditions, risk-sharing works best because it keeps both sides accountable for the outcome (see Figure 3).

in markets where labor and delivery capacity are already tight. In those conditions, traditional contracts are more likely to miss on cost, timing, or quality, driving up owner costs or forcing contractors to build in more contingency.

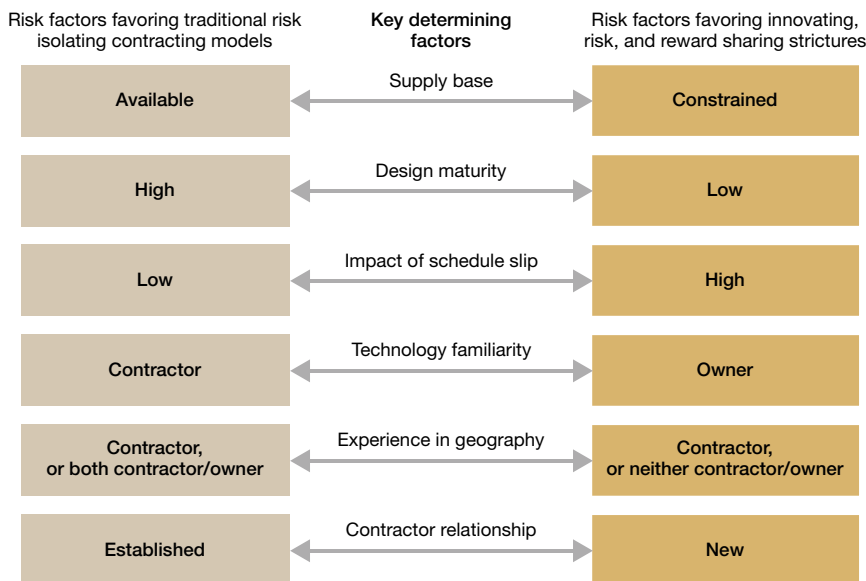
The strategic case for risk-sharing contracts

Execution is becoming the decisive variable in capital project delivery. Record investment in data centers and infrastructure is straining delivery capacity and exposing the limits of traditional contracts.

Risk-sharing works because it aligns incentives around performance and gives both parties a direct

FIGURE 3

Project conditions determine contracting approach



Source: Kearney analysis

That logic becomes more important as risks begin to stack up. When projects involve new technology, unfamiliar locations, tight schedules, or constrained supply, there is less room to recover when problems arise. At the same time, surging demand in infrastructure, power, and technology has intensified the strain, especially

stake in the same outcome. That shared exposure tends to bring stronger teams to the work, speed up decisions, and reduce the procedural friction that builds when each side is protecting its contractual position. Over time, the effect is cumulative and shows up where it matters most, in stronger execution. •

Managing human and AI teams across the supply chain

Building readiness across people, processes, and technology.

By Marisa Brown, APQC

Marisa Brown is the senior principal research lead for Supply Chain Management at APQC. She leads APQC's supply chain team that conducts research to provide insights into benchmarks, best practices, and process improvements in supply chain planning, procurement, logistics, manufacturing, product development, and innovation. Marisa is a leader in supply chain with almost 30 years' experience in business, research, writing, speaking and consulting.

Supply chain teams operate in environments where conditions can change by the hour (or faster). Forecasts shift. Suppliers miss deadlines. Inventory levels fluctuate. Operational priorities evolve constantly across planning, procurement, manufacturing, and logistics functions.

To keep pace, many organizations are embedding AI directly into their workflows. AI-driven systems increasingly help teams monitor operations, identify risks, surface recommendations, and respond to changing conditions in near real time.

While many organizations are moving quickly to integrate AI in these ways, they are not always building the readiness needed to support it effectively. Gaps in operational and workforce readiness make it harder for organizations to scale AI effectively, coordinate responses across functions, and maintain trust in AI-supported decisions.

The sections that follow examine where gaps are emerging and outline practical steps supply chain leaders can take to strengthen foundational processes, improve cross-functional collaboration, and prepare employees to work effectively alongside AI-supported systems.

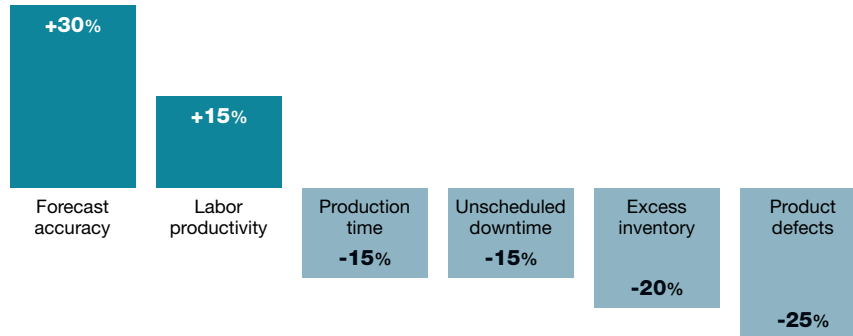
AI is changing how supply chain teams operate

Many supply chain organizations have moved beyond treating AI as a standalone productivity tool. Instead, they are increasingly embedding AI into operational workflows that span planning, procurement, manufacturing, logistics, and inventory management.

That shift is especially apparent in planning and forecasting activities. Organizations are increasingly using AI to support demand forecasting, inventory optimization, spend analysis, and scenario planning. APQC research shows that these efforts are already driving measurable gains: Organizations report a 30% improvement in forecast accuracy and a 20% reduction in excess inventory from AI-driven optimization and automation initiatives (Figure 1).

FIGURE 1

Organizations improve operational performance through AI-driven optimization



Source: APQC

APQC research finds that organizations are also embedding AI into operational processes like predictive maintenance, warehouse automation, manufacturing operations, and production scheduling. Organizations using AI-driven optimization and automation report a 25% reduction in product defects, a 15% reduction in unscheduled downtime, and a 15% increase in labor productivity (Figure 1).

These use cases reflect a broader shift in how supply chain work gets coordinated across functions. As organizations integrate AI more deeply across interconnected processes and teams, operational effectiveness increasingly depends on the strength of underlying data, governance structures, and cross-functional collaboration.

Many organizations still lack foundations necessary to support AI

While the benefits of AI for supply chain are clear, many organizations are implementing AI tools and systems faster than they are building the operational foundations needed to support them effectively.

APQC research suggests significant readiness gaps remain:

- more than one-third of organizations still lack

access to real-time manufacturing data;

- only 24% report fully integrated digital tools and AI capabilities (Figure 2); and
- only 21% consider themselves very prepared to adopt new technologies with strong business process support.

Organizations also continue to struggle with broader operational and governance challenges:

- 53% cite lack of collaboration across functions and external partners as a major obstacle
- 49% identified the implementation of new technologies as a significant challenge
- 35% struggle with governance gaps and poor data management

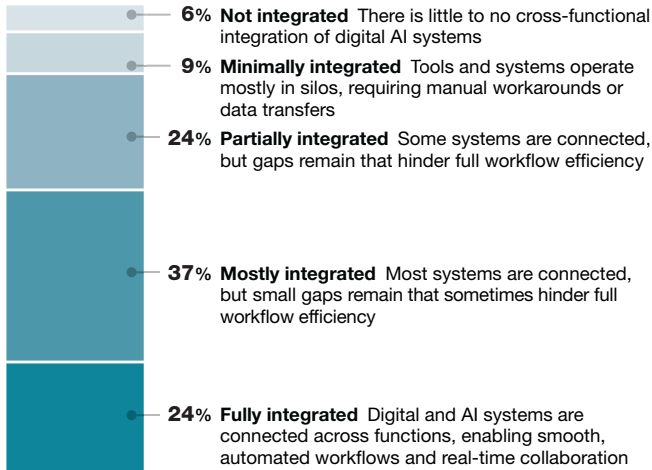
These gaps matter because AI-supported workflows depend on consistent processes, reliable data, cross-functional collaboration, and clear decision ownership. Without those foundations, organizations may struggle to coordinate decisions across functions or maintain trust in AI-supported operational decisions.

Operational readiness checklist

To strengthen operational readiness for AI, supply chain leaders should begin by evaluating the workflows, governance structures, and operational processes that support AI-enabled decision-making.

FIGURE 2

Digital tools and AI integration across functions remains uneven



Source: APQC

Over the next 30 days:

- identify at least one workflow where AI already influences operational decisions;
- assess whether that workflow has standardized processes and clear decision ownership;
- identify gaps in data visibility, system integration, or real-time operational reporting;
- review where employees still rely on spreadsheets, manual workarounds, or disconnected systems to coordinate work; and
- establish clear governance for how teams validate, escalate, and intervene on AI-generated recommendations.

Teams need different skills for AI-enabled operations

Supply chain employees increasingly need to understand how to work effectively within AI-enabled systems and processes. Beyond simply learning how to use new tools, they need to understand how AI-supported decisions affect other teams, suppliers, and broader supply chain

activities and when human collaboration and judgment are still required.

That shift changes the skills organizations need across supply chain teams. APQC research finds that organizations should not only prioritize technical capabilities such as AI fluency, data analysis, and data-driven decision-making, but also interpersonal skills like collaboration and knowledge sharing, leadership and change management, and adaptability (Figure 3).

These skills matter because supply chain operations rarely involve purely technical decisions. Employees must continuously balance cost, service, resilience, supplier relationships, customer expectations, and operational risk while working alongside AI-supported systems. That means everyone—from procurement leaders and managers to frontline employees—need clear guidance on when to trust AI-generated recommendations, when to validate outputs, and when human intervention is necessary.

Workforce readiness priorities

Once organizations begin strengthening operational foundations, leaders also need to prepare employees to work effectively within AI-enabled workflows. Over the next 60 days to 90 days:

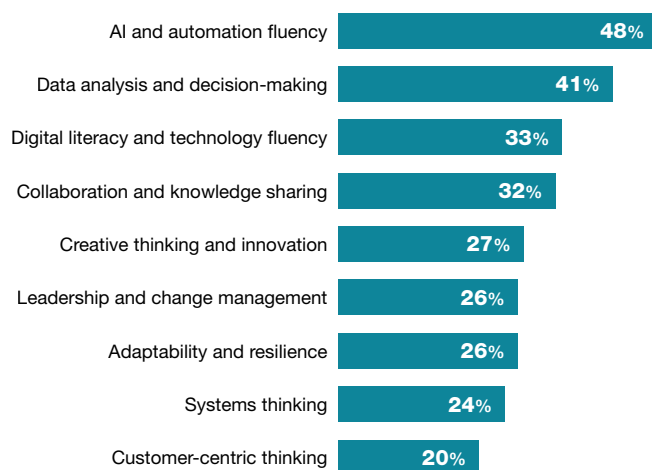
- map one AI-supported workflow and identify where employees are expected to review, approve, escalate, or override AI-generated recommendations;
- define which operational decisions remain human-led and which can be handled primarily through AI-supported processes;
- identify where cross-functional collaboration becomes critical when AI surfaces disruptions, exceptions, or conflicting recommendations;
- build escalation procedures for situations where AI recommendations conflict with operational realities,

supplier constraints, or customer requirements;

- hold cross-functional reviews of AI-supported workflows so employees understand how operational decisions affect upstream teams, downstream operations, suppliers, and customers; and
- update training and onboarding programs to reflect how operational responsibilities change inside AI-enabled workflows.

FIGURE 3

Critical skills organizations need to build for the future



Note:
Values do not add up to 100% because it was a “select all that apply” question

Source: APQC

AI changes the management challenge

As AI becomes more deeply embedded into planning, execution, and operational decision-making, supply chain leaders are increasingly managing teams that include both people and AI-supported systems.

In light of that shift, supply chain leaders will need to think differently about how operational decisions are made, how teams collaborate across

functions, and how to oversee accountability, escalation, and exception handling across interconnected workflows.

AI may accelerate analysis, monitoring, and responsiveness, but supply chain operations still depend on human judgment, collaboration, and relationships. The challenge for leaders now is learning how to manage environments where people and AI systems work together across interconnected processes that span the supply chain.

Data in this content was accurate at the time of publication. For the most current data, visit apqc.org.

About APQC

APQC (American Productivity & Quality Center) is the world’s foremost authority in benchmarking, best practices, process and performance improvement, and knowledge management (KM). With more than 1,000 member organizations worldwide, APQC provides the information, data, and insights organizations need to support decision-making and develop internal skills.

APQC’s Resource Library content leverages data from multiple sources. The Open Standards Benchmark repository is updated on a nightly cadence, whereas other data sources have differing schedules. To provide as much transparency as possible, APQC will always attempt to provide context for the data included in our content and leverage the most up-to-date data available at the time of publication. •



Data maturity is the real foundation of logistics AI

Q&A with **Hans Stig Moller**, CEO, Odyssey Logistics

Q: From your unique perspective, which emerging technologies are having the biggest impact on logistics management strategy in 2026?

A: Everyone's talking about AI, but AI is only as good as the data underneath it, and logistics is generally lacking data maturity. At Odyssey, we spent years building a unified data foundation, consolidating systems, eliminating silos and getting clean data into one place. Now we're applying AI and machine learning on top of this to drive route optimization, mode selection and predictive analytics. AI will have a massive impact this year — but only for the companies with strong data governance.

Q: What are the most pressing operational challenges facing logistics managers today, and how is technology reshaping their approach?

A: Visibility is still the central problem. Too many operations are running on fragmented systems that don't talk to each other, making decisions using days-old information. Freight conditions are shifting too fast for this to remain tenable: tariff changes and capacity swings don't wait for your systems to catch up. It's



something we've thought hard about at Odyssey. Our technology is built around giving customers the visibility and integrated data they need to move fast when conditions change.

Q: What would you say are the biggest benefits that technology is bringing to the modern logistics operation?

A: Ultimately, technology should be about expanding shippers' choices and helping them make better decisions. Having access to mature data and analytics lets you model trade-offs before committing to a lane or a mode — we helped one global customer save over \$1 billion this way by changing routes and

managing their cargo differently. Another real benefit is more accurate and up-to-date performance benchmarking. Through our self-service dashboards, customers can validate for themselves that we're hitting the right outcomes.

Q: Beyond efficiency, how is technology influencing workforce management, sustainability, and customer expectations in logistics?

A: Technology is changing what we hire for. As automation takes on more of the repetitive work, we're increasingly looking for serious strategic thinkers above all else. For sustainability, our data maturity means we can more precisely hit our customers' sustainability goals: dialing in the right mode mix and measuring CO2 impact — which they then use in their own reporting. In general, customer expectations are high: people have connected, real-time experiences everywhere else in their lives. The supply chain can't fall behind.

Contact info:
sales@odysseylogistics.com





Bridging the Talent Gap in Logistics: How SMC³ is Shaping the Future of LTL Expertise Through Education

Q&A with **Brian Thompson**, Chief Commerical Officer, SMC³

Q: How do you perceive the current state of talent in your own organization, and more broadly, in your industry?

A: In our organization and across the logistics industry, talent is evolving rapidly. While we see strong interest in digital transformation, there's a noticeable gap in specialized knowledge—particularly in less-than-truckload (LTL) operations. Programs like SMC³'s LTL Online Education help bridge this gap by offering structured, expert-led training. The pace of change in the supply chain demands continuous upskilling to remain competitive and meet the growing complexity of customer expectations as the supply chain ecosystem continues to grow and evolve.

Q: What challenges are most pressing when it comes to attracting and retaining talent in the industry?

A: Key obstacles encompass a shortage of candidates with specialized knowledge in LTL, ongoing training, and a lack of understanding of career opportunities within logistics. T. Addressing this requires firms to commit resources toward education, mentorship, and adaptable work arrangements. Initiatives like SMC³'s LTL Online Education program bolsters both credibility and employee retention



by providing transparent pathways for advancement and expertise development. It also serves as a valuable resource for onboarding new employees and expertly equipping them with LTL knowledge.

Q: What steps does your industry need to take in blending technologies like artificial intelligence with human talent to develop a more productive workforce of the future?

A: To build a future-ready workforce, industry must integrate AI with human expertise. This means using AI for predictive analytics, route optimization, and pricing models—while training employees to interpret and act on these insights. SMC³'s curriculum

already emphasizes data-driven decision-making, which is essential. The goal is not to replace people but to augment their capabilities, enabling smarter, faster, and more strategic operations across the supply chain.

Q: What initiatives or programs have you implemented, or would you consider implementing, to improve employee engagement and improve retention?

A: SMC³ provides ongoing LTL training, leadership development, and digital learning platforms. Programs such as SMC³'s LTL Online Education courses—combining on-demand modules with live expert sessions—are ideal for engaging employees at all levels. These initiatives foster a culture of continuous learning, boost morale, and align individual growth with organizational goals. SMC³ also currently offers the industry's only path to LTL Certification, demonstrating a proficiency in LTL concepts and best practices.

To learn more about SMC³'s LTL Online Education program, visit smc3.com/onlinelearning



FINDING THE ROI IN SUPPLY CHAIN EDUCATION

By Bridget McCrea



As supply chain roles expand, professionals and companies are looking harder at which certifications and programs deliver the best return on investment.

Supply chain professionals carry a lot on their shoulders, and the job keeps getting bigger. For years, the focus was mostly on functional expertise: procurement, logistics, inventory, transportation, planning, and day-to-day management. All of that still counts, but it's no longer the whole job by any stretch. The global pandemic changed the rules when it pushed supply chains into a spotlight so bright that the average consumer now understands their inner workings and what happens when they get disrupted.

But that was just the beginning. Artificial intelligence, machine learning, automation, data analytics, geopolitical risk, cybersecurity, labor challenges, and shifting customer expectations have also raised the bar. Suddenly, supply chain professionals had to be part data scientist, part statistician and part business strategist, all while maintaining a big-picture view of their global or domestic networks.

It's a big ask, and one that executive education providers are well aware of and working to address. "The profession has really evolved," says Abe Eshkenazi, CEO at ASCM. "Historically, the focus was on the fundamentals: planning, sourcing, manufacturing and execution. Today, risk, AI, analytics and geopolitical uncertainty are all core to the supply chain profession."

Those requirements looked a lot different just five to 10 years ago. And while supply chain professionals still need the fundamentals, they now also have to think strategically, collaborate across the business, and make decisions that can affect customers, costs, service levels, and daily operations. "We need to prepare them not only to execute," Eshkenazi says, "but also to lead."

Still satisfied, still learning

Supply chain professionals may be carrying a heavier load, but most of them still enjoy the work they're doing. According to Peerless Research Group's 2026 Salary and Compensation Study, 76% of logistics and supply chain professionals say the number of functions they perform has increased over the last two to three years. Even with that added responsibility, 93% are either very satisfied or somewhat satisfied with their careers.

As the ground continues to shift under them, these individuals are using certifications, job-related training, conferences, seminars and workshops to sharpen existing skills and learn new ones. For example, the survey found that 31% of respondents had completed a professional certification; 70% cited job-related training, and 47% pointed to industry conferences, seminars, or workshops.

That continuing education pays off in more ways than one. In its most recent Supply Chain Salary and Career Report, ASCM says supply chain professionals with at least one credential earn a median salary 8% higher than those without certifications. That figure rises to 14%

for those with two or more credentials. The organization also says APICS certifications contribute to a 20% median salary increase compared to professionals who don't hold those designations.

Eshkenazi says those salary gains usually come when the learning translates into measurable contributions. "Certification on its own can be a great door opener, but it's the contribution you make to the organization that enables your career," he says. "You don't get the salary lift because you get the certification. You get it because you increase profitability, improve execution, and contribute to the organization's results."

On becoming financial analysts

Certification providers are updating their programs around the skills companies say they need now. For example, the Institute for Supply Management (ISM) is in the middle of a full refresh of its CPSM certification, according to Jim Fleming, manager, product development and innovation. He says digital transformation and risk management remain high on the list, but another area is also getting more attention: financial analysis.

So just when you thought supply chain managers couldn't possibly fit another hat on their heads, they're also being asked to better understand how their decisions affect organizational financial statements. "You can look at profit and loss statements and balance sheets," Fleming says, "and then use the data that goes into these financial reports to understand just how effective your supply chain is."

That's a shift from the days when supply chain teams focused mainly on cost reduction.

Today, CEOs and CFOs expect them to show how their decisions affect the business, from return on investment and working capital to inventory turns and quarterly results. "We're seeing a lot of the executives coming in and saying, 'We need our employees to learn more in these areas,'" Fleming says, "and we need them to be able to look beyond just cost savings."

As he surveys the executive education and certification environment, Fleming says two other themes keep coming up: digital transformation and risk management. AI gets a lot of the attention right now, but it's only one part of a larger technology shift that's changing how supply chain professionals work, he explains. Risk management also remains a constant concern.

"Risk management continues to be front and center because every time you turn around, the news is blaming supply chain for whatever the problem is," Fleming says. "It seems like every day there's a new risk to address."

The biggest bang for your buck

Continuing education works best when it fits the need. An individual may want to fill a specific knowledge gap, prepare for the next role or build deeper expertise in a certain supply chain function. A company may need something broader, especially if it wants to raise the skill level of an entire team or give employees a common base of knowledge.

Either way, the ROI question should focus on what people need to know now, how they can prepare for what's coming next and which program gets them there without wasting time or money in the process. Mark Baxa, president and CEO at CSCMP, says the answer depends on

what the learner or company wants to get out of the experience. Some people want to better understand the role they're already in. Others want to prepare for the next one, become the person in the room who can solve bigger problems or build more expertise across the full supply chain.

Companies usually approach the question from a wider angle. For instance, they may want to build a stronger base of knowledge across the broader team, not just send one person through a lengthy certification program.

Instead of guessing at where to start, Baxa says both individuals and companies can use assessments to identify knowledge gaps across the supply chain. "You don't have to just say, 'Well maybe I'll just start with planning' or 'I'll start with procurement,'" he says. "Instead, a quick assessment will point you in the direction of where you need to go."

That direction can help students understand their jobs and the functions that feed into them. Someone may have the core skills for their current role, for example, but still need a better understanding of what happens upstream or downstream in planning, procurement, logistics, or another area of the supply chain.

Baxa also sees companies putting more emphasis on shorter courses that can reach more people faster. Longer certification programs still have their place, he notes, but some organizations want to raise the overall skill level of a team by function. "When you look at improving the overall competency of an organization," he says, "more of them are investing in the shorter courses that give more instantaneous results and upskill their broader workforces."

Where to start

Supply chain professionals exploring certification and other programs should start with where they want to go next. A specialized program can make sense for someone who wants deeper expertise in contracts, planning, procurement or another specific area.

Professionals who want to move into bigger roles should ask whether the program helps them understand more of the total supply chain and how it affects the business.

"If your career aspiration is to grow and take on more, then you really do have to make a choice around how much of the total supply chain am I learning about," Fleming says.

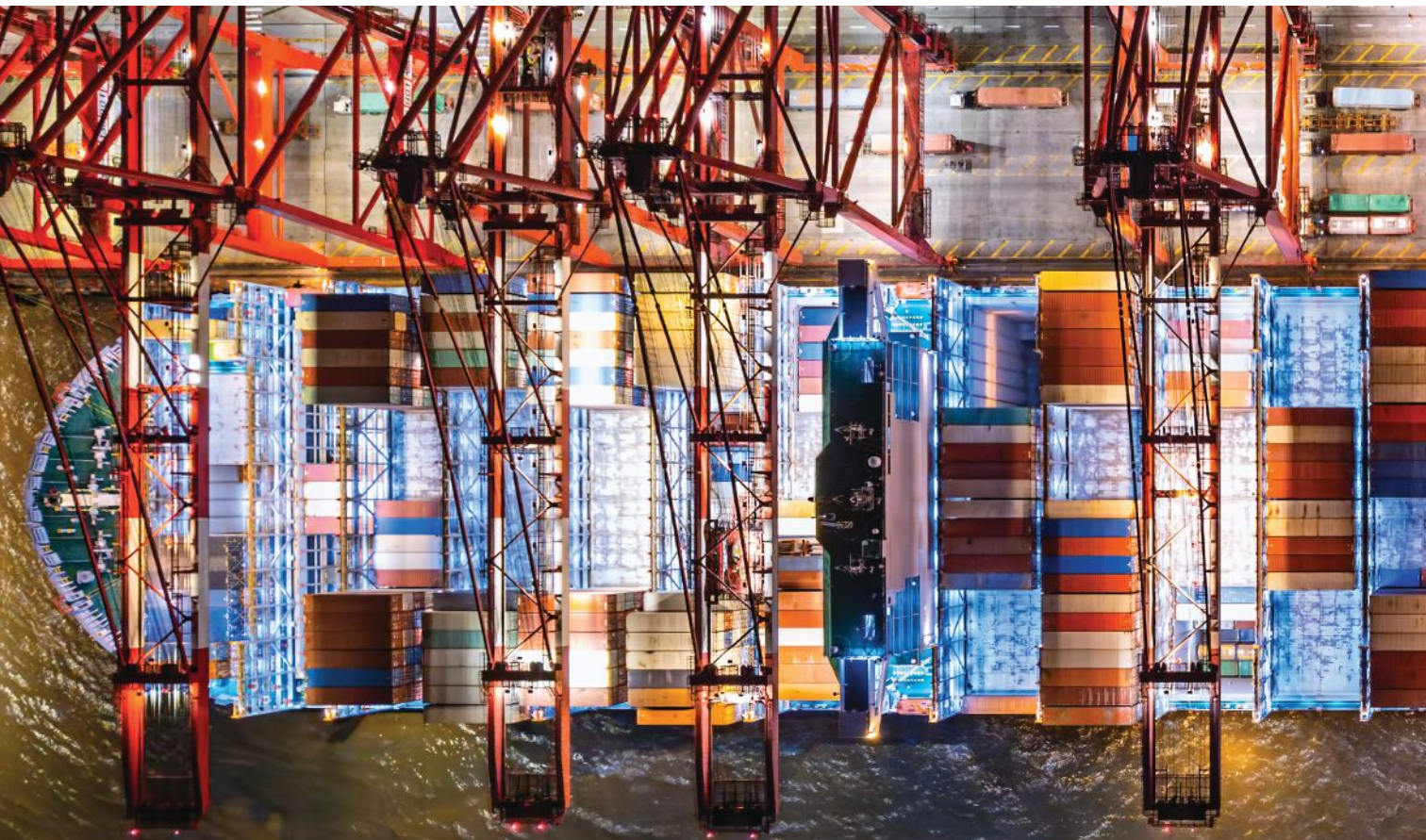
Time also matters, especially for professionals who are already carrying full workloads. Fleming says ISM has been building more digital options that let people study at their own pace, in bite-sized chunks or with instructor support. From an ROI standpoint, he adds, "the best program will always be the one that teaches the right skills in a format the learner can actually finish and apply."

Eshkenazi concurs and says individuals and companies alike should look for programs that address modern supply chain challenges, reflect current practices, carry global recognition, and teach students how to apply what they learn. That last point matters, especially for professionals who expect education to translate into higher pay. "You don't get that bump because you get the certification," he says. "You get it because you increase profitability, improve execution and contribute to the organization's results. That's what we're really trying to impress." •

TOP 50 3PLS: Stability returns, but the bar keeps rising

As market conditions level out, leading 3PLs double down on automation, orchestration, and strategic partnerships to meet growing shipper demands.

BY KAREN E. THUERMER, CONTRIBUTING EDITOR



Many shippers are wondering how the U.S. war with Iran will affect third party logistics (3PL) operators. While the answer depends on the length of the war, market experts concur that this year the 3PL market is stabilizing—especially when compared to the past two years when they faced freight recession, rate compression, and inventory correction.

In fact, analysts see 2026 as the first year since the pandemic that the market feels steady again.

“But it’s a different kind of steady,” says Benjamin Reich, logistics and fulfillment lead at Accenture. “In 2024, we were still dealing with excess capacity



Armstrong & Associates Top 50 U.S. 3PLs

(Largest U.S. Based 3PLs Ranked by 2025 Gross Logistics Revenue/Turnover)

A&A Rank	Third-party Logistics Provider (3PL)	2025 Gross Logistics Revenue (USD Millions)*
1	Amazon.com**	\$172,162
2	C.H. Robinson	14,768
3	GXO Logistics	13,178
4	J.B. Hunt Transport Services	11,284
5	Expeditors	11,069
6	UPS Supply Chain Solutions	8,771
7	Kuehne + Nagel (North America)	8,447
8	Ryder Supply Chain Solutions	7,802
9	Total Quality Logistics	7,433
10	DSV (North America)	7,250
11	RXO	5,742
12	OHL Supply Chain (North America)	5,425
13	Lineage	5,355
14	WWEX Group	5,181
15	Bean	5,111
16	Uber Freight	5,099
17	Penske Logistics	4,210
18	Schneider	4,146
19	Echo Global Logistics	4,000
20	Hub Group	3,946
21	NFI	3,750
22	AIT Worldwide Logistics	3,560
23	CEVA Logistics (North America)	3,305
24	GEODIS (North America)	3,100
25	Landstar	2,860
26	Arrive Logistics	2,691
27	Americold	2,602
28	Maersk Logistics (North America)	2,460
29	Flexport	2,160
30	Werner Logistics	2,149
31	Knight-Swift Transportation	2,135
32	MODE Global	2,100
33	Forward Air	2,000
33	PSABDP	2,000
34	KLN (Americas)	1,940
35	TFI International	1,932
36	Capstone Logistics	1,920
37	Scotlynn	1,811
38	Kenco	1,698
39	FedEx Logistics	1,645
40	Priority-1	1,560
41	SEKO Logistics	1,458
42	Ruan Transportation Management Systems	1,450
43	ArcBest	1,410
43	ITS Logistics	1,410
44	Universal Logistics	1,376
45	Armstrong Transport Group	1,350
46	Allen Lund	1,348
47	Redwood Logistics	1,282
48	Ryan Transportation Service	1,260
49	TRAFFIX	1,200
50	Axle Logistics	1,195

*Revenues cover all four 3PL Segments (DTM, ITM, DCC, and VAWD) and are company-reported or Armstrong & Associates, Inc. estimates. Currencies have been converted to US\$ using the average annual exchange rate. **Revenue shown is that of Amazon's Third-Party Seller Services business segment, which includes its 3PL operations as well as commissions and any related fulfillment and shipping fees, and other third-party seller services. Based on its 3PL warehousing footprint and e-commerce fulfillment focus, Armstrong & Associates estimates most of this segment's revenue is from 3PL services. Copyright© 2026 Armstrong & Associates, Inc.

and rate pressure coming out of the post-pandemic correction. In 2025, we saw slight improvement, but uncertainty was the defining theme caused by tariffs, geopolitical shifts, and constant network adjustments.”

Statistics available from Armstrong & Associates (A&A) show some changes in 2025 ranks and gross revenues among global 3PLs in part due to the DVS acquisition of DB Schenker.

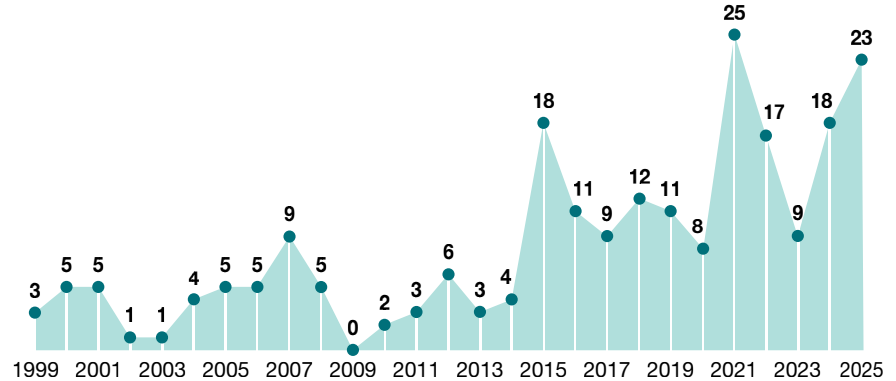
Like 2024, Amazon retained the No. 1 position, with gross revenues of \$172,163 million in 2025, up from \$156,146 million in 2024. DSV moved up from No. 4 to No. 2, with gross revenues of \$37,379 million, compared to \$23,335 million the year prior. DHL Supply Chain & Global Logistics Forwarding slipped from No. 2 to No. 3, reporting \$35,538 million in gross revenues, up from \$33,542 million in 2024.

A&A’s ranking of top U.S. 3PLs showed similarly limited movement. Amazon again held the top spot, while CH Robinson remained No. 2, though its gross revenues declined to \$14,768 million from \$16,848 million in 2024. GXO Logistics held steady at No. 3, increasing gross revenues to \$13,178 million from \$11,709 million the year prior.

Heading into 2026, market conditions were broadly consistent with 2025. A&A estimates that U.S. 3PL net revenues grew 5.1% to \$138 billion in 2025.

“This follows a modest 1.8% increase in 2024,” says Evan Armstrong, CEO of A&A. Additionally, gross revenues across all segments of the 3PL market experienced a year-over-year increase of 5%, which is significantly higher than the 2.8% growth seen in 2024. As a result, the total value of the U.S. 3PL market is estimated to

3PL acquisitions over \$100 million



Note: M&A activity over \$100 million with published terms or A&A estimates

Source: Primary, company information; secondary, Armstrong & Associates estimates

be \$323.4 billion in 2025.

International transportation management (ITM)—which includes air and ocean freight forwarding, customs brokerage and compliance, warehousing, and inland transportation—was the fastest-growing segment in 2025, achieving 7.7% gross revenue growth to reach \$85.9 billion, reports A&A. Net

revenue grew 11% to \$30.4 billion, resulting in a gross profit margin of 35.4%. This growth followed a 7.9% increase in gross revenue and a 2.1% decrease in net revenue in 2024.

Armstrong notes that the growth in the ITM segment can be attributed to concerns about tariffs and trade wars. “Importers have been eager to



Armstrong & Associates Top 50 Global 3PLs

(Largest 3PLs Ranked by 2025 Gross Logistics Revenue/Turnover)

A&A Rank	Third-party Logistics Provider (3PL)	2025 Gross Logistics Revenue (USD Millions)*
1	Amazon.com**	\$172,162
2	DSV	37,379
3	OHL Supply Chain & Global Forwarding	35,538
4	Kuehne + Nagel	33,836
5	CEVA Logistics	18,300
6	NIPPON EXPRESS	17,199
7	Maersk Logistics	15,103
8	C.H. Robinson	14,768
9	Sinotrans	13,580
10	GXO Logistics	13,178
11	GEODIS	11,700
12	J.B. Hunt Transport Services	11,284
13	Expeditors	11,069
14	DP World Logistics	10,501
15	Rhenus Logistics	8,869
16	UPS Supply Chain Solutions	8,771
17	DACHSER	8,361
18	Ryder Supply Chain Solutions	7,802
19	KLN	7,471
20	Total Quality Logistics	7,433
21	LOGISTEED	6,086
22	CJ Logistics	5,817
23	RXO	5,742
24	LX Pantos	5,624
25	Lineage	5,355
26	WWEX Group	5,181
27	Yusen Logistics	5,157
28	Beon (Transportation Insight)	5,111
29	Toll Group	5,100
30	Uber Freight	5,099
31	JD Logistics	5,036
32	Kintetsu World Express	5,018
33	ID Logistics Group	4,430
34	Penske Logistics	4,210
35	Schneider	4,146
36	Echo Global Logistics	4,000
37	Hellmann Worldwide Logistics	3,952
38	Hub Group	3,946
39	CIMC Wetrans Logistics Technology (Group)	3,808
40	NFI	3,750
41	AIT Worldwide Logistics	3,560
42	Savino Del Bene	3,500
43	AWOT Group	3,350
44	Gebrüder Weiss	3,081
45	SAIC Anji Logistics***	3,020
46	Arvato	3,000
47	Mainfreight	2,957
48	Landstar	2,860
49	Scan Global Logistics	2,851
50	Arrive Logistics	2,691

*Revenues cover all four 3PL Segments (DTM, ITM, DCC, and VAWD) and are company-reported or Armstrong & Associates, Inc. estimates. Currencies have been converted to US\$ using the average annual exchange rate.

**Revenue shown is that of Amazon's Third-Party Seller Services business segment, which includes its 3PL operations as well as commissions and any related fulfillment and shipping fees, and other third-party seller services. Based on its 3PL warehousing footprint and e-commerce fulfillment focus, Armstrong & Associates estimates most of this segment's revenue is from 3PL services.

***In-house logistics revenues were capped at 50% for fairness.

Copyright© 2026 Armstrong & Associates, Inc.

receive their goods before anticipated tariff increases, along with shipping uncertainties in the Red Sea and a decrease in ocean traffic through the Suez Canal,” Amstrong says.

Armstrong notes how the removal of the International Emergency Economic Powers Act (IEEPA) should result in less uncertainty for shippers in 2026. “However, with Trump’s ongoing threats for sectoral tariffs to replace the current temporary and past unlawful IEEPA tariffs, the future remains slightly uncertain,” he adds.

3PLs respond through strategic levers

While geopolitical events and government policy decisions make world freight markets seem vulnerable, 3PLs are taking consistent and steady decisions in solidifying their futures. This includes adopting technology advancements, implementing automation schemes, and closely examining and taking stake in their corporate structures.

“Automation is now moving from pilot stage to scaled deployment,” says Paul Chapman, senior editor at London-based consultancy Transport Intelligence (Ti). “Technology and automation investment is increasingly focused on scalable automation ecosystems rather than isolated warehouse upgrades. This includes robotics, AI-based labor planning, predictive analytics, and control tower visibility platforms.”

Large 3PLs are embedding robotics, AI-driven warehouse orchestration, and goods-to-person systems as core operating infrastructure rather than incremental efficiency tools. Examples include how DHL Supply Chain has

U.S. 3PL segment YoY growth

3PL segment	2025 gross revenue (turnover) \$ billions	2025 vs. 2024 gross revenue YoY %	2025 net revenue \$ billions	2025 vs. 2024 net revenue YoY %
DTM	128.3	4.5%	19.6	3.0%
ITM	85.9	7.7%	30.4	11.0%
DCC	32.0	1.6%	32.0	2.5%
VAWD	72.7	4.4%	56.1	4.4%
TOTAL*	318.9	5.0%	138.2	5.1%

* Total 2025 gross revenue (turnover) for the 3PL market in the U.S. is estimated at \$323.4 billion. \$4.5 billion is included for the contract logistics software segment.

Source: Armstrong & Associates

deployed thousands of autonomous mobile robots across its network and CEVA Logistics’ scaling of high-density “Skypod” systems to improve throughput in multi-client environments.

“GXO and others are increasingly standardizing modular automation to reduce labor dependency and manage volatility in e-commerce demand patterns,” Chapman says.

Accenture points to C.H. Robinson’s AI-driven Navisphere as exemplifying how advanced automation is now a baseline requirement, not a differentiator; and how digital native players such as Uber Freight, Flexport, and Redwood Logistics raise expectations for transparency and cross-border visibility.

“Technology, automation, and execution discipline are now baseline expectations, not differentiators,” says Reich. “What differentiates the leaders is their ability to connect all of this, including operations, technology and domain expertise into a solution that helps their clients to manage complexity—not just move freight.”

Consequently, making such technology standard for day-to-day

operations raises the bar of shippers’ expectations of their 3PL partners. “Many companies are no longer just looking for execution of their supply chains; they want coordination across increasingly complex networks, which is where 4PL-type and X-PL-type [including advanced technology] capabilities are gaining traction,” Reich says.

M&A’s continue to reshape competitiveness

Mergers and acquisitions (M&A) continue to grow and reshape the industry’s competitive structure. While M&A activity boomed in 2021 and 2022, it slowed in 2023. Significant M&A transactions were up in 2024 and continued in 2025.

“Last year started strong, with 15 deals over \$100 million, including three transactions over \$1 billion, in the first four months of the year,” says Armstrong. “The year ended with 23 large deals.”

Denmark’s DSV holds the title for the most significant purchase to date, with its acquisition of Germany’s DB Schenker for an astounding \$15.9 billion. This resulted in DSV becoming

the second-largest 3PL globally after Amazon. Ti notes how growth is increasingly driven by sector-specific expertise in healthcare, industrials, retail/e-commerce, and high-tech manufacturing. “Growth is often accelerated through acquisition rather than organic build,” says Chapman.

Examples are GXO’s acquisitions of Clipper Logistics, PFSweb and Wincanton, which strengthened its European footprint and capabilities, and UPS’s vertical expansion into specialist segments such as healthcare logistics through its acquisition of Andlauer Healthcare Group in 2025.

Alongside automation and consolidation, supply chain regionalization

is emerging as a secondary structural driver of change.

The tariffs on Chinese, Canadian, and Mexican imports have accelerated nearshoring and friend-shoring initiatives, with manufacturers and retailers building buffer stock to hedge against potential tariff escalation or supply disruption. “This is driving demand for warehousing in non-traditional inland markets and near emerging manufacturing corridors in the Southeast and Midwest,” says Armstrong.

Value-added warehousing and distribution (VAWD) providers with flexible capacity and the ability to offer value-added services—including kitting, light assembly, postponement

manufacturing, and e-commerce fulfillment—are particularly well-positioned to capture this demand.

Ti notes, however, that reshoring and nearshoring are not reducing the need for 3PL capacity. “Instead, it’s reshaping where and how that capacity is deployed, with increased demand for regional fulfillment networks and more complex, distributed operating models,” says Chapman.

Herman Guzman-Carranza, logistics and transportation advisor at Accenture, adds that nearshoring and expanding U.S.–Mexico trade are creating sustained cross-border complexity, making network design, customs expertise, and binational execution

4PLs gaining momentum

Today, more shippers are exploring 4PL-style models to orchestrate complexity across multiple providers—or bring orchestration capabilities in-house as technology matures.

“That’s pushing 3PLs to evolve beyond execution into more integrated, tech-enabled roles,” says Benjamin Reich, logistics and fulfillment lead at Accenture.

Geopolitical instability, shifting trade policies, climate disruption, cyber risk, and ongoing volatility in transport networks are driving increased momentum for 4PL models.

“Supply chains are no longer linear,” says Paul Lockwood, UK & Ireland group managing director at SEKO Logistics. “Without a central orchestration layer, complexity becomes a liability rather than an advantage.”

In its recent “Magic Quadrant for Fourth-Party Logistics,” Gartner highlights why companies are increasingly turning to 4PLs as neutral orchestrators—

integrating carriers, warehouses, and technology platforms into a single operating model.

“Companies are choosing to make products in different locations...That increases complexity, but also the flexibility they want to retain,” says David Gonzalez, VP, analyst at Gartner.

SEKO notes that many businesses now manage dozens of logistics partners and disconnected systems without end-to-end visibility.

“Fragmented supply chains...are like traffic networks without signals—everything moves, but nothing flows,” says Andy Berkshire. “4PL providers bring the coordination that allows complexity to work rather than break.”

Market data reinforces the trend. The global 4PL market is projected to grow from \$59.6 billion in 2024 to \$133.3 billion by 2034, while rising AI adoption is improving forecasting, inventory—



optimization, and risk management.

“These figures show that orchestration is no longer just about logistics—it’s about data, automation, and strategic oversight,” adds Lockwood.

Gartner notes that 4PL is not a one-size-fits-all model, with challenges including integration complexity and governance concerns.

“The most common question is whether orchestration should be insourced or outsourced,” says Lockwood. “Unless a company already has mature capabilities, the shift is steep. A phased or hybrid approach is often the most effective path.”

—Karen Thuermer, contributing editor

critical differentiators.

“At the same time, technology and real-time visibility have shifted from value add to baseline expectations, while tariff volatility is forcing companies to move away from static supply chains toward scenario-driven, resilient network models,” Guzman-Carranza says.

Strategic partnership

Today shippers and their 3PL partners are shifting from transactional relationships to true strategic partnerships, especially in this market where the gap between tech-forward and legacy 3PLs is widening fast.

For shippers, cost still matters, but it’s not the only primary lever. Shippers are operating in an environment defined by persistent cost pressure, structurally tighter labor markets, and ongoing geopolitical and demand

“Automation is now moving from pilot stage to scaled deployment.”

—Paul Chapman, *Transport Intelligence*

volatility. “This creates a widening gap between service expectations (speed, resilience, transparency) and operational constraints within logistics networks,” Chapman says.

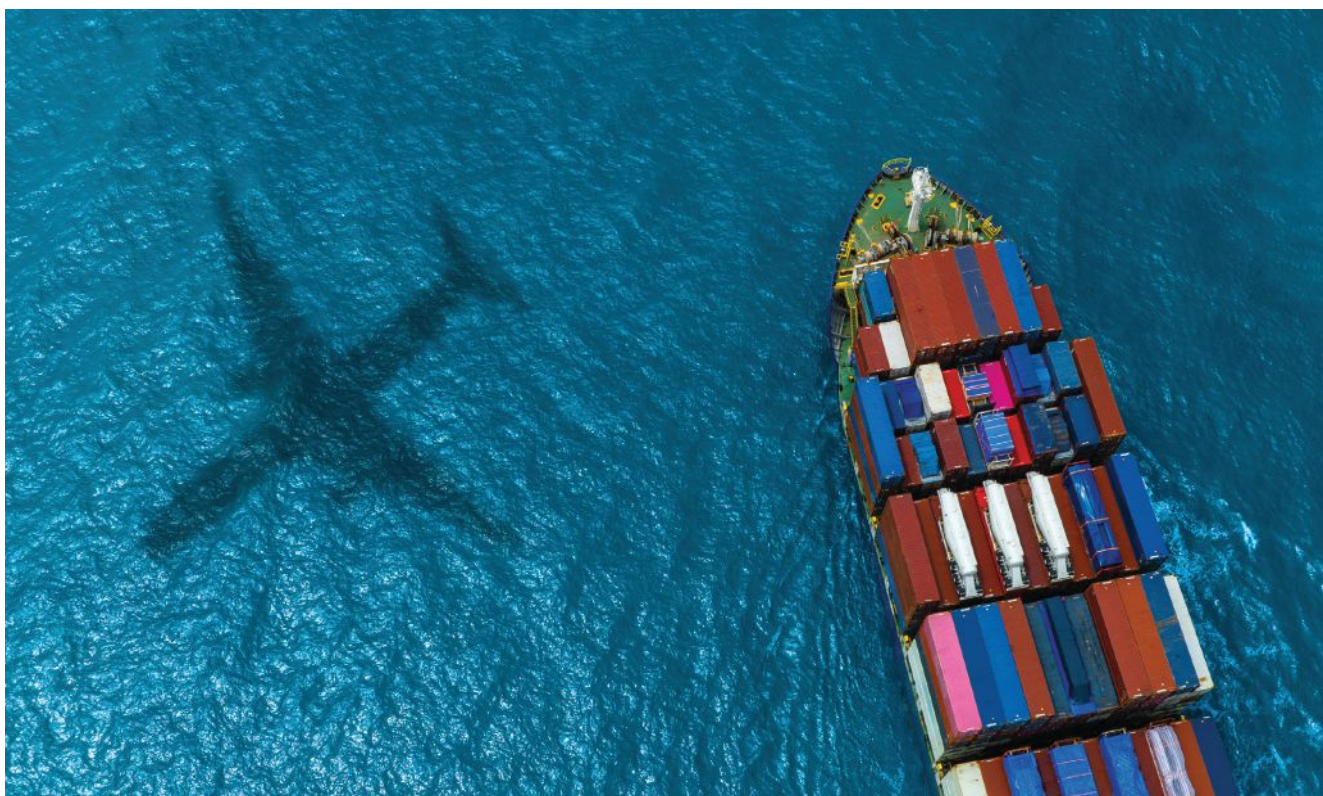
For example, in a market shaped by nearshoring complexity, tariff volatility, and rapid technological change, the cost of working with an under-equipped partner far outweighs short-term rate savings, adds Guzman-Carranza.

It’s also important to know how well a 3PL can perform when things don’t go as planned. How quickly can they adapt when change occurs? How much visibility can the 3PL provide, and how effectively and proactively can they use

data and technology to support decisions? Shippers need to be clear on the role they expect a partner to play.

“In this volatile tariff and trade policy environment, shippers need 3PLs that can quickly pivot sourcing lanes, bonded warehouse locations, and customs brokerage strategies,” says Armstrong. “AI-powered visibility, predictive ETAs, and automated document processing are no longer nice-to-haves.”

According to Armstrong, the bottom line is shippers who treat their 3PL as a strategic partner—not only a vendor—and invest in joint planning and technology integration are the best positioned to navigate this environment.



SMC³ LTL

Online Education

100% online



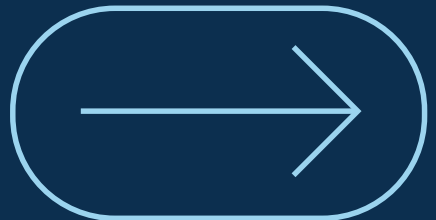
career-focused



interactive



engaging



Expand your professional opportunities with SMC³'s convenient training to increase your knowledge.



Learn more about LTL Online Education and certification at

smc3.com/onlinelearning



sales@smc3.com

800.845.8090

www.smc3.com

LEAD TIME ECONOMICS: What semiconductor supply chains reveal about strategic planning

By Nikhil Vishnu Vadlamudi



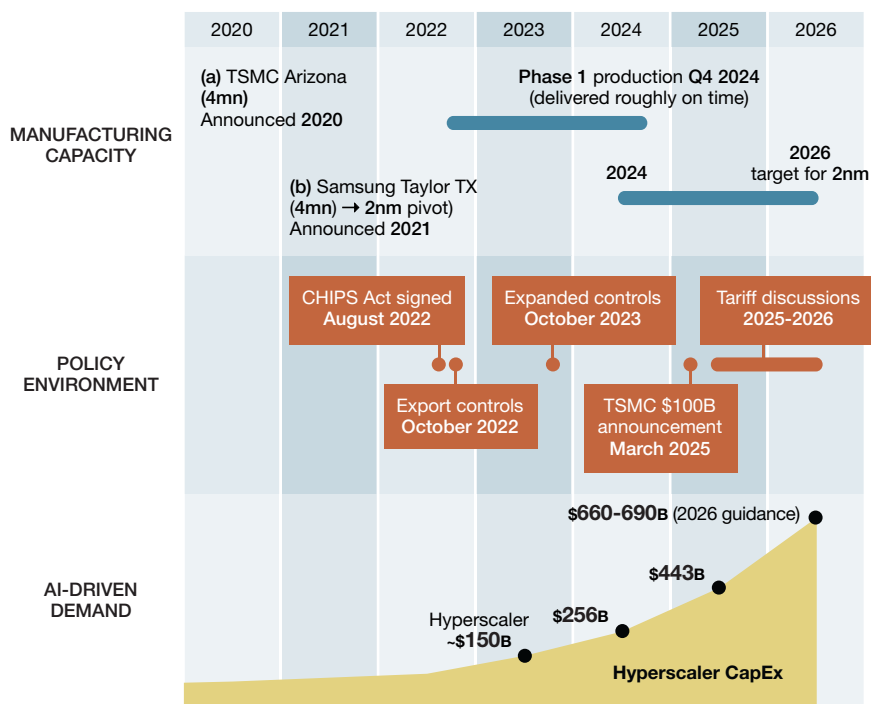
As AI-driven demand, geopolitical volatility, and massive capital requirements collide, semiconductor supply chains are becoming a blueprint for how capital-intensive industries must rethink long-range planning, risk-sharing, and capacity strategy in an era where market conditions can shift faster than infrastructure can be built.

Nikhil Vishnu Vadlamudi works in semiconductor operations with experience spanning the value chain at Applied Materials, AMD, and Intel. He brings a practitioner's perspective to foundry operations, capacity planning, demand forecasting, and S&OP. His work focuses on AI/ML-driven optimization of semiconductor manufacturing operations and strategic decision-making, bridging process technology, supply chain dynamics, and the operational realities of scaling semiconductor production.

When a trade restriction is announced or a hyperscaler revises its AI spending guidance, the semiconductor industry's real response was already set in motion years earlier. A leading-edge fabrication plant costs over \$20 billion and takes three to four years from investment decision to first production wafer. The specialized equipment inside, lithography systems that cost \$200 million to \$400 million each, comes from a handful of global suppliers with lead times of 12 to 24 months. Once the factory is operational, each wafer moves through hundreds of process steps over four to six months before becoming finished chips. Capacity decisions made today will not produce chips until 2029 or 2030. But the demand these fabs must serve, and the policy environment they operate under, can shift in a single quarter (see Figure 1).

FIGURE 1

Capacity decisions



Source: N. Vadlamudi (2026)

The structural tension in semiconductors is defined by three colliding timelines. First is manufacturing capacity, where fabs costing \$20 billion or more are physics-constrained and irreversible once committed. The contrast between announced timelines and actual delivery is stark: TSMC broke ground on its Arizona fab in 2021 and began 4nm production in late 2024, roughly on schedule. Samsung announced its Taylor, Texas, fab in 2021 for 2024 production; it has pivoted from 4nm to 2nm technology and now targets late 2026

at the earliest. Second is the policy environment, where export controls, CHIPS Act incentives, and tariff shifts can occur within weeks. Third is AI-driven demand, where the global semiconductor market is projected to reach \$975 billion by 2026 according to WSTS, on quarterly earnings cycles with annual spending swings exceeding 50%. This tension between long capital commitments and short-cycle volatility exists across capital-intensive industries, but no sector makes it as visible, or as consequential, as semiconductors.

Why lead times cannot be compressed

The semiconductor capacity pipeline is inherently incompressible because it is bound by supplier concentration, the physics of yield learning, and serial qualification requirements. Capital can be deployed quickly. Converting that capital into qualified, high-volume silicon follows a rigid chronological path that resists acceleration.

Supplier concentration and tool lead times. The most significant bottleneck is the extreme concentration of the upstream equipment supply chain. EUV lithography systems, required for any chip at 7nm or below, come from exactly one company: ASML of the Netherlands. ASML shipped 48 EUV systems globally in 2025 and reported full-year revenue of approximately \$39 billion. A standard EUV scanner costs approximately \$200 million, while the latest High-NA variant, needed for sub-2nm nodes, costs \$370 million to \$400 million. With a single supplier producing fewer than 50 systems per year for an entire global industry, delivery slots are committed years ahead. There is no expedited option because there is no alternative supplier. Leading-edge deposition and etch equipment comes from a similarly concentrated

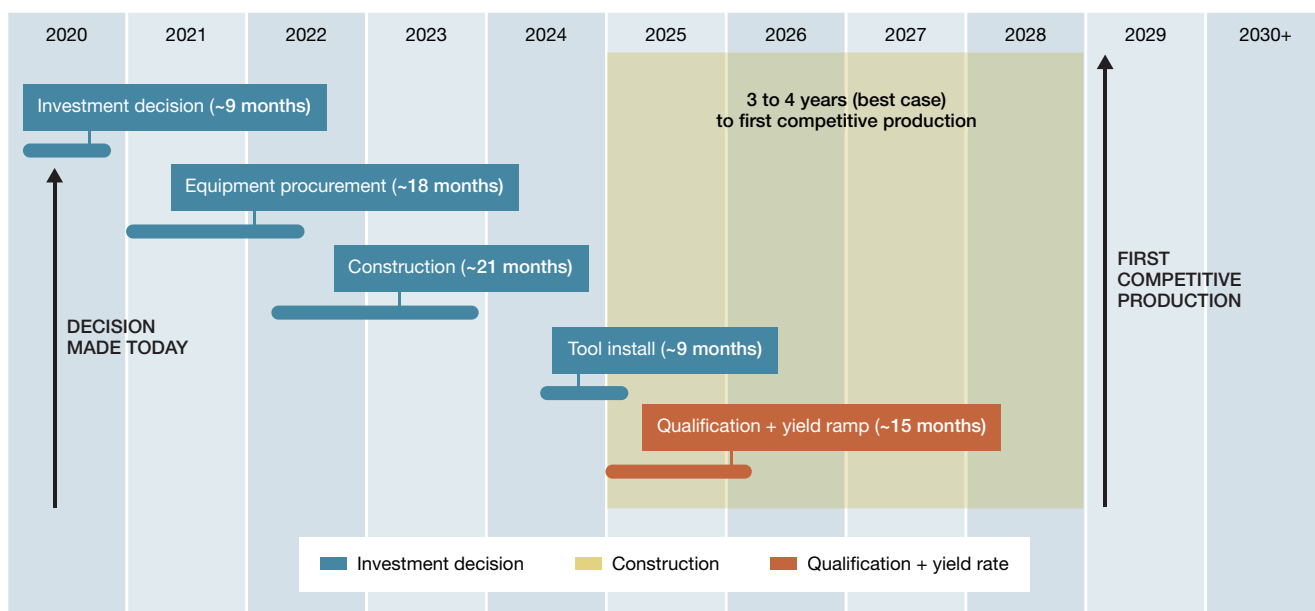
group: Applied Materials, Lam Research, and Tokyo Electron collectively determine the pace at which new semiconductor capacity can be equipped.

The physics of yield learning. A new fab typically starts producing chips at yields of 30% to 50%. Reaching competitive yields above 80% requires 18 to 24 months of systematic process optimization: identifying defect sources across hundreds of sequential process steps, adjusting parameters, and qualifying materials. Each learning cycle takes weeks because the wafer production cycle itself runs four to six months from bare silicon to finished die. Rushing process qualification does not produce faster results; it produces defective chips.

Serial customer qualification. Even after a fab demonstrates stable, high-yield production, customers require an independent qualification process. Automotive-grade chips must meet AEC-Q100 reliability standards. Defense and aerospace components require DMEA accreditation. Hyperscaler customers run proprietary validation suites. These processes typically take six months to 12 months. The total elapsed time from investment decision to qualified revenue consequently extends to four, five, or more years, as multiple reshoring projects have demonstrated (see Figure 2).

FIGURE 2

Investment decisions



The AI demand shock

The semiconductor industry has managed cyclical demand for decades. PC shipments swing 15% to 20% over two- to three-year cycles. Smartphone demand is relatively predictable. Automotive follows long design cycles. AI accelerator demand operates on a fundamentally different scale.

The hyperscaler spending explosion. The five largest hyperscalers, Amazon, Alphabet, Microsoft, Meta, and Oracle, are projected to spend a combined \$660 billion to \$690 billion on capital expenditure in 2026, nearly tripling from approximately \$256 billion in 2024. Amazon alone committed to approximately \$200 billion. Alphabet guided \$175 billion to \$185 billion. Microsoft is on pace for approximately \$145 billion. Each of the four largest hyperscalers will individually exceed \$100 billion in annual infrastructure spending. Goldman Sachs projects total hyperscaler CapEx from 2025 through 2027 will reach nearly \$1.4 trillion, almost triple the approximately \$485 billion spent from 2022 through 2024. Approximately 75% of this spending is directed at AI infrastructure.

The memory bottleneck. The demand pressure extends beyond logic chips. High-bandwidth memory (HBM), essential for AI accelerators, is sold out through 2026 across all three major manufacturers. Micron CEO Sanjay Mehrotra confirmed that HBM capacity is fully committed under multi-year agreements. The constraint is structural: each gigabyte of HBM consumes roughly four times the wafer capacity of standard DRAM, according to TrendForce. This has led to projections of a 171% year-over-year price increase for conventional DRAM in 2026 as consumer-grade supply is reallocated for AI production. Advanced packaging capacity, particularly TSMC's CoWoS platform, remains similarly constrained. AI demand does not simply

compete for fab capacity; it cascades through memory, packaging, and substrate supply chains simultaneously.

A two-front planning challenge. What makes the current environment unprecedented is that demand volatility and policy volatility are hitting simultaneously. An export control change does not just restrict where chips are sold; it redirects global demand in real time. A subsidy program does not just fund new fabs; it reshapes competitive geography, potentially stranding investments in regions that lose their policy advantage. The CHIPS Act and EU Chips Act together are channeling over \$100 billion in public funds into reshaping where semiconductors are manufactured, while tariffs and export controls can shift the competitive calculus in weeks.

The planning question has shifted from “how much capacity do we need?” to “how much capacity do we need, where, for whom, under which regulatory regime, and what happens if any of those assumptions change before the fab is operational?” This combinatorial explosion of scenarios is precisely why traditional deterministic planning fails. The semiconductor capacity decision is no longer an optimization problem with a single best answer. It is a portfolio problem requiring robustness across a range of plausible futures.

How semiconductor companies are adapting

Semiconductor companies cannot eliminate the temporal mismatch between multi-year fab builds and quarterly demand cycles. What they can do is distribute their risks more intelligently. The adaptation strategies now standard in the industry map onto two dimensions: time horizon (near-term operational adjustments versus structural repositioning) and risk ownership (who bears the cost when assumptions prove wrong).

FIGURE 3

Risk sharing matrix

		TIME HORIZON AND PURPOSE	
		Near-term risk management	Structural repositioning
RISK OWNERSHIP	Customer bears risk	Long-term agreements (LTAs) Wafer purchase agreements committing minimum volumes for guaranteed allocation	Vertical integration Direct customer capital funding for dedicated logic or memory production lines
	Supplier bears risk	Flexible capacity buffers Maintaining modular “shell-first” qualified lines to rapidly absorb demand surges	Geographic diversification (Policy insurance) in leading-edge capacity outside traditional clusters to reduce supply concentration
	Shared risk	Predictive analytics and scenario Deep integration in hyperscaler signals and WSTS data to model probabilistic demand outcomes	Industry consortia Leveraging public-private cost-sharing (e.g., CHIPS Act) to fund advanced manufacturing

Source: N. Vadlamudi (2026)

The shift to long-term agreements. Before the 2020 to 2023 shortages, much of the foundry market operated on relatively flexible, shorter-term commitments. That era is over. Take-or-pay LTAs with multi-year volume and pricing commitments have become the standard mechanism for securing leading-edge capacity. NVIDIA, AMD, Apple, and Qualcomm have all publicly disclosed multi-year TSMC commitments. Micron’s CEO Sanjay Mehrotra has described the company’s HBM supply agreements as “multi-year in nature,” fundamentally different from the transactional contracts of the past. The strategic implication: companies that locked in capacity early now hold durable advantages. For customers, LTAs are no longer a procurement decision; they are a board-level strategic commitment that shapes product roadmaps years into the future.

Geographic diversification as policy insurance.

No geography is immune to policy risk. TSMC’s expansion to Arizona (now totaling \$165 billion across six planned fabs), Kumamoto in Japan, and Dresden in Germany reflects explicit “policy insurance.” Research by BCG and the SIA found that a new fab in the U.S. costs approximately 30% more to operate than equivalent capacity in Asia. Companies are paying this premium because concentrated exposure to any single government’s decisions is now considered unacceptable strategic risk. Intel’s Fab 52 in Chandler, Arizona, reached Intel 18A high-volume manufacturing

in late 2025, adding US-based 2nm-class capacity to a global advanced-node supply base that has historically concentrated in Asia.

Modular and flexible fab design. To manage the risk of building a fab that may face different demand by the time it is operational, suppliers are increasingly adopting modular construction, building the shell and cleanroom infrastructure first, then phasing equipment installation as demand signals clarify. Within the fab, tool fungibility adds another layer of flexibility. While lithography systems are largely node-specific, much of the equipment base, deposition, etch, and metrology tools can serve multiple process nodes with recipe changes. A fab designed for one node can partially reallocate capacity to adjacent nodes as demand shifts. This does not eliminate the temporal mismatch, but it reduces the portion of the commitment that is irreversible.

Predictive analytics and scenario planning. Traditional capacity planning used deterministic models: forecast demand, optimize the production plan, and commit. This approach fails when forecast horizons of three to four years collide with quarterly demand revisions of 30% to 50%. Leading semiconductor companies are shifting to probabilistic approaches that model ranges of outcomes. Multi-signal demand forecasting integrates macroeconomic indicators, industry-specific metrics (WSTS shipment data, equipment booking trends, fab

utilization rates), and customer-level signals (hyperscaler earnings guidance, CapEx revisions) to reduce forecast error, particularly during regime changes when historical patterns break down. Emerging signals such as AI inference token generation growth rates are providing capacity planners with earlier visibility into demand trajectories.

The honest limitation: even sophisticated analytics cannot predict export control decisions or the trajectory of AI adoption. What it can do is narrow the range of uncertainty that must be managed through the other strategies. Analytics does not replace risk-sharing; it right-sizes the cost of managing uncertainty.

Beyond semiconductors: A framework for any capital-intensive supply chain

The semiconductor industry's extreme capital intensity and lead times forced it to develop these adaptation strategies first. But the underlying dynamics are not unique to chips. Two other industries illustrate how the same framework applies.

Aerospace: The geared turbofan crisis. Pratt and Whitney's PW1000G geared turbofan engine, which powers approximately half of all Airbus A320neo-family jets, has been subject to a massive recall since 2023 due to a powder-metal defect in turbine disc forgings. As of late 2025, approximately 835 GTF-powered aircraft were grounded according to Cirium fleet data, roughly one-third of the GTF-powered Airbus fleet. Maintenance turnaround times ballooned from 60 days to over 300 days. RTX expects recovery to extend through the end of the decade. In February 2026, RTX announced a \$200 million investment to install a seventh isothermal forging press, aimed at increasing critical engine component output by 30% by 2028. The constraint is not funding; it is the physics of

metallurgical inspection and the concentration of qualified manufacturing capacity.

Energy: The power transformer shortage. The utility sector faces lead times for large power transformers of 128 weeks (approximately 2.5 years), while generator step-up transformers reach 144 weeks. Demand has surged more than 100% since 2019, driven by AI data centers, EV charging infrastructure, and aging grid replacement. Wood Mackenzie projects a 30% supply deficit for power transformers. The DOE's \$1.9 billion SPARK program represents public-private cost-sharing for grid modernization. Hitachi Energy's \$1 billion manufacturing investment, including a \$457 million transformer factory in Virginia, aims to reduce U.S. dependence on imported units. Despite billions in investment, supply deficits are projected to persist into the 2030s because production remains constrained by a global shortage of grain-oriented electrical steel.

Closing. The temporal mismatch between long capital commitments and short-cycle volatility is not an anomaly of semiconductor manufacturing. It is becoming the defining challenge of capital-intensive supply chains, intensified by AI-driven demand creating unprecedented volatility, policy intervention reshaping competitive geography faster than manufacturing can respond, and concentrated supply bases creating structural bottlenecks resistant to brute-force investment. There is no solution that eliminates this mismatch. The goal is not to resolve the tension but to manage it through risk-sharing mechanisms, robust capacity configurations, and planning processes that model uncertainty rather than assuming it away. The semiconductor industry developed these approaches first because it had no choice. The rest of manufacturing would be wise to adopt them before the same forces arrive at their door. •