SUPPLY CHAIN MANAGEMENT REVIEW
July/August 2025

Digital downhill

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BRIAN STRAIGHT *Editor in Chief* bstraight@peerlessmedia.com

Don't get lost with AI

Technology may drive supply chains of the future, but people and communication still power success.

As artificial intelligence continues to transform every corner of the supply chain, from forecasting and procurement to logistics and planning, it's tempting to believe that technology alone will drive the next era of progress. But a closer look, particularly at the hiring process and team collaboration, reveals an inescapable truth: the human element still matters. And in many ways, it matters more than ever.

Norman Katz, president of supply chain consultancy Katzscan Inc. and a regular *Supply Chain Management Review* columnist, looked at the findings of the "2025 Skills Report for Supply Chain and Procurement" report from Skills Dynamics. What stood out most to him, he said, wasn't the latest hard-skill demand or software trend, but rather the enduring need for something much older: interpersonal skills.

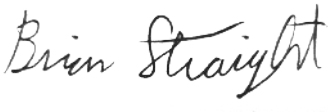
Katz noted that for most of the questions asked, the majority cited interpersonal skills as the top requirement. For example, when asked what, if any, skills do you look for in new/prospective procurement professionals, the top requirement named by 62% of the respondents was interpersonal skills. Katz's takeaway: Soft skills matter.

In a world where efforts to streamline each and every process turns to automation, it is tempting to turn over hiring to AI. But should you? While technology, and AI specifically, has streamlined the hiring process, the point Katz makes is not whether it provides value, but whether it provides the right value. Some people have become skilled at filling out resumes or automated application systems with the right keywords, but that doesn't always translate to the skills that will determine success. Is AI missing these? It's a question that HR professionals across the supply chain should be asking. While AI can analyze keywords, job history, and certifications, it can't yet judge empathy, collaborative ability, or communication style with any meaningful accuracy. These traits are essential for building relationships across internal departments, with suppliers, or when managing exceptions in real-time operations.

The truth is, AI can support great talent. It can empower teams with faster insights, reduce administrative overhead, and help identify trends before they become problems. But it can't, as of yet, replace the human relationships that bind the supply chain together. Until it can (if it ever can), we need to invest in people—not just technology.

NextGen Supply Chain Conference

We are inching closer to the 2025 NextGen Supply Chain Conference, taking place Oct. 22-24 in Nashville this year. As one of the premier events for senior-level professionals in the supply chain field, this conference brings together leaders who influence domestic and global supply chain operations. This year, we will focus on four key industry verticals in supply chain management and technology. Those are: Third-party Logistics; Food and Beverage; Consumer Packaged Goods; Life Sciences. As I write this, we are finalizing speakers in each of these areas, so check out scmr.com or nextgensupplychainconference.com for the latest updates on speakers, the full agenda, or to register to attend. I look forward to seeing you in Nashville.



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SUPPLY CHAIN MANAGEMENT REVIEW

Supply Chain Management Review® (ISSN 1521-9747) is published 7 times per year (Jan/Feb, Mar/Apr, May/Jun, July/Aug, Sept/Oct, Nov, Dec) by Peerless Media LLC, 50 Speen St, Ste 302, Framingham, MA 01701. Annual subscription rates: USA $199, Canada $199, Other International $241. Single copies are available for $60.00. Send all subscription inquiries to Supply Chain Management Review, PO Box 677, Northbrook, IL 60065-0677 USA. Periodicals postage paid at Framingham, MA and additional mailing offices. POSTMASTER: Send address changes to: Supply Chain Management Review, PO Box 677, Northbrook, IL 60065-0677.

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Speak financially, get results: Revisited

To elevate S&OP from tactical to strategic, supply chain leaders must speak the language of finance—and involve finance early and often.

By Larry Lapide

I recently attended a New England Chapter of the Institute of Business Forecasting and Planning (IBF) presentation, given by a seasoned planning manager from a local Boston-area based company. She was formerly at a large, well-known Midwest company and gained plenty of experience working on its sales and operations planning (S&OP) /integrated business planning (IBP) process team. She moved to the Boston area to implement a new S&OP process at the local company.

While successful in implementing it there, she said she was struggling a bit to get timely input from the finance department with respect to whether or not finalized S&OP demand-supply plans were synchronized with the company's financial performance goals. It seemed that the input was not provided on a routine basis, and if so, provided after S&OP plans were approved. Near the end of the talk, she asked the audience if anyone had ideas on how to get finance more involved. I offered a simple solution to her problem: Just break up, or parse, your S&OP process into two or more pieces to force the finance group to calculate the performance numbers for each one and just add them up.

After looking at me quizzically, I elaborated, explaining that I had students do research for their MIT Master's thesis on what businesses do when they have to develop multiple S&OP plans. (In whimsical terms, the students needed to address the challenge, analogously recalling that after "Humpty Dumpty had a great fall, all the king's horses and all the king's men could not put Humpty together again.")

The students' research found out that P&G, for example, has around 100 forecasting processes and 100 S&OP processes running simultaneously. When asked how it put all the pieces together, P&G managers said the finance group does it. The students' final recommendation in the thesis was that in order to make sense of multiple independent S&OP plans, financial managers needed to run the numbers for each, and add them together to get the company's enterprise-wide S&OP plans.

The manager rephrased that this, for example, means a profit-and-loss statement needs to be developed for each process. And of course, she noted that one has to make sure that demand and supply match for each process to ensure independence of the processes. To wit, I said: "Yes." (See Insights column: "Parsing holds key to better S&OP" (March/April 2012).

I view an SO&P team as being navigators that advise the executive team on whether a company is projected to be on a trajectory to achieve its annual financial performance goals. This includes both the profit-and-loss (P&L) statements, as well as the financial balance sheets that show assets. Thus, it is paramount that all S&OP operational plans be translated into their implications for a company's financial picture. In addition, this task has to be done by a finance manager(s) on the S&OP team. If not, there would be no reason to have representation by the finance organization on the team.

It has been my long-held view that supply chain managers need to be more adept at understanding financial statements and analyses. Much of supply chain planning is done in terms of the number of units to be sourced, made, and delivered. Minimally about the dollars and cents of it all. Over 12 years ago, in my Insights column titled "Speak financially, get results" (September/October 2012), I postulated that because finance is the language of business, managers should become schooled in financial analyses. A revision to that column follows.

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I got my doctoral degree from the University of Pennsylvania's Wharton School of Business in an area called operations research (OR). As a new graduate, I'd explain to people unfamiliar with the discipline that it involves the use of the scientific method and quantitative analysis to solve business problems. I had been trained in decision theory, quantitative modeling, and optimization techniques.

When someone would ask what my favorite graduate course was, I would carry on excitedly about my OR methodology course. It was taught by a famous professor who delighted students with stories about companies that had successfully used OR to solve some of their most pressing business problems. Math applied to the real world of business—what course content could be better than that? At least that's what I thought at the time. I now think "introduction to accounting" should be added to the mix.

Financials are the language of business

During my 45-plus years of business experience, several things have made me realize the importance of accounting and financial reports to understanding what really makes a business tick. Here are several points to consider.

First, in my November 2008 Insights column, titled "The operational performance triangles," I presented a triangle that can be used to help conceptualize whether a balanced set of operational performance objectives align to competitive corporate strategies. Two points of the triangle, efficiency and asset utilization, represent those types of performance objectives that directly affect a company's income statement and balance sheet, respectively. (The third point on the triangle represents customer response objectives that do not directly affect financial reports). My point in that column was that supply chain professionals need to understand how the first two types of operational objectives—efficiency and asset utilization—relate directly to financials.

Also, whenever a large-scale project is to be undertaken, a business case analysis must be developed in financial terms. So, before a supply chain project can get started, executives need to be convinced that it will improve financial performance over the long run.

Lastly, I'm now convinced that all future supply chain leaders will need to be good business people first and supply chain experts second. For this to happen, they must become conversant in the language of business, which is accounting and financially based.

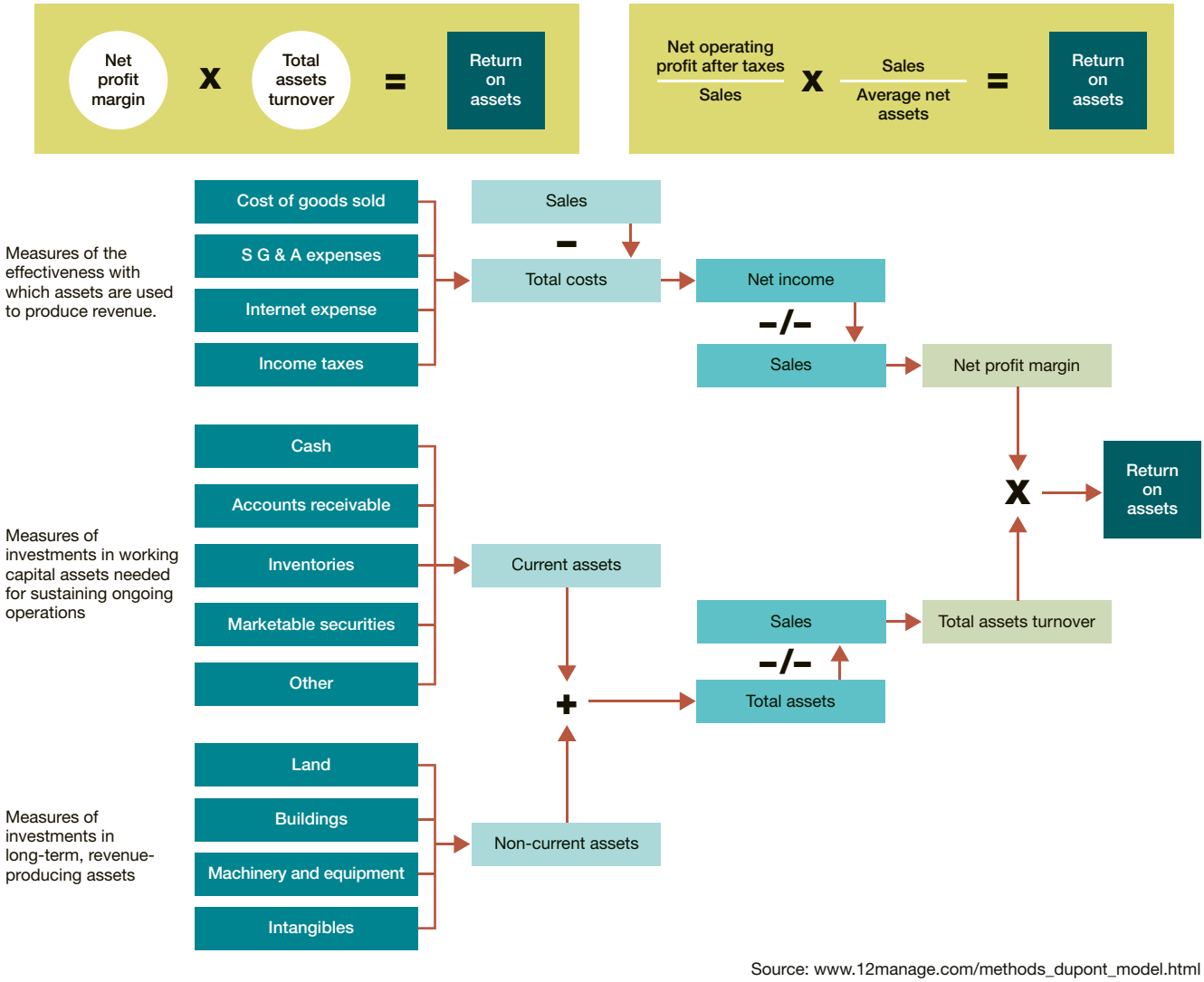
The DuPont Model

Put very simply, all supply chain managers should become conversant in accounting and finance if they want to get ahead. Once conversant, they will be able to build business cases that will resonate closely with executive-level thinking. The DuPont Model (shown in Figure 1) is a good blueprint to use when developing a business case. The model, which according to Wikipedia was established in the mid-1920s, has been used by managers over the years to translate operational plans into their expected financial impact on return-on-assets (ROA). While simple, the model is robust in showing the interconnections among operational productivities, revenues, operating costs, assets and inventories, and their impact on ROA.

Using a model such as this allows managers to translate operational supply chain improvements into their financial impact. For managers that adopt the model and follow my advice to "think financials," their executive presentations will go from being "bored-level" to "board-level." This will help them get the executive approvals they need, as well as those promotions they want. •

FIGURE 1

The Dupont model



Source: www.12manage.com/methods_dupont_model.html

AI's supporting role in supply chains

Despite advances, developing workplace systems that facilitate AI-human working relationships is still in its early stages. Companies need to invest in systems that enable robots and humans to assume more sophisticated roles gradually.

By Ken Cottrill, editorial director, MIT Center for Transportation & Logistics

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As AI advances in the workplace, more applications that augment, not necessarily replace, human capabilities are emerging. It is essential to understand how these technologies can be integrated into collaborative partnerships with employees as we prepare workforces for AI-related transformative change.

Different combinations

In his book The Magic Conveyor Belt: Supply Chains, A.I., and the Future of Work (MIT CTL Media, 2023), MIT CTL director Yossi Sheffi describes the roles humans and machines play in controlled activities.

"At one extreme, a person might be fully in the loop, in that they must execute one or more essential steps every time the task must be done," writes Sheffi. Automation handles certain aspects of the task, but human workers remain an indispensable part of the process.

Another workplace configuration involves a machine automatically processing most of the routine elements of a task but alerting humans when exceptional, anomalous, or complex issues need to be addressed. The task is automated most of the time. A more advanced version of this arrangement involves a person monitoring the task through a dashboard, intervening only when an alert is triggered.

In some cases, human involvement occurs only at a higher level, like designing a fully autonomous, machine-driven system. The system operates continuously without requiring human participation. An engineer might design a warehouse refrigeration control system that operates autonomously, eliminating the need for workers or managers to adjust the system.

Bot-powered procurement

Utilizing AI to augment human capabilities can free employees to focus on strategic challenges and those that deliver high returns.

For example, a leading retailer is using AI-driven bots in its procurement function to negotiate low-value, often infrequent, purchases from suppliers where the potential returns for the company are relatively modest. The retailer described the arrangement at MIT CTL's Crossroads 2025 conference on March 17, 2025. High-value negotiations with strategic suppliers are still overseen by human procurement managers. Deploying bots in this way enables the company to utilize its in-house procurement expertise more effectively.

The bots also provide valuable intelligence that the company is using to improve its procurement operations, explained the retailer. This includes identifying which days of the week tend to yield the best outcomes, as well as more precise information on what constitutes successful negotiations. Interestingly, the retailer has found that including bots in sourcing events can remove the emotion from interactions with suppliers and promote smoother negotiations.

Warehouse partnerships

In supply chains, a useful example of a place where different combinations of human and machine capabilities are deployed is the warehouse. Maria Jesus Saenz, director of the MIT Digital Supply Chain Transformation Lab, and Benedict Jun Ma, postdoctoral associate at the MIT Digital Supply Chain Transformation Lab, have researched this environment and the implications for the roles of humans and machines.

In many areas, such as picking items from racks and sorting them into bins, assistive technologies like pick-to-light systems have decreased the need for human expertise. Employees only have to follow computer instructions. However, there are value-adding tasks, such as processing order returns, that can require human judgment and problem-solving skills.

The degree of robot autonomy required in warehouses also varies. Low-autonomy machines, including automated guided vehicles, follow predefined paths. However, there are also high-autonomy robots at work in warehouses that utilize sophisticated sensors to plan their routes dynamically without human intervention. Given these variations and the diverse operating environments in facilities, the Digital Supply Chain Transformation Lab has developed a framework that helps managers optimize the mix of human and machine expertise in warehouses. It can also be used to help configure different combinations of skills and prepare managers to equip their facilities to meet future market demands.

The human-robot collaboration (HRC) framework is based on the degree of human expertise and robot autonomy involved in carrying out tasks. Situations where there are high levels of robot autonomy and limited human expertise (e.g., autonomous mobile robots), or vice versa (e.g., experienced humans performing value-added tasks), are referred to as Robot-in-the-Lead and Human-in-the-Lead configurations, respectively.

Examples of HRC in warehouses are at an early stage, according to the researchers, a notable example being collaborative order picking. An aspirational vision, known as Advanced HRC, is one where both human and machine elements are highly developed and integrated.

Regarding the use of AI, the researchers propose five key areas of impact for Advanced HRC.

For instance, Contextualization is where AI empowers robots to understand and adapt to their operational surroundings. An example is an AI-powered robot capable of automatically detecting changes in a warehouse layout and adjusting its movements accordingly. AI can also enhance the clarity and accuracy of robot responses by enabling seamless communication between machines and humans. An example is where human operators communicate with robots via voice commands. In another area, called Customization, AI helps to tailor robot behavior to humans' skills and work routines.

Helping small retailers

Utilizing AI to enhance human performance is a central mission of the MIT Low-Income Firms Transformation (LIFT) Lab, led by Josué C. Velázquez from MIT CTL. However, in this case, the focus is on micro and small enterprises (MSEs) in developing countries. As well as playing a critically important economic role in local communities, MSEs represent a significant economic force worldwide. In Latin America and the Caribbean, for example, a region the LIFT Lab has prioritized, MSEs account for an estimated 99% of companies and 47% of employment. They also make up a sizable customer base for leading consumer products companies.

However, MSEs struggle to survive. Their mortality rate in developing countries is estimated to be over 30% annually during the first five years of operation. A key reason for this relatively short shelf life is their low productivity compared to larger firms. Store owners often lack education and training, and many use paper-based methods to manage their retail operations. Helping MSEs, particularly micro- and small-sized retailers, also known as nanostores, address this productivity gap is one of the LIFT Lab's primary goals.

The Lab has developed a groundbreaking chatbot called Lupita, an AI tool for nanostore owners and operators that is analogous to Amazon's well-known virtual assistant, Alexa. Shop managers can interrogate Lupita and access a wealth of information such as the price of specific products in other retail outlets in the locale and details of their store's inventory and delivery schedules. The chatbot supports critical store management functions like purchasing, report generation, inventory tracking, and sales monitoring.

Lupita provides shopkeepers with a powerful efficiency-building tool, including individuals who may have difficulty using off-the-shelf store management systems. Research conducted by the LIFT Lab in Mexico revealed that shopkeepers perceived Lupita as more efficient than established point-of-sale systems.

The chatbot is a prime example of how AI can raise productivity by supplementing and enhancing human expertise.

AI as a change agent

Despite advances like these, developing workplace systems that facilitate AI-human working relationships is still in its early stages. Research at the MIT Digital Supply Chain Transformation Lab suggests that most warehouse operations today are in the "Elementary HRC" quadrant of the Lab's framework (e.g., automated guided vehicles and humans performing tasks at stationary workstations), where humans and robots collaborate only on structured tasks. These collaborations must be taken to a higher level if facilities are to operate in the "Advanced HRC" quadrant.

Achieving such a transition should be an incremental process, the researchers suggest. Companies need to invest in systems that enable robots and humans to assume more sophisticated roles gradually. An example might be empowering robots with increased autonomy in repetitive tasks, such as sorting and picking, while training human workers to undertake more complex decision-making. Upskilling workers in this manner can also help prepare them for the future workplace. As Sheffi writes in The Magic Conveyor Belt, "AI and digital tools can augment the power of people, enabling them to handle jobs they could not in the past." •

Rethinking planning... Start with how you make decisions

After decades in this industry, one truth continues to rise above the rest: your supply chain is only as effective as the decisions you make across multiple planning horizons—strategic, tactical, and operational. Yet too many decisions are still being made too slowly, with too little context, and all too often in isolation.

By Karin Bursa

Karin Bursa is the CEO of NIRAKIO, LLC and can be reached at kbursa@nirakio.com.

In the evolution from enterprise supply chain management to ecosystem supply network management, each decision made results in intended and unintended consequences. Lack of visibility to the unintended consequences and context generally leads to risk and disruption. Legacy planning systems and siloed spreadsheets simply can't keep pace with the speed, scale, complexity, and volatility of modern global business. Most of these systems were never designed for today's data sources and volumes—which are doubling every two years, according to IDC—nor were they built to support intelligent (artificial or human) decision-making at scale.

The leaders we work with every day are feeling that pressure: data is flooding in from internal and external sources, alerts are constant, and analysis paralysis is taking hold. Supply chain team members are exhausted, second-guessing their recommendations, and falling behind on tomorrow's targets—all because they're stuck using yesterday's tools.

But here's the good news: you don't have to rip and replace everything. What's needed is a smarter intelligence layer that connects and augments the systems you already have. Decision Intelligence is that layer — weaving together data and decisions across ERP, supply chain planning, transportation, warehouse, and

operations execution systems—turning siloed information into synchronized, real-time action.

Why decision intelligence now?

Decision intelligence (DI) is not a buzzword. It's a business imperative.

It's the evolution of how supply chains operate — a shift from analysis to action. DI leverages real-time data, AI, and process automation to continuously optimize decisions, helping your team respond faster, reduce risks, and act with confidence.

Gartner defines decision intelligence as "the practical discipline used to improve decision-making by explicitly understanding and engineering how decisions are made, and how outcomes are evaluated, managed, and improved by feedback."

Instead of spending hours analyzing what happened last week, DI empowers your team to simulate what could happen tomorrow—and recommends the best action to take in real time to achieve your business goals.

By 2027, 50% of all business decisions will be augmented or automated by AI agents, according to Gartner (Source: Gartner Market Guide for Analytics and Decision-Making Platforms for Supply Chain, 14 January 2025). And for supply chain leaders, the curve is steeper. A recent MIT Sloan/BCG study found that 89% of executives believe AI will be a key competitive differentiator within the next five years.

AI enables us to evaluate massive, complex data streams while providing us with the context to anticipate the cascading impacts (intended and unintended) of decisions across the global ecosystem supply network — avoiding the trap of solving one problem while creating several more…unintended consequences.

And yes, AI is "data hungry." But when properly trained and fed, AI doesn't just automate — it elevates. AI agents work around the clock to analyze patterns, make recommendations, simulate alternatives, and, in some cases, take action autonomously.

Key pillars of decision intelligence

- ***Data-driven decisions.*** Real-time, historical, structured, and unstructured data fuels smarter, more holistic insights both internal and external.
- ***AI and automation.*** Applied logic and machine learning reduce manual effort and accelerate execution.
- ***Context-aware intelligence.*** Decisions account for business goals, constraints, and operating environments.
- ***Scenario planning.*** Simulations evaluate trade-offs and outcomes before action is taken.
- ***Continuous learning***. Each decision fuels and initiates a feedback loop, constantly improving future choices.

Decision intelligence repositions humans as "decision orchestrators"—designing how decisions are made, with AI executing and optimizing them at scale.

Decision intelligence spans three levels.

• ***Decision support*** (human in the loop): AI delivers insights and scenarios. Humans decide.
• ***Decision augmentation*** (human in the loop): AI recommends and explains; humans validate.
• ***Decision automation*** (human out of the loop): AI makes and executes decisions autonomously with auditable process automation and control.

The challenges we see most often

Across industries and regions, we hear the same issues:

• "We can't see across silos — the full picture is missing."
• "Our data isn't real-time or at the right level of granularity."
• "We make decisions that conflict across departments and make collaboration impossible."
• "Our planning cycles don't align with the speed of disruption."
• "We're buried in alerts, but don't know what truly matters."
• "Our teams spend more time gathering data than acting on it."

The fallout? Long days. Slower responses. Risky spreadsheets. Reliance on tribal knowledge. And constant second-guessing.

Let's talk about spreadsheets. A 2022 McKinsey study found that 73% of supply chain executives still rely on spreadsheets to manage planning—and the Corporate Finance Institute estimates the error rate in spreadsheets to be as high as 88%. That's a staggering risk when you're making multi-million-dollar decisions.

No wonder leaders are racing to embrace AI and Gen AI—not just for analysis, but to ask smarter questions, detect anomalies, and prescribe next steps instantly.

What's changing: From analysis to action

New platforms are emerging that fundamentally rethink how decisions are made and executed. These aren't just dashboards or alerting tools — they're decision engines, purpose-built for supply chain agility, performance, and resilience.

And perhaps most importantly, decision intelligence does not replace your existing systems—it enhances them. Decision intelligence unlocks the data hidden in your ERP, TMS, WMS, and APS solutions, and orchestrates decisions across them so each action is informed by a broader operational and strategic context. Further, decision intelligence identifies new data and sources that can be leveraged to facilitate ecosystem network collaboration… internally and externally.

These innovative platforms combine:

• ***cloud-native, hyper-scalable architectures*** with no-schema flexibility;
• ***low-code/no-code extensibility*** to adapt fast without overhauling infrastructure;
• ***digital twins*** to simulate end-to-end ecosystem and enterprise network impacts;
• agentic AI that dynamically reasons, recommends, and acts;
• ***prescriptive guidance*** that is explainable, traceable, configurable, and auditable; and

• ***event-driven and ad hoc analysis***—not just scheduled planning runs.

And critically, they enable human oversight at scale. AI manages and leverages the repeatable, the routine, and the real-time—while your people focus on the strategic, the nuanced, and the innovative.

Resuscitating S&OP: Is it dead?

Some ask if S&OP is dead. My answer? No—but it needs a serious reboot.

Traditional S&OP is often too slow, too rigid, and too disconnected from the realities of execution. DI does not replace planning—it makes it better… dynamic, real-time, and cross-functional. It integrates and enables demand sensing, supply response, inventory optimization, and risk management into one integrated flow of intelligent (and, collaborative) decision-making.

This is not about killing S&OP. It's about enhancing and leveraging it to finally become what it was meant to be: a framework for automated or autonomous decision-making support with visibility and context to respond to cascading consequences; especially, unintended ones.

What happens when you get it right?

When companies embrace decision intelligence, they see tangible results.

• ***Inventory is optimized,*** reducing working capital and increasing service levels

• ***Response times drop*** from days to minutes.

• ***Teams shift from reactive to proactive***, focusing on strategy over scrambling.

• ***Decisions become explainable and consistent***, not gut-based guesses.

• And most critically: ***your supply chain becomes a competitive advantage***.

According to Gartner, companies that excel at decision intelligence outperform peers in operational efficiency and customer responsiveness by more than 25%.

Are you ready to lead the shift?

If your organization's leadership is still trying to scale tomorrow's supply chain with yesterday's technology, it's time for a new approach.

Decision intelligence does not replace your existing systems — it makes them exponentially smarter. It unlocks their data, orchestrates decisions across functions, and ensures supply network decisions are aligned with your broader business strategy.

It's time to unlock the full potential of your data, your people, and your operations…extending relationships throughout the enterprise and ecosystem supply network. Because better, faster, smarter decisions aren't just possible. They're essential. And they are available now. •

About Global Links

Global Links appears in each issue of *Supply Chain Management Review*. Richard J. Sherman, retired guru of SCM, is the Global Links column editor and collaborator. If you are interested in participating in the column, he can be reached at rsherman@goldanddomas.com.

Mastering the slippery slope of digital transformation to enable game-changing performance

By Stan Fawcett, Sebastian Brockhaus, Amydee M. Fawcett, and A. Michael Knemeyer

Lindsey Vonn pushed limits to reach the summit of the ski world. Her perseverance and approach to technology offer lessons that supply chain managers can adopt to travel their own fall lines to technological greatness.

I want to keep pushing the limits to see what's possible. That's the nice thing about ski racing— no one is stopping you from going faster.

—Lindsey Vonn

In mid-March 2009, at the World Cup finals in Åre Sweden, Lindsey Vonn did something remarkable: She won both the downhill and super-G, Alpine skiing's glamor speed events. Vonn finished the World Cup season with 1,788 points, a decisive 384-point margin over second place Maria Riesch. Vonn didn't just defend her overall World Cup title, she put the skiing world on notice: She wouldn't settle for business as usual. Over the next 10 years, Vonn rewrote Alpine skiing's record book, securing her place as one of skiing's greatest competitors.

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TABLE 1

Lindsey Vonn by the numbers

Record—man or woman—43 World Cup downhill wins
Record—man or woman—28 World Cup super-G wins
Record 8 World Cup downhill crystal globes (i.e., season titles: 2008-2013, 2015, 2016)
Five World Cup super-G crystal globes (**second most** ever)
Three consecutive World Cup combined crystal globes (**second most** ever)
Record 20 World Cup crystal globes (Ingemar Stenmark won 19)
Record 27 small crystal globe podiums (Ingemar Stenmark won 23)
Total World Cup **wins**: 82 (third most all-time: 43 downhill, 28 super-G, 4 giant slalom, 2 slalom, 5 combined)
Only U.S. woman to win downhill Olympic gold
Oldest woman Alpine skier (age: 40) to make the podium of a World Cup race
One of only six women to win a World Cup race in all five classic Alpine disciplines

Source: Authors

Vonn's 2008-2009 season was remarkable for another reason: She started racing on men's skis, an unheard of technology shift. Men's skis are longer, stiffer, and potentially faster, but much, much harder to control (the reason women typically don't use them). Vonn embraced the risk—a bold move calculated to shave fractions of a second off her race times. With results decided by tenths or hundredths of a second, Vonn's decision proved a game-changer. You must be just as bold—and calculating—as you make the technology choices that will define your supply chain capabilities. Your margins for error aren't much bigger than Vonn's.

Now, a little backstory to stress why you should read on. In August 2008, the U.S. ski team trained in New Zealand. Skiing slalom next to Olympic gold medalist Ted Ligety in super icy conditions, Vonn couldn't get a grip. She was sliding all over. Conversely, Ligety was crushing it. In typical Vonn style, she asked, "What are you using?" and then, "Can I try them?" Baffled, Ligety replied, "They're men's skis." Minutes later, on Ligety's skis, Vonn carved through the gates effortlessly. Her take: "It was the easiest slalom I'd ever had. They were so much faster."

What happened next? At Levi, Finland, the season's first World Cup slalom, Vonn put the men's skis to the test—and won! Three weeks later, Vonn won downhill at Lake Louis. Vonn recalls that rumors quickly spread that she was testing men's skis. Rivals thought, "She's insane. … She'll never be able to make the turns." As Vonn racked up wins, the chatter changed to "Wow!" You can guess what happened. Other women tried to make a go on men's skis. They couldn't, however, make the turns.

Can you relate? Do you operate in an intensely competitive industry, where rivals monitor and copy each other's tech investments? In our 30 years' experience working with SC leaders, we've frequently met managers who lamented: "Our industry's technology arms race is keeping me awake at night." Their anxiety: We can't afford to fight tomorrow's competitive battles with yesterday's technology. The perceived need to keep pace has led many companies, like Vonn's rivals, to invest in tech that just didn't work for them.

The timing of Vonn's technology shift may also resonate. Hit hard by the 2008-2009 financial crash, Rossignol, Vonn's sponsor, cut one-third of its global staff and slashed skiers' salaries 50%. This economic threat spurred Vonn to find a better ski. This too may feel familiar. Economic pain has rocked most industries, forcing decision makers to rethink their companies' value-creation capabilities. The go-to response: Turn to tech for a solution.

With Vonn on the market for a new ski and a new sponsor, Head Sports GmbH made a calculated play. Head's CEO, Johan Eliasch, met with Vonn to seal the deal. His pitch: "I have a technician for you." Knowing Vonn valued talent—and teamwork—he offered Bode Miller's "ski man," Heinz Hämmerle. Vonn couldn't resist. No technician on the slopes could get more out of a pair of skis than Magic Heinzi, as Vonn called him. With the right skis and the right team, Vonn was ready to chase Alpine skiing greatness.

Vonn's realities likely parallel yours. You both face fierce rivals intent to keep you off the podium. And you both rely on technology to stay in the mix.

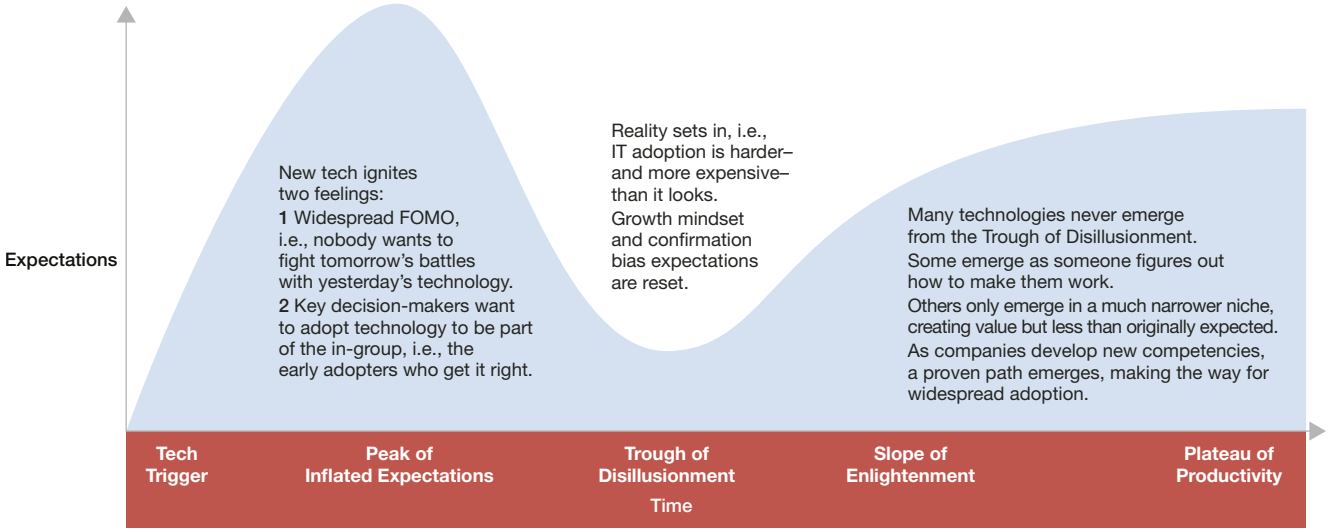
Vonn, however, made sure her approach to tech elevated her preparation and delivered remarkable results—likely two of your goals. Vonn's secret: She recognized that tech either distracts or enables. By being deliberate and disciplined, she made tech work for her. Her approach follows six principles that define the fall line to successful technology adoption. Before we explore Vonn's approach, let's consider why so many companies crash out on the slippery slope of technology.

It's harder than it looks

Think back to your first ski trip, that is, if you didn't grow up on skis. Friends had perhaps hyped their exploits on the slopes, igniting your sense of missing out—and your desire to belong. No doubt, if you had watched skiing on TV, you had sensed skiing's adrenaline rush and were even more psyched to strap on skis and whoosh down a mountain. Experienced skiers make it look so easy. You may have even thought: "I'm a good athlete, I can do this."

FIGURE 1

The Hype Cycle



Stage	Definition	RFID Example
Innovation Trigger	A technology "breakthrough" triggers market interest. Media coverage creates buzz. FOMO drives adoption.	As the 2000s began, pundits hyped RFID as the tech for "total visibility." Media amplified the noise, touting it as the "better barcode." Quick, and relatively easy, rollout was expected.
Peak of Inflated Expectations	Early publicity amps the hype, which is fed by a few success stories. Failures, which are more common, tend to be ignored.	In June 2003, Walmart mandated its Top 100 suppliers launch RFID by 2005. By 2006, all suppliers would be included. The DoD followed suit in October with the same timeline. Pundits proclaimed the "RFID Revolution."
Trough of Disillusionment	As implementations don't deliver the desired ROI, interest wanes.	By 2007, Walmart rescinded its mandate, citing high costs and tech readiness. The DoD delayed its initiative. Some called RFID a "solution in search of a problem," noting: "RFID's promise unfulfilled."
Slope of Enlightenment	Someone figures out the path to commercial success, defining a proven path and renewing interest in the technology.	In 2014, a WSJ headline read, "Zara Builds Its Business Around RFID." The article claimed that Zara had "learned from others' mistakes." By 2015, the cost per tag was down 90% (from 50-75 cents to 3-8 cents). Other retailers soon followed.
Plateau of Productivity	Adoption goes mainstream. Companies that hold back risk being left behind.	By 2020, Walmart had launched a new mandate for all apparel suppliers (toys and home goods followed in 2022, other categories in 2025). With costs per tag down to 2-3 cents, pundits reveled, "RFID: A gamechanger for retail."

Source: Authors

TABLE 2

Avoid the technology detours

Technology detour	Description
Technology as a Silver Bullet	Many managers shop for tech as a silver bullet. They find it easier to buy tech than to fix cultures or re-design underperforming process.
Follow-the-Leader Mentality	Trying to avoid being out-gunned in a tech arms race makes it easy to play defense and invest in the tech "everyone" is buying.
Shiny-Hardware Syndrome	Don't get caught up in the quest to own the latest "shiny" hardware (or software). Buy the tech you need to get the job done.
Island of Automation	Don't invest in cool tech that simply shifts a bottleneck. Ask, "How will this investment improve the entire value-added system?"

Source: Authors

Now, what was your reality? When you stepped off the lift for your first run, did you—like most first-timers—spend more time picking yourself up off the slopes than whooshing down them? Perhaps you've tried to forget this part of the story. Now, the good news, science is starting to grasp why there's a gap between the aspirations you had and the outcomes you experienced.

The explanation starts with the concept of a growth mindset—the mentality that gives us confidence we can do new things. When our growth mindset is hijacked by lack of perspective, we fail to appreciate the experts' depth of skill. We underestimate the effort, and often painful learning, they invested to make "it" look easy. Confirmation bias further distorts our perspective, telling us, "I've done hard things before. I've got this."

Here's the catch. We don't know what we don't know. And our brain remembers past positive outcomes more vividly than the difficult journey required to achieve them. Reality ultimately restores perspective and resets expectations. Now, a question: Does this pattern sound familiar? It should. In the SC technology world, we describe this path as the Hype Cycle.

What's your takeaway? If you jump on new tech out of the starting gate, you will likely struggle. Check out Figure 2, which shows popular technologies of the past 40 years that tracked to the Hype Cycle. Early adopters chased elusive benefits, burning resources—both time and money. They seldom emerged first on the slope of enlightenment. Chasing the Hype Cycle is as expensive as it is ineffective. Our five yard-sale stories illustrate the costs of "sloppy" technology adoption. Vonn's deliberate, disciplined approach models how you can avoid riding the peak of inflated expectations only to get stuck in the trough of disillusionment.

A proven path to the technology podium

Vonn's deliberate, disciplined approach to technology is as unique as she is, largely because it emerged from her world view. Consider three traits.

1. An adrenaline junkie, Vonn loved ripping down mountains at 85 mph. She often said, "Adrenaline is something I feed off of; I need it. I love it. It's what gets me going. I need a challenge, something to push me."
2. Gritty—and fearless—Vonn hated to lose and was willing to pay a steep price to win. She trained harder than anyone and endured painful rehabs to get back on the slopes.
3. As an eyes-wide-open scanner, Vonn was an all-of-the-above tinkerer. If anything—from tech to training—could enable her quest for success, she was willing to check it out. One outcome: No woman on the World Cup circuit paid more attention to her equipment than Vonn.

Your takeaway: Vonn possessed a singular focus, i.e., she knew what she wanted: To push her limits to go faster. And although she was open to out-of-the-box thinking, she didn't buy into technology silver bullets. Her proven path focused on process and preparation.

Gate #1: DO approach technology as an enabler

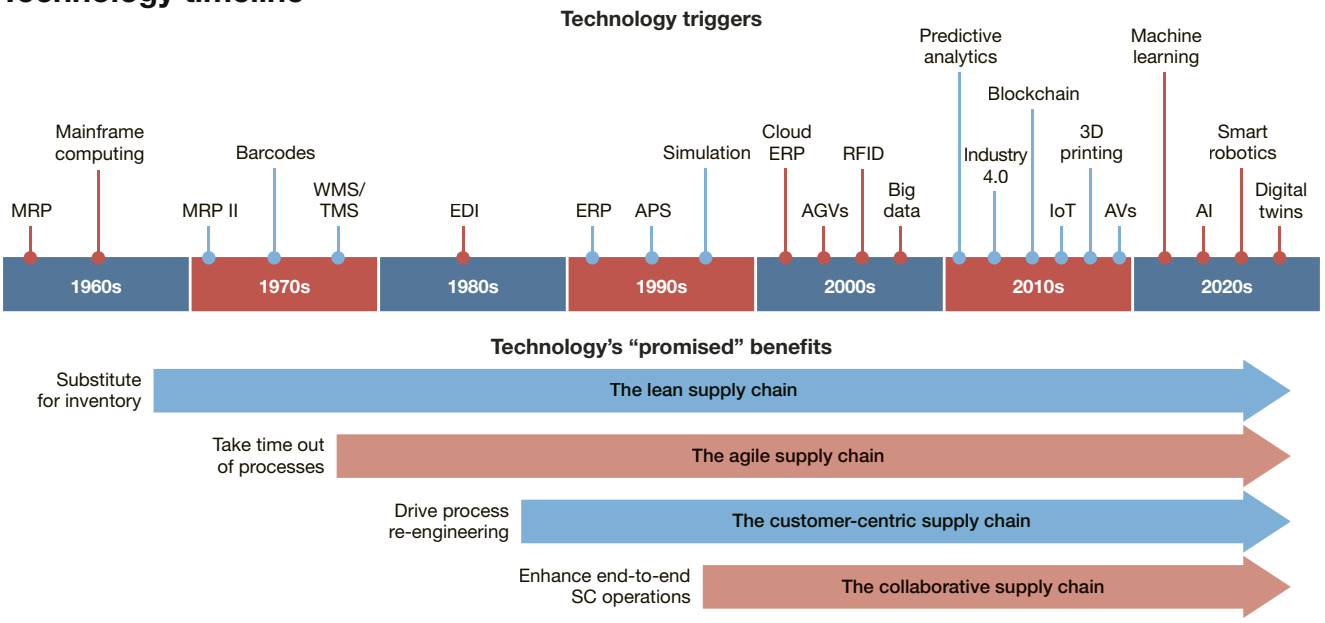
Vonn—known for fast, powerful starts out of the gate—described her state of mind in the gate as automatized, i.e., calm and in the moment. In those brief moments Vonn could …

"… see the entire course spilling out in front of me. I anticipated exactly what I'd have to do five, ten, twenty gates down the mountain, while remaining focused on the gate that was right in front of me. That was always my approach … It helped me stay in the moment and made the impossible feel possible."

Being in the moment didn't just happen. It was the result of hours of brutal gym work, a careful course

FIGURE 2

Technology timeline



Classic technology yard sales

Hershey ERP
A failed launch, coinciding with Halloween and Christmas caused missed shipments. Hershey lost over $100 million, leading to a 19% drop in quarterly profits, and an 8% drop in stock price.

Nike APS
To digitally transform its global supply chain, Nike launched i2's APS system in 1999. The system was a poor fit for Nike's complex supply chain, leading to stockouts and overstocks. Losses topped $100 million. The stock price dropped 22%.

Walmart RFID
In 2003, Walmart overtly mandated its top 100 suppliers adopt RFID. By 2007, Walmart quietly pulled back the mandate because high tag costs and technical issues made RFID infeasible–and too expensive.

IBM/Maersk blockchain
In 2016, IBM partnered with Maersk to develop TradeLens, a blockchain-enabled digital trade platform. TradeLens never caught. Lagging adoption in the SC ecosystem led IBM/Maersk to pull the plug in 2022.

Google AI
To compete with OpenAI, Google released Gemini AI in February 2024. Social media posts quickly reported Gemini created politically correct but absurd images that mis-assigned gender and race. By the end of the month, Google paused Genimi for retraining.

Source: Authors

analysis, prepping the right skis, and visualizing the course "a thousand times in my head." Vonn leveraged technology, but only as an enabler. Tech was a small but vital part of her holistic preparation, not the driver of her strategy.

Many companies slip up, letting tech take over. Thibault Boldin, Heineken's chief transformation officer, commented on this lapse, saying, "most companies manage transformation as a tech project." One result: Digital transformations suffer a huge failure rate—north of 70% according to McKinsey.

Heineken's European operations redesign succeeded because Boldin stayed deliberate. He trusted a holistic process to ensure tech-enabled core goals: Harmonizing and leveraging network operations, simplifying product and packaging complexity, and reducing Heineken's carbon footprint. Consider how his "heads, hearts, and hands" approach enabled strategy.

- **Heads:** Address the questions in people's heads, i.e., the whys driving the change.
- **Hearts:** Engage people in the transformation and incorporate their feedback.
- **Hands:** Stay focused on capabilities, both the ones you are building and the ones your people possess so they can support the end processes.

You might think this approach constrained the tech tools Heineken used. It didn't. Heineken employed all of today's hot tech—AI, big data, digital twins, and robotics—to get to targeted outcomes. Ultimately, Heineken went from 25 planning teams to one, reduced

bottle types and packaging 50%, and cut carbon emissions 24% (compared to 2018).

Gate #2: DON'T forget the 3 Ps

Vonn was a tech enthusiast. She relied on tech to give her an edge in training—in the gym, on the slope, and in her after-action analyses—during races, and ultimately to rebuild the knee that forced her retirement. She knew, however, that tech couldn't make up for a lack of preparation, which she grounded in the 3Ps.

- **People.** The first P started with Vonn. Per Lunstam, Red Bull's director of athlete performance, described Vonn as relentless, "looking behind every door, every rock" for ways to go faster. He described her as "so in tune with her equipment, with her own body, with preparation."

Vonn's team prepared like she did. She lauded Magic Heinzi who "tuned her skis for hours on end" and Lindsay Winninger who "helped me get back from all my injuries." Her point: "The team is everything." Each team member leveraged tech to enhance Vonn's preparation.

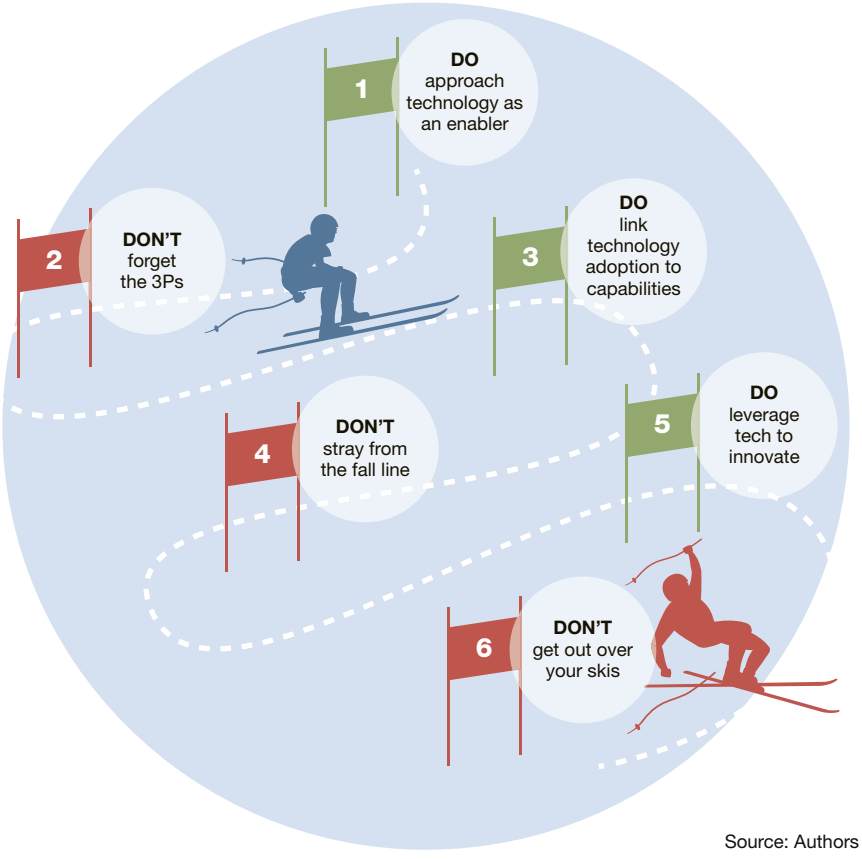
- **Process.** Vonn lived the Vonn way—"on the slopes and off." Employing tech to gain an edge in every aspect of preparation was part of the Vonn way.
- **Performance measurement.** Consider this Vonnism: "To get to the next level, what is there I can change?" Vonn drove change via measurement, using the latest tech the Red Bull High Performance Center offered or going old school, taking notes on the feel of her skis. She was the rare skier who watched film of her crashes, always looking for a way to improve. The bottom line: Vonn got tech right by making the 3Ps part of the Vonn way.

To improve the performance of the Xbox production process, Microsoft turned to digital transformation. To gain engineers' buy-in, Jerry Knoben, corporate VP of manufacturing and supply chain, turned to the 3Ps.

- **Process & performance measurement.** Stage 1 involved building control towers to create visibility into how key processes really worked. A year of data collection and discovery led to dashboards that displayed "everything we cared about" from suppliers to shipping. Here's the key: The team repeatedly asked, "What's the vital data to hit our key KPIs?"
- **People.** Stages 2 and 3 built out predictive analytic and machine learning capabilities. Here's the key: As the AI system's training progressed, it shared alerts. For example: "Yesterday, when this occurred, you did this. Maybe you should do the same." Over time, the AI earned the engineers' trust. They turned routine quality problems over to AI so they could focus on "bigger" things—a big deal in a setting where "you get yelled at for cost problems but fired for bad quality." Staying focused on the 3Ps helps you

FIGURE 3

Deliberate do's and disciplined don'ts of the proven path



Source: Authors

build momentum in the technology arms race.

Gate #3: DO link technology adoption to capabilities

From a young age, Vonn was fast. She attacked the fall line, the straightest route to the finish, and aggressively leaned into her turns. Two realizations transformed Vonn's love of speed into a deliberate, disciplined quest for speed.

1. **Losing didn't feel good.** Vonn discovered that "if I wasn't winning, I didn't like the feeling." Vonn decided to figure out how to avoid that feeling in the future.
2. **She could find a way.** As she watched U.S. ski team rivals on the slopes, Vonn realized, "I couldn't will anyone else to go slower … but I could find the ways to make myself faster."

Vonn resolved to do "whatever I needed to, all in service of being fast." And she did, targeting each investment to enhance her ability to go fast. She viewed risks the same way, saying, "taking risks became second nature—as long as the risks I took could make me faster."

Walmart is equally capabilities-driven. In the 1990s, Walmart relied on a technology-capabilities map to evaluate tech investments. Desired capabilities appeared across the top, potential technologies on the left. Tech that didn't enable critical capabilities didn't make the cut. Today, Walmart is putting tech to the test via its digital transformation. The goal: Leverage EDLP, enhance the customer experience, and enable faster omnichannel delivery. Consider how Walmart is investing to become a legitimate threat to Amazon's online dominance.

- Walmart developed Walmart Global Tech to modernize its website, build a next-gen search engine, and create mobile apps.
- Walmart partnered with Microsoft to use the tech company's AI, cloud, IoT, and machine learning solutions to enhance forecasting, product placement, and the shopping experience.
- Walmart leveraged its 4,600 stores to enable customers to buy online, pick up in store, a big deal as over 90% of U.S. consumers live within 10 minutes of a Walmart store.
- Walmart launched Walmart+ and InHome to make home delivery attractive. Same-day deliveries can be made to over 93% of U.S. addresses.
- Walmart invested in micro-fulfillment centers as well as Spark, a home delivery service, to make home delivery convenient. Ninety-five percent of orders can be picked in 12 minutes.

The result: Post-pandemic, Walmart has doubled its share of U.S. e-commerce sales. David Guggina, EVP supply chain operations, argues that digitization has enabled the retailer to "meet customers where they want to be met." Amazon is now playing catch-up.

Gate #4: DON'T stray from the fall line

By linking technology—and everything else she did—to her quest for speed, Vonn made it easier to set priorities and avoid distractions. Her decision rule: "If something wasn't going to bring me success on the slopes, then I ought not to be doing it."

Many SC decision makers have yet to figure this out. They get distracted by technology detours (see Table 2) and stray from the technology-adoption fall line. Zara is an exception. In the early 2000s, Xan Salgado Badás, head of IT, had a decision to make: Replace Zara's existing (and quite old) DOS-based

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Island of Automation	Don't invest in cool tech that simply shifts a bottleneck. Ask, "How will this investment improve the entire value-added system?"

Source: Authors

point-of-sales (POS) terminals with a modern POS platform, or not. Salgado and his team very deliberately weighed the pros and cons before sticking with the DOS-based system. Why, you ask? The old system worked, supporting exceptional store growth. More critically, the new POS platforms didn't provide any new and needed capabilities.

You may think Zara is a tech laggard. That's not the case. In the early 2010s, Zara cracked the code for using RFID to better manage inventory. Having learned from others' mistakes, Zara put the RFID chip inside the security tags it attached to each item, allowing for reuse. Zara could better find the items customers wanted and reduced by 90% the time needed to conduct a storewide inventory count. More frequent counts provided a more accurate view of fashion trends. Zara is now in the midst of an AI-enabled digital transformation, building out its omnichannel capabilities— and being disciplined enough to stick to the tech fall line.

Gate #5: DO leverage tech to innovate

Seeking efficiency through tech was a part of Vonn's routine. After each run, for example, Magic Heinzi asked, "Does it ski fast? Does it turn well? Do I like it? Do I not like it?" The goal: Make the small changes that make a difference in performance. Heinz did more than use the information to tune Vonn's skis. He also took more substantive insights to the engineers at the Head factory, who tweaked the construction or design of Vonn's ski.

Vonn also pursued radical innovation. Her switch to men's skis typifies her willingness to do "whatever it took for me to be the best, even when it meant doing things differently." Earlier in her career, she brought ultrahigh-speed, high-definition video to skiing. Her goal: Evaluate the interplay between her equipment and snow conditions. And in 2024, she became the first Alpine racer to ski on a titanium knee, a game-changer that enabled her to become the oldest woman to reach a World Cup podium. Vonn never stopped leveraging tech to innovate. She always sought a "way to be better and faster."

IKEA shares the same mindset, i.e., seek efficiencies while pursuing innovation. Check out the AI across IKEA's fulfillment processes. AI algorithms enhance IKEA's online media, automate warehousing and distribution, forecast demand and optimize inventory to get the right SKUs in stock in the store while minimizing overstocks, and streamline the checkout process. Efficiencies earned stack up, keeping IKEA in the retail race. BCG, for instance, estimates that AI-enablement delivers a 15% reduction in inventory costs and a 30% increase in service levels.

But IKEA is pushing its, and AI's, limits to create an online shopping experience just as immersive and memorable as visiting one of its labyrinthine stores. Picture this. You snap a few photos, upload them to IKEA's Kreativ app (launched in 2024) and voila, in a few brief moments, you get a 3D model of your room, i.e., a virtual showroom. Using LiDar, AI, and VR, Kreativ enables you to pick and place IKEA's modern pieces in your own living space. You can play with options until you get just the right look and feel—and share them with friends to get their take. The result: Online sales reached 26% in 2024, and product returns dropped 20%.

Gate #6: DON'T get out over your skis

Google "Lindsey Vonn quotes." You'll find one that stands as a warning: "You have to push limits in order to find your limits." Vonn spent her career trying to get as close as humanly possible to her limits. Sometimes she pushed too hard, and crashed—this despite hours and hours invested in testing her equipment, taking notes, and working with Magic Heinzi to make sure any needed fixes were made.

Vonn would argue: "I know the risks, I accept the risks, but I'm not afraid of the risks." She would likewise acknowledge that pushing the limits was "possibly the biggest downfall in my career." Injuries caused her to miss major portions of four World Cup seasons and forced her to retire in 2019. Of course, pushing the limits, combined with her personal grit and intense preparation, is what made Vonn arguably the greatest downhill skier ever.

Domino's has pushed technology's limits to enable you to order how you want, wherever you are (almost). The goal: Redefine convenience to dominate delivery. Consider your options.

1. **AnyWare ordering.** You order via app, smart TV, voice assistant, social media, or your favorite wearable. And you can stay connected via real-time tracking and "Points for Pies."
2. **Carside delivery.** You order and pay online. When you arrive, you sign in and a Domino's employee will deliver to your car in fewer than two minutes, or your next pizza is free.
3. **Pinpoint delivery.** You pick the place, say a park bench or a beach, you open the app and drop a pin, and your pizza will be delivered to you, wherever you are (almost).

The result: Domino's has passed Pizza Hut to become the largest, fastest-growing, and most profitable major pizza chain in the world—and 85% of orders are made digitally.

Here's what's remarkable: From launch, each innovation just works, seamlessly. And you've never heard about a Domino's yard sale. Why not? According to Kelly Garcia, Domino's chief technology officer, Domino's makes its tech stackable, like Legos—and a "fail-fast" culture with extensive testing done early identifies the ideas that will likely work, and those that won't. Garcia notes that testing "takes the emotion out of it. We let the data speak." Because Domino's is disciplined enough to not get out over its skis, you may see robots and autonomous delivery soon, two ideas Domino's is testing today.

Conclusion

Now, a warning: The six gates will help you get IT right, but they aren't foolproof. Vonn says crashes are inevitable, "part of the job description." What do the six gates do? They help you mitigate risks as they guide your quest to use tech as a game changer.

One final thought: When you crash, get up, and get back in the race. Walmart, a highly successful tech adopter going back 40 years, popularized crossdocking in the 1980s, but crashed out with RFID in the early 2000s. Walmart didn't back away from tech, but stuck to the deliberate Do's and disciplined Don'ts. The result: Walmart rewrote the rules for omnichannel retailing.

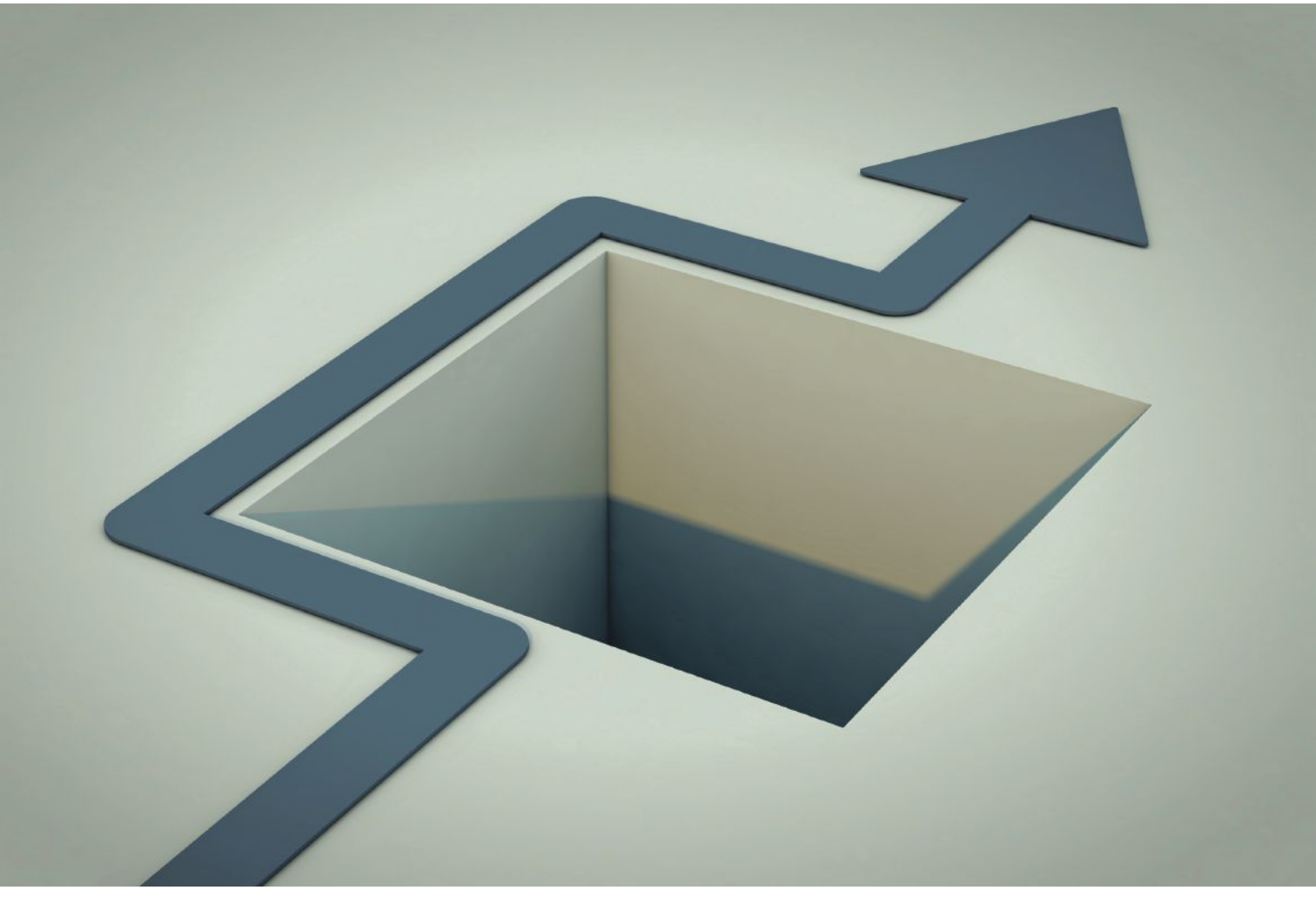
If you are going to push the limits, "scratching and clawing to get to the finish," Vonn offers a hint: You need to "have a short-term memory." That's the nature of technology's slippery slope. •

Prioritizing risk using structural simulation for complex global supply chains

By Greg Schlegel, Jim de Vries, and J. Chris White

Disruptions in your supply chain can hurt your business, but not all disruptions are the same. Structural modeling offers an opportunity to evaluate the types and locations of possible disruptions, and determine the proper approach to mitigate the risks.

Since the pandemic it has become readily apparent that our global supply chains are very complex, and in some cases, very brittle. The pandemic exposed these flaws and attracted the attention of C-suites and boards very quickly. Unfortunately, many organizations' supply chains were too brittle and could not adapt to the largest imbalance of demand and supply in over 50 years. This is historically coined the bullwhip effect. Post-pandemic, more and more disruptions to global supply chains continue to plague companies. Consequently, the importance of some suppliers in the overall supply chain is beginning to emerge, one of which is the nexus supplier. This article looks at the role of nexus suppliers and offers simulation-based results of a hypothetical, yet realistic, set of scenarios to guide companies as they continue to operate their supply chains in the VUCA (volatility, uncertainty, complexity, ambiguity) world in which we now find ourselves.



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Jim de Vries *is the founder and managing partner of Enhance International Group (EIG), a global management and marketing consulting firm focused on delivering practical and transformational solutions to help organizations work smarter and faster. He is a senior-level executive with over 35 years of experience in Lean Six Sigma, supply chain risk and resiliency, operational excellence, program management, digital transformation, and strategic planning across a wide range of industries including energy, manufacturing, logistics, and consumer goods. De Vries holds a BS in mechanical engineering with a minor in physics from the University of Dayton.*

J. Chris White *is the co-founder & CEO of scmBLOX, a software development and consulting company aimed at improving planning and operations for organizations, especially in the domain of supply chain management. He is a senior-level executive with over 30 years of experience in Lean, Six Sigma, supply chain management, program management, modeling/simulation, organizational design, leadership development, and strategic planning within both government and commercial organizations.*

There are many definitions and perspectives on nexus suppliers. One that is referenced often by academicians is "any supplier in a multi-tiered supply network that potentially exerts a profound impact due to its network position" (Yan et al., 2015, p. 53). Yan et al. go on to say that a "supplier a few tiers removed can be a critical supplier to a focal buying firm based on how it is connected in the extended supply network." For nexus suppliers, the structural embeddedness (i.e., which firms the supplier is connected to and how these firms operate in broader networks) has a major impact on the supply chain (Choi & Kim, 2008). Furthermore, Namdar et al. (2024) discuss the impact of disruptions in supply chains, specifically how disruptions cascade or ripple through supply chains. Combine the two concepts of cascading disruptions and nexus suppliers and we have a formula for potentially disastrous impacts on supply chains. Along those lines, Namdar et al. (2024) were able to show the devastating operational impact of disruptions at nexus suppliers.

Structural modeling approach

Due to the structural nature of the concept of nexus suppliers, we use a structural modeling approach in our simulation scenarios. A structural modeling approach differs from the traditional statistical and network modeling approaches as it relates to supply chains in several ways. Structural modeling has the following three major benefits.

1. The structural modeling approach focuses on the activities and operations that occur in the supply chain. Data is used to calibrate and enhance the structural model, but data are not necessary to build the structural model. Structural models are activity-oriented. Conversely, the statistical modeling approach focuses on data related to the supply chain and treats the activities and operations of the supply chain as a black box that we cannot look into. For statistical models, data is foundational because the statistical model is a data-oriented model. No data, no model. Network models, such as the one used by Namdar et al. (2024), focus on connections of nodes, where the nodes and the connections may have properties associated with them. Like statistical models, network models do not focus on activities and operations like structural models. As with statistical models, data related to nodes and connections may not be available. Because data is not required to build the structural model, structural modeling can provide scenario analysis capabilities when data is not readily available or easy to obtain.

2. The structural modeling approach is more realistic when projecting or forecasting far into the future (i.e., months, years). Structural models include feedback mechanisms that control how entities in the supply chain act, react, and respond to various things happening in the supply chain. Consequently, as conditions change throughout the supply chain (e.g., orders drastically change, deliveries are disrupted), the feedback mechanisms in a structural model can show how the supply chain as a system is capable of adapting or recovering. On the other hand, statistical models and network models are direct calculations of future results. Thus, these types of models have no ability to incorporate the feedback associated with adaptations and responses from various entities in the supply chain as conditions change over time. In essence, statistical models and network models are static, not dynamic. With the ability to model dynamic, changing conditions and the responses of companies in the supply chain to those changing conditions, structural modeling is a powerful method for conducting long-range, strategic what-if scenarios.

3. Structural models can accommodate new situations and conditions that have never occurred previously. Because structural models include activities and operations, structural models can show how entities in a supply chain act or react to different conditions in the supply chain. Typically, these are set as policies for the entities in the supply chain. Similar to Agentic AI, these policies guide the decisions and actions of the entities in the structural model. Statistical models cannot accommodate new situations or conditions. Because statistical models rely completely on data, if there is no data for the situation (i.e., because it is new and has not been experienced previously) then there is no data to build the statistical model. Statistical models are excellent predictors in stable or consistent conditions, but their

reliance on data makes them ill-suited for looking at major changes in supply chains such as disruptions or shipping delays. Network models can look at different configurations of the network nodes and connections, but this is a static view with no ability to show how the network may change and adapt to move from one configuration to another. In many cases today in our VUCA environment, structural modeling proves to be more effective because it can accommodate these disruptions or other major changes in the supply chain that have never been seen or experienced before.

Simulation scenarios

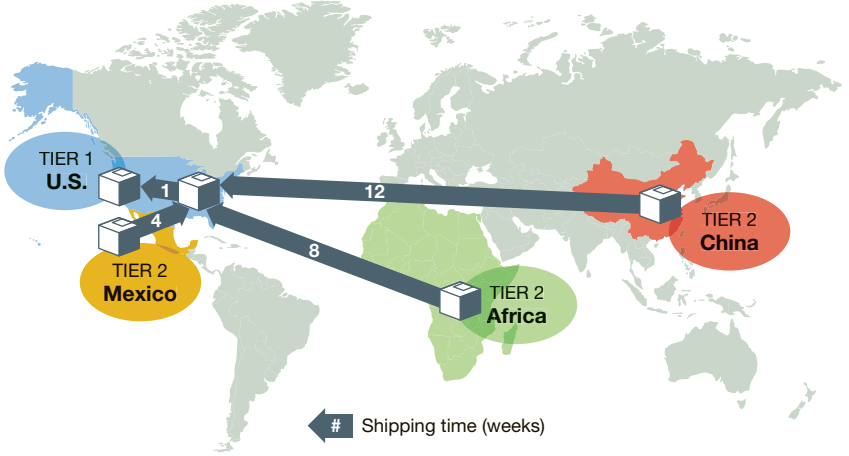
Figure 1 provides the backdrop for a hypothetical supply chain that may experience disruptions with key nexus suppliers. In Figure 1, the primary OEM (original equipment manufacturer) resides in the U.S., represented by the black box in the upper left of the figure. This OEM has a Tier 1 supplier in the U.S. that has three Tier 2 suppliers scattered in China, Africa, and Mexico. These Tier 2 suppliers each provide a different component that goes into the subsystem at the Tier 1 company. Thus, a component from each Tier 2 supplier is required. These are not three Tier 2 suppliers all providing the same part that would allow shifting orders among the suppliers to mitigate issues. The white numbers seen on the black arrows are the average transportation times in weeks. The Tier 1 can deliver to the OEM in one week. The Tier 2 in Mexico delivers to the Tier 1 in four weeks. The Tier 2 in Africa delivers to the Tier 1 in eight weeks. The Tier 2 in China delivers to the Tier 1 in 12 weeks. Essentially, transportation and shipping times are proportional to the distance from the Tier 2 supplier to the Tier 1 company.

A baseline plus four scenarios was analyzed with the structural modeling approach using a system dynamics-based simulation model. The objective is to show how an OEM is impacted differently by disruptions in the supply chain depending on where the disruptions occur. The five scenarios are the following:

- **Baseline:** Normal operations for all companies. Steady demand at 100 orders/week.
- **Scenario 1:** Same as the baseline, but the U.S.-based Tier 1 supplier shuts down for two months (i.e., experiences a two-month disruption) beginning in Week 25. All other companies operate normally.
- **Scenario 2:** Same as the baseline, but the Mexico-based Tier 2 supplier shuts down for two months beginning in Week 25. All other companies operate normally.

FIGURE 1

Overview of hypothetical supply chain with nexus suppliers



Source: Authors

- **Scenario 3:** Same as the baseline, but the Africa-based Tier 2 supplier shuts down for two months beginning in Week 25. All other companies operate normally.
- **Scenario 4:** Same as the baseline, but the China-based Tier 2 supplier shuts down for two months beginning in Week 25. All other companies operate normally.

One of the benefits of structural modeling is the ability to conduct experiments much like the scientific method. One variable or condition can be changed while all other variables and conditions remain the same. This isolates any impacts to determine easily which variable or condition is responsible for the impact. For these scenarios, all variables will remain the same except

for the two-month disruption that occurs at the exact same time in the simulation (Week 25), but at a different supplier in each of the scenarios.

To maintain similarity, each company in the supply chain model is the exact same agent model. This agent model has a flow from receiving into a raw material inventory which goes into production to create a finished goods inventory to be used for deliveries to the next entity in the supply chain (or the final customer if this is the OEM). In all scenarios, each company has an inventory policy of holding four weeks of raw material inventory and four weeks of finished goods inventory. At the beginning of the simulation, when the demand is 100 orders/week, this results in 400 units in raw material inventory and 400 units in finished goods inventory, with 100 units/week flowing through receiving, production, and deliveries.

Figure 2 shows the results for the OEM from the five scenarios in a table. The simulation run is two years with a weekly time step, which results in 104 weekly time steps for the simulation. In Figure 2, the baseline scenario with constant demand of 100 orders/week has no high/low spikes in raw material inventory or finished goods inventory, and lead time remains constant at one week with 100% on-time deliveries. Financially, the lowest profit margin ever experienced is 20%, and the total cash available at the end of the 104-week simulation is $120,800 (from a beginning balance of $100,000). All other scenarios results will be compared against this baseline.

Figure 3 through Figure 5 show the results over all the time steps (weeks) of the simulations for the OEM for its raw material inventory, finished goods inventory, and deliveries for all five scenarios. The order of the scenarios is such that the disruption occurs further away with each successive scenario. Yan et al. (2015) showed that disruptions have less of an impact on the operations of an OEM when these disruptions are deeper in the tiers of a supply chain. That is, a disruption at Tier 1 has a worse impact on the OEM than a disruption at Tier 2, and a disruption at Tier 2 has a worse impact on the OEM than a disruption at Tier 3, and so on. The results shown in Figures 3 through 5 replicate those tier-based results. A disruption at the U.S. Tier 1 supplier has a worse impact on the OEM than disruptions at the three Tier 2 suppliers. Furthermore, the simulations in these scenarios also show that the geographical distance can change the impact of a disruption. In this case, a disruption at the Mexico Tier 2 supplier has more of an impact on the OEM than a disruption at the Africa Tier 2 supplier, and a disruption at the Africa Tier 2 supplier has more of an impact on the OEM than a disruption at the China Tier 2 supplier. In essence, the "distance" of the disruption from the OEM in terms of both depth of tiers and geographical

FIGURE 2

Table of final results for OEM for all scenarios

Variable	Baseline	Scenario 1 (US T1 out)	Scenario 2 (MX T2 out)	Scenario 3 (AF T2 out)	Scenario 4 (CH T2 out)
Cash available	$120,800	$44,673	$109,454	$120,617	$121,030
Recovery time to 50% deliveries		13 weeks	4 weeks	2 weeks	
Recovery time to 100% deliveries		15 weeks	6 weeks	3 weeks	
High/low RM inventory spikes		+165% -100%	+75% -99%	+75% -96%	+75% -90%
High/low FG inventory spikes		+0% -100%	+0% -97%	+0 -83%	+0% -48%
Highest orders backlog spike		+1,280%	+345%	+68%	
Longest lead time	1 week	14 weeks	4.5 weeks	2 weeks	1 week
% on-time deliveries	100%	71%	87%	93%	100%
Minimum profit margin	20%	-Infinity	-375%	-11%	-8%

Source: Authors

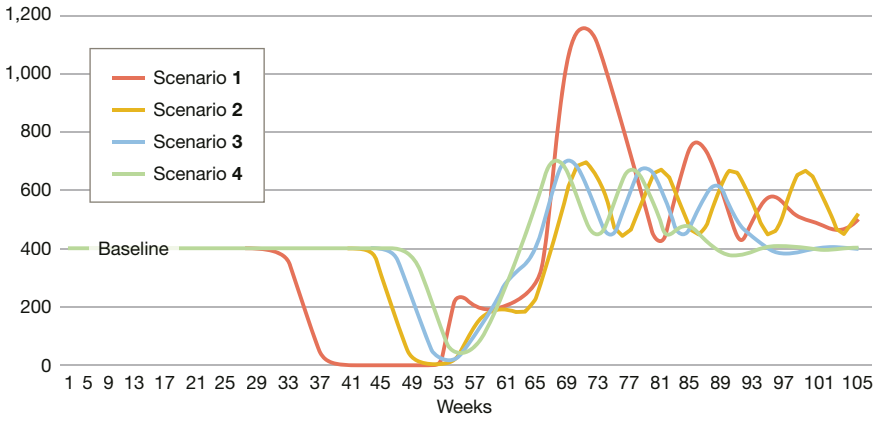
distance impacts how badly the operations at the OEM are affected. The closer the disruption (either in terms of depths of tiers or geographical distance), the worse the impact.

For example, consider the impacts on the raw material inventory of the OEM in Figure 3. For the baseline (solid black line), the *raw material inventory* holds steady at 400 units (i.e., four weeks of inventory based on 100 orders/week). For Scenario 1 with the two-month disruption at Week 25 at the U.S. Tier 1 supplier (red dashed line), notice that the *raw material inventory* drops about eight weeks after the disruption occurs because there are four weeks of finished goods inventory that still get delivered from the Tier 1 to the OEM and the OEM also has four weeks of raw material inventory. After the disruption, the bullwhip impact to the OEM causes a high spike of +165% for its *raw material inventory* (above the baseline value of 400 units), as also indicated in the table in Figure 2.

Without getting into all the details, Figures 3 through 5 show much more volatility to the operations of the OEM when the disruption occurs at the U.S. Tier 1 supplier than when it occurs at the other three Tier 2 suppliers. Furthermore, among the Tier 2 suppliers, the volatility and operational impact to the OEM is worse when the disruption occurs at the Mexico Tier 2 supplier and least when the disruption occurs

FIGURE 3

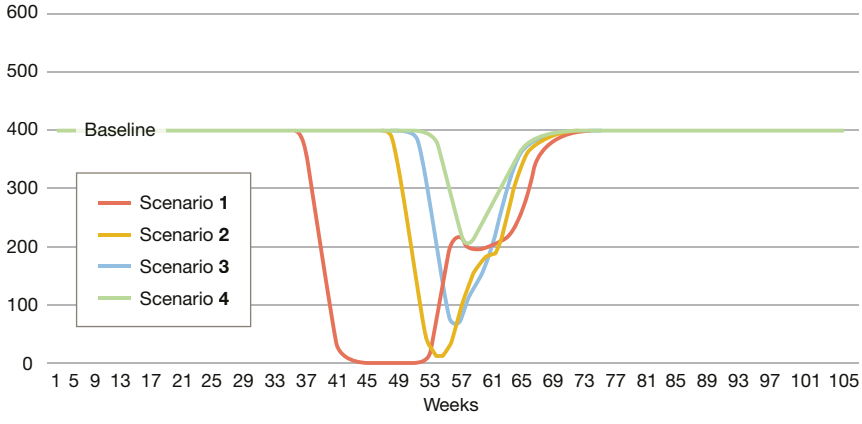
Raw material inventories for OEM for all scenarios



Source: Authors

FIGURE 4

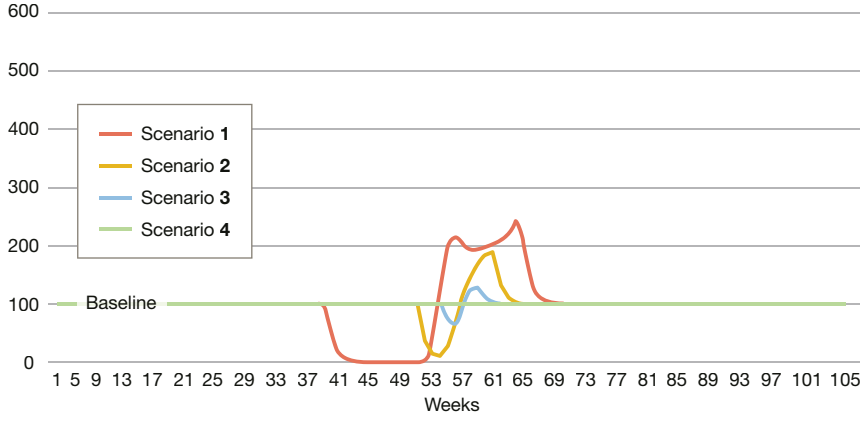
Finished goods inventories for OEM for all scenarios



Source: Authors

FIGURE 5

Deliveries for OEM for all scenarios



Source: Authors

at the China Tier 2 supplier. For the Tier 2 suppliers, there is inventory tied up in the transportation routes. Essentially, the inventory that is in transit serves as buffer inventory that "buys time" for the OEM. The longer the transportation route, the more inventory is tied up and acts as a buffer. For instance, the four-week average transit from the Mexico Tier 2 supplier to the U.S. Tier 1 supplier represents four weeks of additional deliveries to the Tier 1. For the Africa Tier 2 supplier, the eight-week transit time represents eight weeks of additional inventory. And, for the China Tier 2 supplier, the 12-week transit time represents an additional 12 weeks of inventory in the pipeline.

Turning theory into practice: benefits of structural modeling

The results of this simulation effort provide several insights and opportunities for companies.

First, as discussed in the opening section, Namdar et al. (2024) were able to show the devastating operational impact of disruptions at nexus suppliers. The network model used by that team to study the operational impact of disruptions at various suppliers took several months to develop. The structural model used on the project presented here only took several days. In the span of a single week, we replicated the results of the Namdar study. This has serious business and financial implications for companies. The ability to understand the impact of supply chain disruptions quickly means decisions can be made quicker and the impacts of disruptions can be mitigated (or removed) quickly.

Second, our analysis expanded the theory of the impact of disruptions and nexus suppliers. Yan et al. (2015) showed that disruptions have less of an impact on the operations of an OEM when these disruptions are deeper in the tiers of a supply chain. In addition to this behavior, we also showed that disruptions have less of an impact on the operations of an OEM when these disruptions occur at a larger geographical distance from the OEM because in-transit goods essentially represent additional buffer inventory. Consequently, both tier-level and geographical distance can be mitigators of the impacts of disruptions. This geographical distance impact leads to counterintuitive responses to disruptions. It is typically thought that disruptions tend to expand or grow as they propagate from supplier to supplier or over long distances that have transportation delays. Instead, we have demonstrated that the opposite is true. With the focus on redesigning supply chains by nearshoring or reshoring from other countries, especially China, this action may unintentionally intensify operational issues associated with disruptions. There may be other reasons or benefits for nearshoring or reshoring from other countries, but operational impacts may not be one of them. If we add the fact that changing suppliers and setting up new suppliers can take 9-18 months at an approximate cost of $1M-$2M, we may find that there are situations where it is more beneficial to continue to use suppliers in the foreign countries rather than nearshoring or reshoring them.

Third, the results of Namdar et al. (2024) and these simulations show that all disruptions are not created equal. The same disruption (i.e., same magnitude, same duration) can have a different operational impact on the end company (e.g., OEM) depending on where it occurs in the tiers of the supply chain. Thus, when risk reports show potential disruptions at numerous suppliers in a company's supply chain, the company may be able to prioritize those risks based on the "distance" from the OEM, both in terms of depth of tiers and geographical distance. The closer disruptions get attention first, followed by the disruptions that are further away. The structural modeling approach used for the scenarios in this article is paramount to understanding these operational impacts over time from disruptions. As can be seen in the oscillations in the figures presented here, structural models can show how well a supply chain system can respond and recover (i.e., how chaotic the oscillations are) as well as how long it takes for the supply chain system to settle down to its new stable state. In the real world, there are many times when supply chain managers make knee-jerk reactions to the

oscillations they see in orders, inventories, production, etc. Often, these oscillations will naturally settle after some period of time. We can unintentionally exacerbate these oscillations if we are unaware of their calming cycle.

Fourth, the approach used on this project shows how digital twin models can benefit organizations. Using a digital twin model, we can run "scientific experiments" where all variables remain constant except for one variable. Any changes seen in the simulation results can be directly associated with that one variable. This is extremely beneficial because companies can use digital twin models to run hundreds or even thousands of simulations over a very short time period (e.g., days) and learn how every variable in the model has its singular impact on other variables. With that information, variables can be prioritized concerning their ability to mitigate or remove the negative operational impacts of disruptions or other major changes in a supply chain system.

Recommendations for joint future research

Review the impact study by Namdar et al. (2024) of modularity within a supply chain on how disruptions mitigate through the supply chain. Their results are extremely insightful and provide guidance on how to prioritize disruptions. However, their team used a network model, which is static in nature and cannot handle dynamic, adaptive changes that result in a real-world system like a supply chain as companies react and respond to conditions. To extend their research on modularity, we propose conducting similar what-if scenarios using a structural modeling approach like the one presented in this article.

Conclusions

Disruptions in your supply chain can hurt your business, but not all disruptions are the same. Our study shows that where a disruption happens really matters. If the problem is close to you, like at a supplier in your own country or in the first tier, the damage is much worse than if it's farther away or deeper in the supply chain. Surprisingly, longer shipping distances can help because the goods already on the way act like a buffer and give your business more time to adjust.

We used structural modeling, which is a type of digital twin, to run smart simulations that act like scientific experiments. The structural modeling approach is faster and more flexible than traditional statistical and network models. With structural modeling, you can test different scenarios, see how your supply chain reacts, and make better decisions quickly, instead of waiting months.

This approach also shows that quick reactions to disruption data aren't always helpful. Sometimes supply chains settle down on their own. Acting too fast and interfering with that "calming process" can actually make things worse.

In short:

- disruptions closer to home hit harder;
- longer-distance suppliers might give more stability;
- digital twins let you test and prepare before disruptions happen; and
- not every disruption deserves the same level of response.

If you're thinking about reshoring or switching suppliers, you should run these types of structural simulations first. The costs and risks might not be what you expect. •

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To make or buy the supply chain?

By Sangho Chae, Thomas Y. Choi, and Glenn Hoetker

Decisions on how deeply to manage your supply chain require in-depth analysis and discussion, and even mirror classic make-or-buy decisions. The question is: Which approach is correct for your business?

All companies are engaged in outsourcing. They outsource production or service operations, and when they do, they typically rely on their first-tier suppliers to select and manage second-tier suppliers and beyond—what we call deep-tier suppliers. However, cost pressure, high-profile supply disruptions, quality failures, and sustainability scandals caused by deep-tier suppliers have raised concerns about delegating sourcing decisions to the first-tier suppliers.

For example, a Toyota first-tier supplier worked with a semiconductor supplier called Renesas. In 2021, there was a fire at this second-tier supplier. This unfortunate incident amid the global chip shortage forced Toyota to cut production by 40%. The question of whether Toyota should have been more involved in selecting this second-tier supplier arises. Similarly, H&M faced public backlash recently when reports linked its second- and third-tier cotton suppliers in Xinjiang, China, to forced labor. It posed reputational and financial risk for H&M.

Such incidents point out the importance of visibility and control over deep-tier suppliers. However, it is neither practical nor feasible for companies to manage all upstream suppliers directly. This raises a critical question: *How should companies strategically approach the selection and management of deep-tier suppliers?* Many firms tend to react only after supply chain problems happen, often by creating direct relationships with deep-tier suppliers that caused the problem or pressuring first-tier suppliers to switch their suppliers. But these reactive measures are often arbitrary and devoid of a systematic approach.

In our *Journal of Supply Chain Management*

article published in April 2024, we introduced a practical, structured decision-making framework to guide companies on when and how to approach the selection and management of deep tier suppliers. The key insight behind our framework is that decisions regarding the selection and management of second-tier suppliers and beyond (i.e., deep-tier suppliers) mirror the classic make-or-buy decision, but at the supply chain level. When a company delegates the sourcing decision involving subcomponents or sub-services to its first-tier supplier, it is effectively "buying" this first-tier supplier's supply chain. This buying company relies on the first-tier supplier to select and manage the suppliers that lie further upstream. In contrast, when a company takes an active role in selecting or managing certain deep-tier suppliers, it is "making," at least in part, the supply chain by directly shaping supplier choices and oversight. Building on this make-or-buy analogy, we identify three strategic approaches that companies can adopt to govern multi-tier supplier networks: *supply-chain buy, supply-chain make,* and *hybrid* approaches.

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Supply-chain buy

In the supply-chain buy model, a buying company outsources production or service operations to its first-tier suppliers and delegates the selection and management of second-tier suppliers and beyond. The buying company considers this first-tier supplier a one-stop shop. It follows a *hands-off* strategy, where the first-tier supplier is responsible for managing the suppliers that lie beyond the buying company's purview. A well-known example is how global retail brands partner with supply chain management firms like Li & Fung. Li & Fung coordinates sourcing, logistics, and supplier relationships across a vast network of over 15,000 suppliers in 60 countries, allowing brands to concentrate on design, branding, and customer engagement rather than upstream supply chain management.

Supply-chain make

Under the supply-chain make approach, the buyer continues to outsource production or service operations to its first-tier suppliers but retains the right to directly control the selection, contracting, and management of some second-tier suppliers and beyond. The buying company is now looking deeper into the supply chain beyond its first-tier supplier. This strategy follows a more *hands-on* approach, where some deep-tier supplier selection and management decision-making remains centralized in the buying company. Honda and Toyota employ a supply-chain make practice known as directed sourcing, where the company directly contracts with some second- and third-tier suppliers and mandates that the first-tier suppliers work with these designated deep-tier suppliers. Another notable example is Apple's supply chain strategy. While Apple contracts manufacturers like Foxconn for final assembly, it holds on to most of the sourcing decisions at the component level. Apple actively manages relationships with over 180 component suppliers worldwide, ensuring strict compliance with quality, sustainability, and labor standards.

Hybrid approaches

Hybrid approaches distribute responsibility of supply-chain make or buy decisions across the buyer, its first-tier suppliers, and some external stakeholders. The intent is to collaboratively select, manage, and monitor deep-tier suppliers. Companies employing hybrid approaches often implement strategies such as the following.

- Approved vendor lists: Buyers and suppliers share a pre-approved list of deep-tier suppliers to ensure compliance and reliability.
- Collaboration with deep-tier suppliers: Buyers and deep-tier suppliers strategically collaborate to improve coordination, quality standards, and operational efficiency.
- Joint supplier training and risk assessments: Buyers and first-tier suppliers collaborate with non-governmental organizations and monitoring agencies to ensure sustainability, ethical sourcing, and compliance with labor regulations.

An example of a hybrid approach comes from IKEA's sustainability initiative in its cotton textile supply chain. IKEA conducts training and workshops with both first-tier suppliers (cutting and stitching) and deep-tier suppliers (dyeing, weaving, ginning, and farming) to improve social and environmental outcomes. By working across several supply chain tiers, IKEA strengthens supplier capabilities while reinforcing resilience and sustainability commitments. Table 1 summarizes the three approaches to supply-chain make or buy.

Having introduced the three approaches to supply chain make-or-buy decisions, we now present a practical decision-making framework to help companies evaluate the options across supply-chain make, supply-chain buy, or hybrid approaches. The insights are taken from two influential theories from economics and management: transaction cost economics and the capabilities view. We adapt them to the complexities of multi-tier supply chains.

Transaction cost economics, recognized with Nobel Prizes in Economic Sciences in 1991 (Ronald Coase) and 2009 (Oliver Williamson), explains how firms decide between in-house production and outsourcing by assessing transaction costs—the costs associated with managing external exchanges. These include costs for gathering information, negotiating contracts, monitoring suppliers, and managing risks associated with outsourcing. The higher the complexity and uncertainty of an exchange, the greater the costs. If outsourcing reduces overall costs

and improves efficiency, companies often choose external providers. However, when managing suppliers becomes costly and risky, keeping operations in-house may be the better option. Many firms also adopt hybrid approaches, collaborating with suppliers while maintaining partial control through long-term partnership or joint ownership.

Outsourcing decisions also depend on a company's core strengths—some firms outsource activities in which they lack expertise, while others retain certain processes in-house to safeguard their competitive advantage. The capabilities view emphasizes the importance of aligning outsourcing decisions with a company's key competencies. Even if outsourcing incurs higher transaction costs, a firm may still choose this option if the required capabilities for in-house management do not align with its existing expertise. Conversely, if outsourcing appears cost-effective but the activity in question strengthens the company's core competencies, it may be strategically beneficial to keep it in-house. Ultimately, the decision between outsourcing and internal management requires a careful balance between transaction costs and company capabilities to enhance efficiency and maintain competitiveness in supply chain operations.

TABLE 1

Three approaches to supply-chain make or buy

Governance strategy	Description	Control level	Example
SUPPLY-CHAIN BUY	The buyer outsources manufacturing to first-tier suppliers, who then manage the selection and oversight of deep-tier suppliers.	**Low** First-tier supplier handles sourcing and management.	**Li & Fung's customers** Delegates management of supplier networks to Li & Fung.
SUPPLY-CHAIN MAKE	The buyer outsources manufacturing but directly selects and contracts some deep-tier suppliers to ensure quality and compliance.	**High** Buyer retains direct control over deep-tier suppliers.	**Apple** Manages 180+ component suppliers in the deep tier while outsourcing assembly to its first-tier supplier.
HYBRID APPROACHES	The buyer, first-tier suppliers, and third parties collaborate to select and manage lower-tier suppliers.	**Medium** Shared responsibility across multiple stakeholders.	**IKEA** Works with suppliers at multiple tiers to enhance sustainability.

Source: Authors

In the context of the supply-chain make or buy decision-making, sourcing capability becomes the most prominent capability. Sourcing capability is a company's ability to find, evaluate, and work with suppliers effectively. Think of it like a chef selecting ingredients for cooking in a restaurant—it is not just about picking the cheapest option but also about ensuring quality, reliability, and good relationships with suppliers. A company with strong sourcing capability has skilled purchasing managers, clear processes for selecting and working with suppliers, and good communication between different departments. These abilities help the company avoid risks like suppliers delivering poor-quality products or failing to meet deadlines. Over time, businesses develop these capabilities through experience, technical knowledge, and strong supplier partnerships.

One critical risk in managing multi-tier supply chains is opportunism from the first-tier supplier. When a company delegates sourcing decisions to a first-tier supplier, it assumes that the supplier will act in its best interest when selecting and managing deep-tier suppliers. However, if performance evaluation is difficult or information is not fully transparent, the first-tier supplier may take advantage of its position. This could include cutting costs by choosing lower-quality suppliers, misrepresenting costs to increase margins, or neglecting proper oversight of deep-tier suppliers. Such opportunistic behavior can lead to quality issues, compliance failures, and reputational risks for the buying firm. Understanding when and how to mitigate this risk is essential for making informed supply chain governance decisions.

Integrating these premises of transaction cost economics and the capabilities view and extending them into the context of multi-tier supply chain management, we offer the decision-making framework seen in Figure 1.

Consider a supply-chain make approach if:

Your company has invested in specialized assets linked to some deep-tier suppliers.

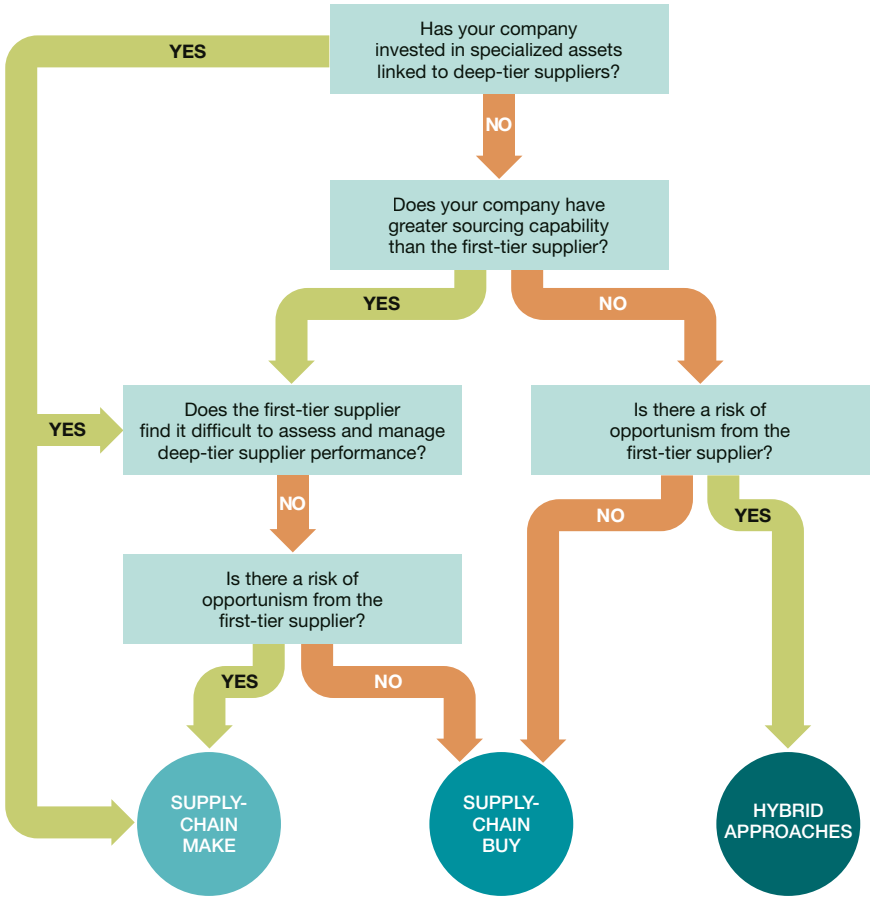
Buyers sometimes invest in specialized assets—such as production equipment and know-how—when working with deep-tier suppliers, especially for key components. These investments develop through direct collaboration, engineering programs, and prior experience. For example, Apple worked with Catcher Technology, a second-tier supplier, to develop the MacBook's aluminum body. Instead of sourcing from Foxconn, which also had aluminum casing production capabilities, Apple remained committed to Catcher due to its prior investments in the supplier's capabilities. This ensured access but also created dependency, leading Apple to manage this second-tier supplier more closely. When a company has made significant investments in a deep-tier supplier, allowing a first-tier supplier to control sourcing decisions poses a risk—the first-tier supplier might replace the specialized supplier. Therefore, companies should consider supply-chain make to mitigate such risk.

Your company has stronger sourcing capabilities than your first-tier supplier, and the first-tier supplier struggles to assess and manage deep-tier supplier performance.

Evaluating a supplier's performance can be complex. While buyers can analyze quality data and conduct inspections, some issues may surface only after further use or processing. Identifying the root cause of defects can be difficult, and suppliers may shift the blame. Moreover, factors like environmental and social compliance are often hard to measure. When deep-tier supplier performance is difficult to track, the risk of hidden quality issues, cost-cutting, or non-compliance increases. If your first-tier supplier struggles to assess certain deep-tier suppliers, but your company has the expertise to do so more effectively, it is best to take direct control. In such cases, a supply-chain make approach ensures greater oversight and reduces risks. For example, Boeing's first-tier supplier, Vought, was making the rear-end fuselage model for its 787 Dreamliner. Vought struggled to manage the deep-tier suppliers that were making components for the module. The problem became aggravated to a point where Boeing had to take a drastic measure by acquiring the Vought operation that was making this module.

FIGURE 1

Decision-making framework for supply-chain make or buy



Source: Authors

There is a risk of opportunism from the first-tier supplier.
The first-tier supplier may exploit its position as the broker between your company and deep-tier suppliers by hiding costs, selecting lower-quality suppliers, or neglecting supplier management. When you suspect this type of behavior from your first-tier supplier, you should first assess your sourcing capability and seriously consider managing deep-tier suppliers directly. For instance, Keyboardio discovered its first-tier supplier had secretly sourced keycaps from a deep-tier supplier using inferior materials, only realizing the issue after months of disputes over quality. In such cases, closer oversight of deep-tier suppliers helps prevent hidden risks and ensures product integrity. If your company has stronger sourcing capabilities than the first-tier supplier and there is a risk of the first-tier supplier acting in its own interest against your company's, supply-chain make approaches can help maintain quality and transparency.

Consider a supply-chain buy approach if:
The first-tier supplier has the capability to assess deep-tier supplier performance, and the risk of opportunism from this supplier is low.
If the final product's quality can readily be assessed, any issues with subcomponents should be traced back to the first-tier supplier, thereby making it accountable for its sourcing decisions. In such cases, the risk of opportunism is low, and your company can comfortably delegate sourcing to the first-tier supplier. For example, when Google partnered with Flex to develop Chromecast, it relied on Flex's sourcing and manufacturing expertise without concerns about supplier mismanagement. Because Chromecast is a relatively simple product, Google had no difficulty assessing Flex's performance and did not need direct control over deep-tier suppliers.
Your first-tier supplier has strong sourcing capabilities, and you can rely on them to manage deep-tier suppliers without risk of opportunism.
When a first-tier supplier has strong sourcing capabilities and can be trusted to manage deep-tier suppliers effectively, delegating sourcing decisions can streamline operations and reduce administrative burdens. A well-established first-tier supplier often has expertise in their particular industry, closer relationships with upstream suppliers, and better negotiation power, allowing it to secure higher-quality components at competitive prices. Your company's direct involvement in deep-tier supplier selection and management may be comparatively inefficient and may even be disruptive. In such cases, a supply-chain buy approach enables your company to focus on core competencies while benefiting from the first-tier supplier's expertise in supplier selection and management.

Consider hybrid approaches if:
Your first-tier supplier has strong sourcing capabilities, but you do not have confidence that they will manage deep-tier suppliers without risk of opportunism.
If you deem your first-tier supplier's sourcing capability to be good, maybe even better than your own, taking full control of indirect transactions may not be the best option. The supplier may be better equipped to manage deep-tier suppliers, negotiate favorable terms, and ensure smooth operations. However, completely handing over these decisions can create challenges, especially when there is uncertainty about the first-tier supplier's transparency or trustworthiness. A hybrid approach can help strike a balance. By working closely with both the first-tier and deep-tier suppliers, your company can benefit from the first-tier supplier's expertise while selectively maintaining oversight to reduce the risk of hidden quality issues or cost-cutting. This collaborative approach allows your company to retain strategic influence without taking on the full burden of managing deep-tier suppliers.

Conclusion

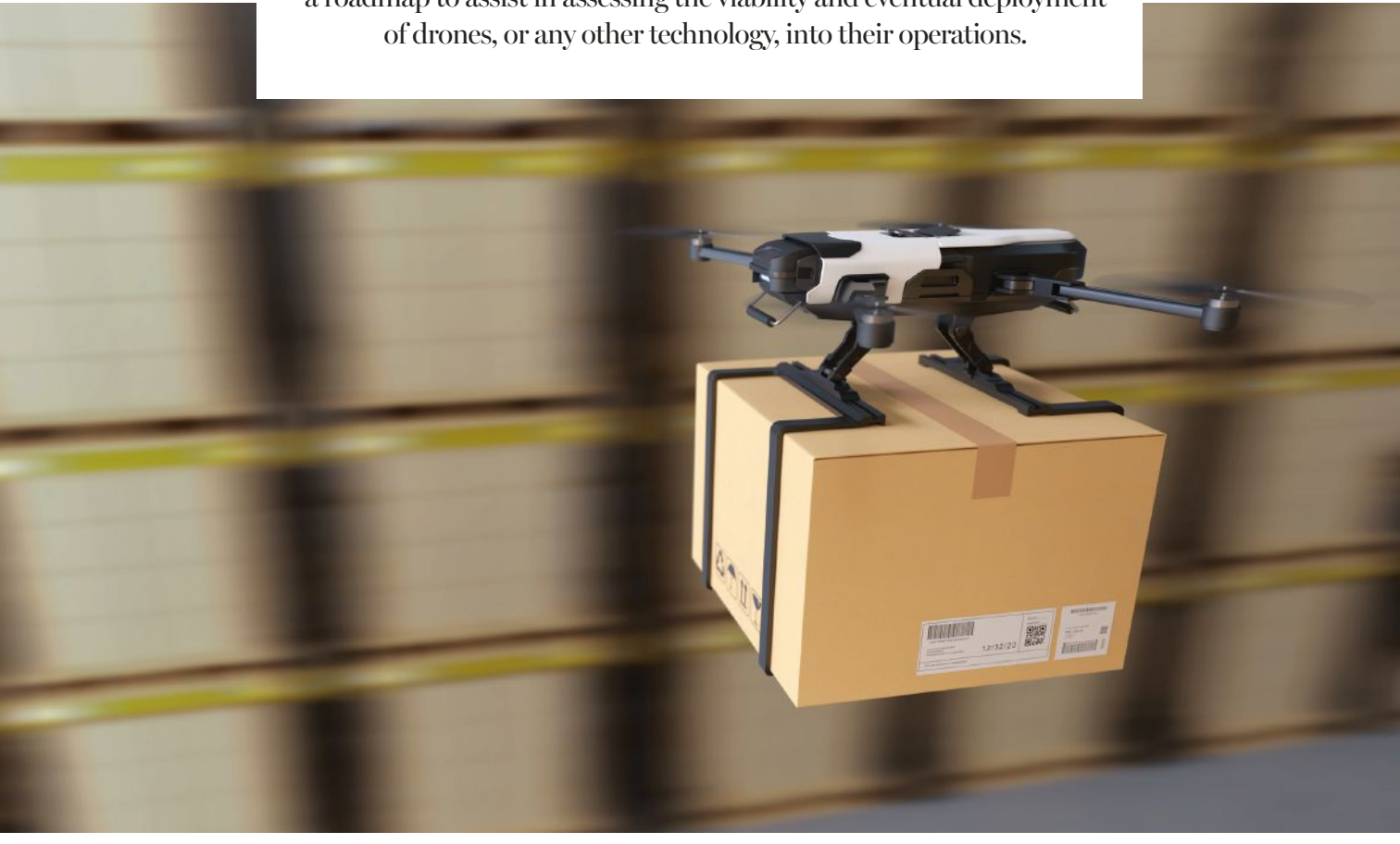
In navigating the complexities of supply chain make-or-buy decisions, companies must carefully balance cost efficiency, risk management, and strategic sourcing capabilities. While a hands-off supply-chain buy approach may offer cost savings and operational simplicity, it can also expose firms to potential supply disruptions, quality failures, and reputational risks. In contrast, a supply-chain make strategy may provide greater control. Still, it demands more investment in supplier oversight. Hybrid approaches may offer a middle ground, enabling firms to collaborate with first-tier and deep-tier suppliers while maintaining flexibility. Ultimately, there is no one-size-fits-all solution. Each company must assess its transaction costs, sourcing capabilities, and strategic priorities to determine the most suitable governance approach. By applying our decision-making framework, as shown in Figure 1, companies can move beyond reactive multi-tier supply chain management and adopt a proactive, structured strategy to enhance resilience, sustainability, and long-term competitiveness. •

FLYING FORWARD:

Lessons learned from drone logistics in healthcare supply chains

By Rishabh Gupta, Vipul Garg, and Ila Manuj

A best-practice framework provides supply chain managers a roadmap to assist in assessing the viability and eventual deployment of drones, or any other technology, into their operations.



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Healthcare supply chains face unique challenges in getting supplies to remote and hard-to-reach areas, particularly due to geographical barriers, poor infrastructure, and frequent stockouts at local healthcare facilities. Traditional transportation methods can prove slow and unreliable, especially when mountainous terrain or adverse weather conditions block road access, delaying access to critical medical supplies. Drones address these challenges by providing faster and more reliable deliveries, significantly reducing response times, and ensuring a continuous supply of essential medicines and vaccines.

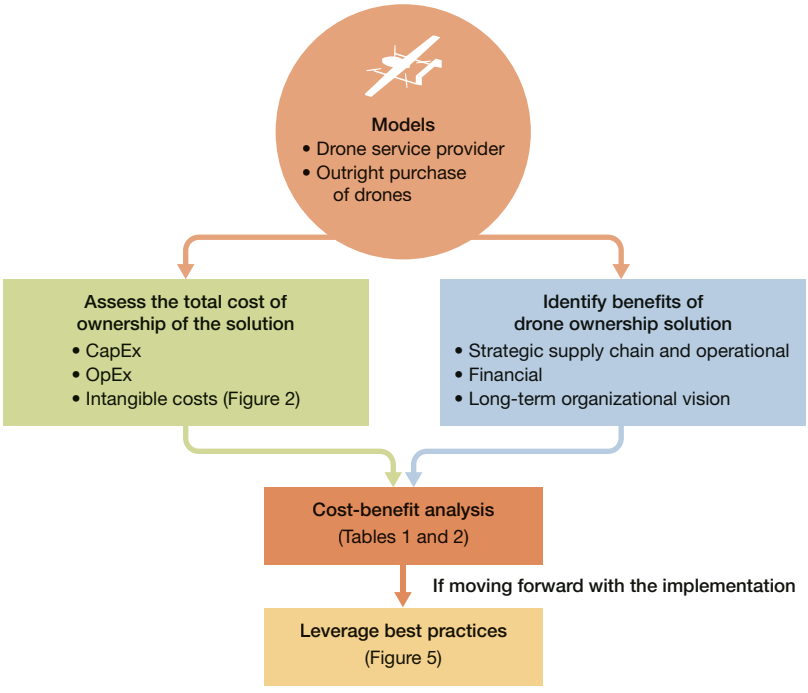
In Kenya, a partnership between the Elton John AIDS Foundation, Zipline, and Kisumu County has successfully used drones to deliver vital medical supplies to remote communities, dramatically cutting delivery times. A drone can cover a 12-kilometer distance in just 20 minutes—compared to up to five hours on foot or an hour by vehicle—demonstrating the life-saving potential of this technology. Similarly, in India, in the state of Arunachal Pradesh, drones have revitalized defunct healthcare facilities and minimized environmental impact by reducing CO_2 emissions without the requirement of extensive road infrastructure (weforum.org/stories/2024/10/india-drone-delivery-healthcare/). While drones are often associated with military applications, their potential to enhance civilian supply chains is undeniable, especially for critical, time-sensitive deliveries.

The global civilian drone market, valued at around $24.98 billion in 2023, is projected to reach $65.49 billion by 2030 (researchandmarkets.com/report/civilian-drone). India's civilian drone market, worth approximately $1.2 billion in 2023, is expected to grow to $4.87 billion by 2030, making up an increasing global market share (blueweaveconsulting.com/report/india-drone-market). While supply chain professionals understand the costs and service implications of traditional modes of transportation, recent research reveals the primary barrier to broader drone adoption is the ambiguity around the financial implications of drone operations (Garg et al., in *Drones in last-mile delivery: A systematic review on efficiency, accessibility, and sustainability, Transportation Research Part D: Transport and Environment*).

Due to the nascent and innovative nature of the industry, there needs to be more knowledge about the process of implementing drones into supply chains and the challenges and best practices related to this process. This article examines drone implementations in healthcare supply chains to extract valuable insights for broader commercial applications. We present a comprehensive framework (see Figure 1) designed

FIGURE 1

Framework for drone adoption



Source: Authors

for supply chain leaders to evaluate the integration of drones, addressing key considerations such as financial and operational costs, potential challenges, and supply chain impacts—including increased flexibility, resilience, and service quality enhancements.

Framework for drone adoption

In evaluating drone integration into supply chains, two primary models emerge: partnering with a drone service provider or purchasing and operating drones outright. In the first, more common model, businesses like Walmart or healthcare facilities collaborate with service providers such as Wing, DroneUp, or Zipline, who manage drone operations from end to end. This partnership model allows companies to adopt drone delivery with minimal upfront investment, as the provider operates out of its own hubs or regional facilities, taking responsibility for logistics, scheduling, and regulatory compliance.

The second model, direct drone ownership, is less common due to the complexity and emerging nature of drone technology. Here, the business purchases drones and works directly with the manufacturer or a third-party integrator. Unlike the service provider model, the customer typically must establish and maintain its own drone hub—a centralized location where drones can take off, land, recharge, and load or unload packages. This hub becomes essential for managing the infrastructure, logistics, and scheduling needed to support efficient drone operations.

In both cases, decision-makers assess the total cost of ownership (TCO), balancing capital expenditure (CapEx) and operational expenditure (OpEx) against the potential benefits drones bring to supply chain efficiency, flexibility, and resilience. By carefully considering the appropriate adoption model and, if necessary, establishing their own drone hubs, businesses can leverage drone technology to enhance service levels and respond dynamically to supply chain demands.

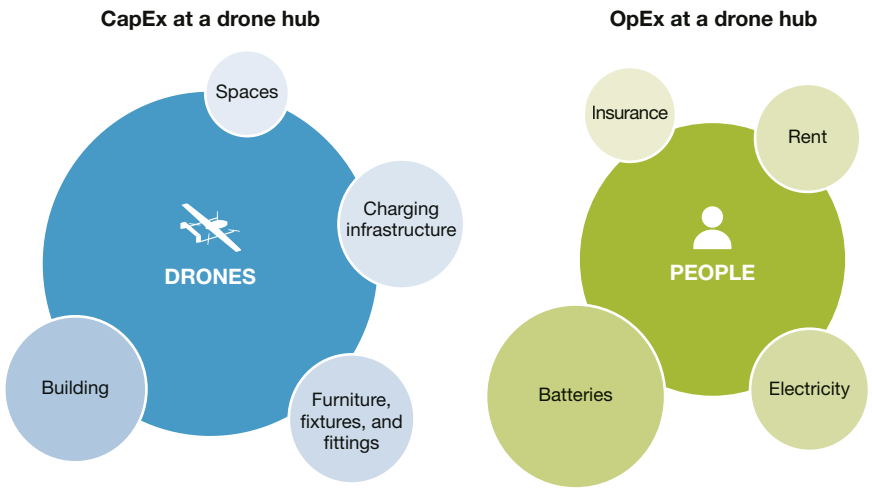
Total cost of ownership of a drone implementation solution

Adopting drones in a supply chain requires a thorough analysis of both CapEx and OpEx, which together form the TCO for the implementation.

Figure 2 outlines the key expenses involved in establishing a drone hub, such as drone acquisition, infrastructure, and ongoing operational costs. Regardless of whether a company chooses a drone service provider model or outright drone ownership, the costs—both direct and indirect—must be carefully evaluated to understand the financial and operational implications of drone integration.

FIGURE 2

CapEx and OpEx breakdown at a drone hub



Source: Authors

In the drone service provider model, the customer pays for CapEx and OpEx as part of a recurring monthly fee, allowing them to spread these costs over time rather than facing a large initial investment. This model is advantageous for businesses that prefer to avoid CapEx ownership and benefit from a shared network setup. Here, drone capacity is distributed among multiple customers, lowering individual costs and increasing network efficiency, as drone providers

manage and maintain the operational hubs.

On the other hand, the outright drone purchase model involves a more substantial initial commitment. The customer invests upfront in CapEx to acquire and set up drones, along with signing an annual maintenance contract (AMC) to ensure ongoing support for the infrastructure. Additionally, monthly OpEx costs cover operational aspects such as battery replacements and utilities. This model is ideal for organizations seeking exclusive control over their drone network, offering full autonomy over operations, which aligns well with long-term strategic objectives, particularly when customization or specific regulatory control is essential.

Beyond these tangible costs, it is vital for organizations to account for intangible costs associated with establishing and maintaining relationships with drone providers or integrators. Relationship-building expenses can vary depending on the vendor's expertise, the customer's familiarity with drone technology, and the organization's technical capabilities. While these factors are often overlooked, they significantly affect the speed and effectiveness of implementation. Investing in these relationships early on can accelerate the learning curve, improve operational alignment, and ensure scalability for future drone deployments.

By considering both tangible and intangible costs, as well as selecting the right adoption model and operational setup, supply chain leaders can effectively leverage drones to drive efficiency, flexibility, and resilience within their logistics networks.

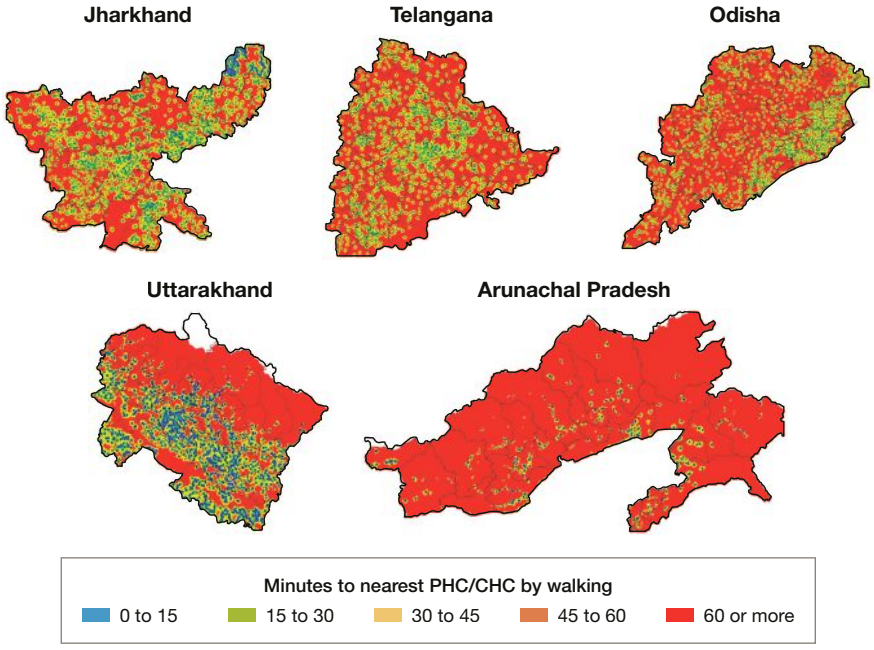
Cost-benefit analysis of drone implementation in supply chains

In this article, we showcase a real-world use case of drone implementation in healthcare supply chains and focus on analyzing the cost-benefit of drone deployment for both short-range and long-range deliveries, specifically within business-to-government (B2G) and business-to-business (B2B) contexts.

As with any strategic supply chain decision related to transportation assets or services, adopting drones must align with overarching supply chain and operational objectives, such as enhancing flexibility, improving customer service, and optimizing delivery times. Key considerations include capital availability, budget constraints, return on investment, breakeven metrics (such as payback period or number of flights), and the organization's long-term vision to stay abreast of technological advancements.

FIGURE 3

Healthcare accessibility heatmap in remote regions of India



Use case: Overcoming healthcare access challenges with drone operations

India's healthcare infrastructure faces significant challenges, especially in remote and underserved regions where access to medical facilities is limited. In collaboration with the Association for Scientific and Academic Research, Redwing developed heatmaps

that highlight these accessibility issues nationwide. Figure 3 illustrates areas in red, marking locations where road access to a healthcare facility takes over 60 minutes due to rugged terrain or inadequate infrastructure. In such regions, timely healthcare access is a critical necessity.

Redwing deployed autonomous drone networks to bridge this gap, transforming healthcare access in some of India's most challenging regions, such as Arunachal Pradesh and Odisha. By delivering life-saving medications, vaccines, and collecting diagnostic samples directly to and from remote communities, Redwing's drones bypass logistical obstacles like mountainous terrain and poor road networks. In areas where a road journey might take several hours, drones can complete the same delivery in just 20-40 minutes, ensuring rapid access to essential medical supplies.

Figure 4 provides an overview of Redwing's drone delivery cycle.

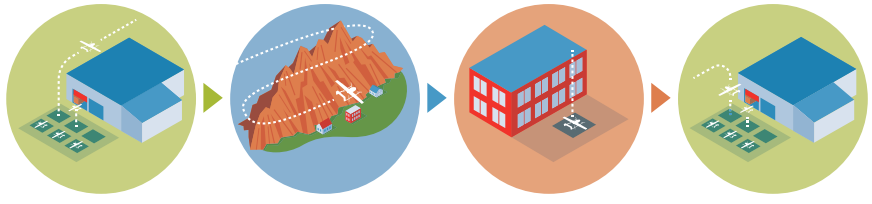
1. **Order placed.** A central hub receives an order for medical supplies and prepares the package for dispatch.
2. **Flight operations.** The drone autonomously navigates to the destination, overcoming challenging landscapes.
3. **Proof of delivery.** Upon arrival, supplies are delivered directly to healthcare personnel or secure drop points.
4. **Return to hub**. After completing the delivery, the drone returns to the hub to recharge, establishing a continuous and efficient supply chain cycle.

This model exemplifies how drones serve as a logistical lifeline for remote healthcare supply chains, drastically reducing delivery times and ensuring reliable last-mile connectivity. Through our partnership with Redwing, we conducted a cost-benefit analysis to assess drone implementation's economic and operational impact. The data confirms that drones not only improve healthcare accessibility but also present a scalable model for addressing logistical challenges in other remote regions.

By transforming supply chain limitations into opportunities, Redwing's drone solutions underscore the potential of drones as a transformative asset in healthcare logistics, offering resilience, efficiency, and expanded reach for regions that need it most.

FIGURE 4

Redwing's drone operations for healthcare



Source: Authors

Framework for evaluating drone use cases in healthcare supply chains

For supply chain managers to assess the viability of drone deliveries effectively, we present a structured framework that considers both capital and operational costs in relation to anticipated benefits. Tables 1 and 2 illustrate this framework for short-range and long-range flights, providing an analysis of key cost drivers and benefits, which helps decision-makers align drone technology with strategic and financial objectives.

Drone adoption models and operational design

Our analysis centers on two primary drone implementation models as follows.

1. **Business-to-government (B2G).** Focused on long-range deliveries to remote healthcare facilities, this model enables healthcare providers to overcome geographic barriers, facilitating the timely delivery of essential medical supplies.
2. **Business-to-business (B2B).** Aimed at short-range, high-frequency deliveries within urban areas, this model supports medical supply transport between facilities, bypassing urban congestion and reducing delivery times.

Cost-benefit analysis for long-range and short-range drone solutions

Tables 1 and 2 provide detailed cost-benefit analyses for long-range and short-range applications. We identify the key drivers of costs and benefits (and associated assumptions) and then assess each driver based on actual data accessible to one of the authors or data derived from publicly available

sources. For the long-range B2G model, the analysis highlighted the benefits of reduced infrastructure requirements and minimized patient travel, making drones a cost-effective option in remote healthcare logistics. For the short-range B2B model, the benefits include labor savings and improved delivery speeds in dense urban environments where traffic congestion is a significant barrier. There are other intangible benefits beyond what this study highlights such as reduced environmental impact, increased skill level in populations that adopt it, reduced road congestion etc.

TABLE 1

Cost-benefit comparison of long-range drone vs. traditional delivery

Cost or benefit driver	Long-range drone solution	Long-range traditional solution (non-drone)	Description
Coverage radius	50 km per drone	50 km	Each drone operates within a 50 km radius, ensuring wide coverage.
Geographical coverage	~7,850 km^2 (using 7 drones)	~7,850 km^2	Total area covered by the drone network, based on drone radius and number of drones.
Number of drones in operation	7 drones	N/A	Total drones used to cover the specified area in the drone network.
Drone capacity	6 deliveries per hour	Dependent on healthcare facility capacity	Average number of deliveries each drone completes per hour.
Operating hours per day	8 hours per day	Dependent on facility operating hours	Average operating hours per drone per day.
Total deliveries per day	336 deliveries per day	Dependent on facility capacity and patient travel	Calculated based on total drones and their delivery capacity per hour and operating hours.
Initial capital expenditure (CapEx)	$100,000 for drones and setup	$2 million+ for building healthcare infrastructure	One-time investment needed to acquire and set up drones and infrastructure.
Recurring monthly operational expenditure (OpEx)	$25,500 (including pilot salaries, maintenance, and batteries)	$50,000 - $100,000 per month (facility management, staffing, and patient transport)	Includes recurring expenses for operation and maintenance.
Capital expenditure savings (CapEx)	$2 million savings compared to building traditional infrastructure	High CapEx required for building new infrastructure in remote areas	Cost savings by avoiding the construction of traditional infrastructure.
Operational Expenditure Savings (OpEx)	$61,500 per month savings in facility and transportation costs	Higher OpEx due to ongoing facility and transportation costs	Monthly savings from reduced facility and transportation costs compared to traditional methods.
Labor cost comparison	Reduces patient travel costs	$68,000/month for riders vs. $30,747/month for drones	Comparison of monthly labor costs between traditional methods and drones.
Out-of-pocket expense savings (OOPE)	Significant reduction in patient travel expenses	Not Applicable	Patient cost savings by reducing out-of-pocket travel expenses.
Breakeven period estimate	2-3 years depending on OpEx Savings	1-2 years based on labor cost savings	Estimated time to recover investment based on operational savings.
Operational constraints	Regulatory approvals, weather limitations	Regulatory approvals, traffic constraints for riders	Factors that may limit or delay operations.
Scalability potential	High scalability for expanded healthcare reach	Moderate scalability, ideal for dense urban centers	Potential to scale operations across different geographical areas or population densities.

Source: Authors

TABLE 2

Cost-benefit comparison of short-range drone vs. traditional rider delivery

Category	Drone delivery model	Short-range traditional rider-based model	Description
Drone radius	3 km	N/A	Maximum operational radius for each drone.
Geographical coverage	~28.3 km² (using 7 drones)	Limited to rider availability and range	Total area covered by the drone network for short-range deliveries.
Number of drones	7 drones	34 riders	Total drones or riders used to cover the specified area.
Drone capacity	6 deliveries per hour	10 deliveries per rider per day	Average number of deliveries each drone or rider completes per hour.
Operating hours per day	8 hours per day	8 hours per day	Average operating hours per drone or rider per day.
Total deliveries per day	336 deliveries per day	340 deliveries/day (10 deliveries/rider/day)	Calculated based on total drones or riders and their delivery capacity per hour and operating hours.
Initial CapEx investment	$100,000 for drones and setup, including charging stations and software	$0 (No upfront CapEx)	One-time investment needed for drone equipment and setup.
Recurring monthly costs (OpEx)	$30,747 (including pilot salaries, maintenance and software)	$68,000 (34 riders at $2,000/month–average payout)	Includes recurring expenses for operation and maintenance.
Labor cost savings	$37,253/month	N/A	Labor cost savings from reducing rider costs.
Total monthly cost	$30,747	$68,000	Total operational cost per month.
Operational efficiency	More efficient–higher capacity	Dependent on rider availability and traffic	Comparative efficiency in operation without delays.
Breakeven period estimate	2-3 years depending on OpEx Savings	1-2 years based on labor cost savings	Estimated time to achieve breakeven based on operational savings.
Scalability potential	High scalability for dense urban areas	Moderate scalability, limited by rider availability	Potential to scale operations across dense urban areas.

Source: Authors

Implications for supply chain leaders

The framework presented here enables supply chain leaders to evaluate the cost-benefit dynamics of drone implementations comprehensively. Our findings suggest that drones are particularly valuable in B2G healthcare applications for remote areas, reducing costs associated with infrastructure and patient access. In B2B urban applications, drones effectively reduce labor expenses and mitigate traffic delays, making them ideal for high-frequency deliveries in densely populated regions.

In the B2G model, healthcare providers often initiate pilot projects to gather preliminary data, refine cost estimates, and assess scalability in specific markets. Over time, these pilot projects can expand, integrating drones as a core component of last-mile logistics to improve speed, cost efficiency, and service reach.

A best practice guide for supply chain managers: Implementing drone operations

Implementing drone technology in supply chains presents unique risks and operational challenges that supply chain leaders must address proactively.

Pre-implementation phase: The pre-implementation phase emphasizes strategic planning to mitigate regulatory, financial, and partnership risks.

1. **Regulatory and compliance review.** Conduct a detailed review of regional and international regulatory requirements. Engaging with regulatory bodies early ensures compliance with airspace restrictions, certification needs, and other aviation standards. This proactive step helps identify potential roadblocks before operational deployment.
2. **Financial feasibility analysis.** Assess capital and operational expenditures (CapEx and OpEx) to understand the financial implications of drone adoption. Use tools such as ROI, NPV, and breakeven analysis to determine whether the projected benefits align with budget and strategic objectives.
3. **Third-party vetting and contracts.** Select reliable technology and logistics partners, ensuring they meet strict security and operational standards. Establish clear contractual terms, including compliance requirements and regular audit clauses, to secure a dependable partnership network.

FIGURE 5

Best practices for drone implementation in supply chain

Source: Authors

This best-practice guide provides a structured approach to help mitigate risks across all stages of drone implementation: pre-implementation, during implementation, and post-implementation. By focusing on regulatory, operational, and financial considerations, supply chain managers can integrate drones deliberately and resiliently into logistics operations, with a keen eye on assessing key financial metrics.

During implementation: The focus of this phase should be on testing, monitoring, and risk management. During implementation, the focus shifts to real-world testing, data gathering, and operational risk management.

4. **Pilot programs.** Start with small-scale pilots to test drone operations under real-world conditions. These pilots allow the organization to refine delivery processes, monitor performance, and identify risks specific to different environments (e.g., urban areas

vs. remote regions). Pilots also help test for payload capacity limitations and gauge delivery speed.

5. **Real-time operational monitoring.** Implement systems to track key performance indicators (KPIs) like delivery speed, system reliability, and payload handling in real-time. Active monitoring helps address operational issues promptly, ensuring the drones meet service-level expectations without disruptions.
6. **Ongoing compliance audits.** Conduct regular audits of third-party providers to ensure they maintain adherence to security and operational standards. This is especially critical in multi-party arrangements, where lapses by one partner could affect the entire supply chain operation.

Post-implementation. The focus in this phase should be on evaluation, scaling, and continuous risk assessment.

7. **Performance and financial reviews.** Periodic reviews of operational performance and financial ROI help validate the initial cost-benefit projections. Analyze actual CapEx and OpEx against the planned budget to adjust the financial model and improve future investment decisions. The following tools and metrics can be employed:

- **Return on investment (ROI):** Assesses the potential financial returns from drone adoption, factoring in savings on infrastructure and operational costs.
- **Total cost of ownership (TCO):** Includes all CapEx and OpEx over the lifespan of the drones, allowing managers to see the full cost picture.
- **Breakeven point:** Determines how long it will take to

recover the initial investment compared to traditional delivery methods.

- **Net present value (NPV):** Projects long-term profitability by analyzing future cash flows, helping assess drone operations' sustainability.
- **Payback period:** Shows the time needed to break even, essential for gauging initial investment feasibility.
- **Scenario analysis:** Tests different variables, such as demand fluctuations and regulatory changes, to provide robust insights for planning and risk management.

8. **Scalability assessment and future planning.** Evaluate the feasibility of scaling drone operations based on post-implementation data. Identify opportunities for technological upgrades or process improvements, such as enhancing battery life or increasing payload capacity, to support larger-scale operations and improve cost efficiency.
9. **Continuous risk assessment.** Regularly reassess regulatory, operational, and financial risks, especially as market dynamics and regulations evolve. This ongoing evaluation allows organizations to adapt their strategies and ensure sustained compliance and efficiency.

SCM implications from Redwing's drone network: Key takeaways for supply chain leaders

Redwing's drone network has addressed core supply chain issues within India's healthcare system, offering valuable insights for broader SCM applications.

- **Access to remote populations.** Redwing's drones have extended last-mile connectivity to remote areas where traditional transport faces significant barriers. In these isolated regions, drones provide a reliable delivery method, reducing delays and ensuring critical care supplies reach those in need despite infrastructure or weather challenges.
- **Reducing delivery lead times.** By achieving speeds up to 10 times faster than road transport, drones have revolutionized the delivery of emergency medications and diagnostic samples. This speed is vital for rural health centers where delayed treatments can have severe consequences.
- **Supply chain continuity and efficiency.** The consistent delivery of essential supplies via drones helps prevent disruptions in healthcare inventory. By reducing the need for bulk orders, drones minimize the risk of stockouts or overstocking, which helps healthcare providers optimize costs and resources. Real-time tracking further enhances operational precision, reducing CapEx otherwise required for large infrastructure setups in primary healthcare centers.
- **Community and economic benefits.** Integrating drones has also provided local economic benefits by creating job opportunities. Redwing has trained local youth as drone operators and technicians, promoting economic inclusion and encouraging talent retention in rural areas, thus supporting community upliftment alongside supply chain effectiveness.

Building a future-ready supply chain with drones

Looking forward, supply chain managers must consider how drones can integrate into and reshape their logistics networks. Drones facilitate decentralized distribution models and enable faster delivery routes, proving especially valuable in reaching underprivileged or underserved populations. The framework and best practices presented here equip SC managers with the foundational knowledge to start preparing for drone integration now—through pilot programs, strategic partnerships, and early investments in drone-compatible infrastructure.

While this article focuses specifically on drone technology, the framework can be applied to other emergent technologies. For example, autonomous robots in warehouses or on roads can be evaluated using similar cost-benefit analysis methods. By adopting this best-practice approach, SC managers can assess the alignment of new technologies with both short- and long-term supply chain strategies, using it as a roadmap for pilot and advanced deployment.

As supply chains evolve in complexity, embracing technological innovations like drones will be essential for building resilience and responsiveness. By preparing today, supply chain leaders can position their organizations to thrive in a dynamic, technology-driven future. •

SPOTLIGHT ON

You can't always get what you post: Why Gen Z isn't clicking on your job ad

By Andrew Zeiser, Sebastian Brockhaus, and A. Michael Knemeyer

Like most industries, procurement is facing a talent shortage. Targeting potential candidates earlier in their career journeys and continuing to invest in them can prove an effective anecdote.

You are looking to shape the future of your supply chain, not just add a new hire. Yet, if you are using the same HR-approved template from 2018, you may be deterring the very Gen Z talent you're trying to attract.

Gen Z includes those born between the late 1990s and early 2010s, makes up nearly all recent college graduates, and comprises nearly 20% of the current workforce, on pace for 30% by 2030. They are digitally fluent, socially aware, educated, and career-focused, but deeply skeptical of inauthentic messaging and a lack of transparency, according to a 2021 EY Report on Gen Z. Their values and skillsets—they are digital natives—differ from other generations. They have short attention spans, according to a 2022 McKinsey study, and will scroll right past job ads that read like marketing copy filled with corporate jargon that seems inauthentic.

As educators, we hear frustrations from both sides. Students don't understand vague job ads and hiring managers wonder why applications are low or off the mark. To better understand the disconnect, we analyzed over 2,000 early-career job ads using the search terms "supply chain" and "logistics" on Handshake, a digital

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career platform designed specifically for Gen Z. The dataset includes postings from 2019 to 2024, pulled from a large Midwestern university's Handshake database. We reviewed each ad to include only roles involving actual supply chain processes; "logistics" frequently referred to unrelated contexts like "coordinate logistics of field trips." The final dataset spans a wide range of industries, geographies, and roles and shows a broad, yet insightful snapshot of how employers communicate early-career SCM roles to potential Gen- Z applicants.

We set out to present our findings in a format hiring managers (and Gen Z job seekers) know well—a job ad. We planned that each section of this article would mimic the standard template. However, the job ads, at least in our sample, have no standard format. Some even omitted the exact job title! Gen Z, who came of age during major disruptions (COVID-19, Climate change, AI reshaping job markets) values transparency and consistency, according to Monster's 2025 State of Graduate Report. Increasing uncertainty from inconsistent job ads may drive job seekers to scroll right past your open position. Most job ads at least describe the 1) position, 2) qualifications, 3) logistics (pay, location, career development, etc.), and 4) a call to action (directions how to apply). We've structured our findings accordingly.

Job title & responsibilities

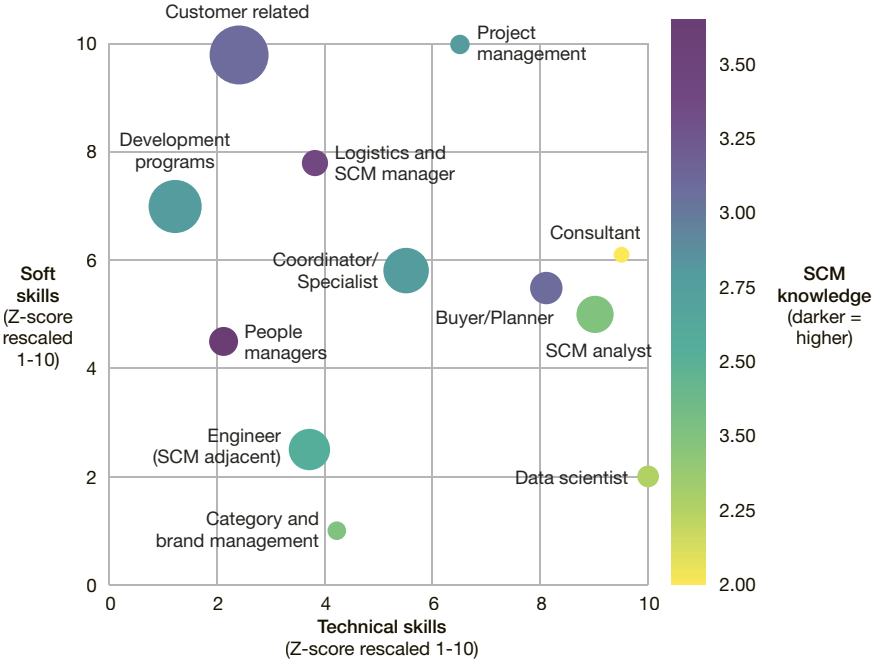
Even your job title might be deterring candidates. Our data revealed widespread inconsistency in job title, as well. Titles like "coordinator," "analyst," and "specialist," were used somewhat interchangeably—even for roles with similar responsibilities. One company's "planner" was another's "operations associate." Job seekers are left wondering: What does this mean? If your title doesn't match the role or breaks search logic, job seekers will miss out.

Job summaries did not help much either. The best clearly explained what the job does and why it matters. Most did not. Some launched into bullet points; others leaned on buzzwords or hype. Responsibilities were just as inconsistent; a "supply chain coordinator" might spend their days deep in ERP data at one employer but calling vendors to track down late shipments at another. For a generation that values clarity, ambiguity deters job seekers.

To cut through the noise, we grouped roles into functional job clusters based on real responsibilities and skills (see Table 1). Each cluster represents a distinct combination of technical demands, responsibilities, and potential career paths, helping candidates better align their strengths with opportunities.

FIGURE 1

Skill profiles of SCM job clusters



Source: Authors

Gen Z is not afraid of complexity. They simply want to understand the job they are applying for and how it might shape their future. Clearer titles, sharper summaries, and responsibility descriptions that reflect actual outcomes (not corporate jargon) are the minimum. Unclear job ads will not yield strong applications. Gen Z wants transparency. Vague titles and generic tasks are a fast track to your ad being ignored.

Required qualifications

Job ads often ask for a lot, but not always clearly. Job ads that simply list 10 software tools, five SCM processes, and vague descriptions of "ability to work cross-functionally," are confusing, if not misleading, applicants.

In our analysis, we found three core skill categories: 1) technical tools describe data analysis and software like Excel, SAP, and R, 2) SCM knowledge includes terms like inventory or Six Sigma, and 3) soft skills include phrases like communication, teamwork, and presentation. We mapped the frequency of these in our sample using standardized Z-scores (see Figure 1); larger circles correspond to more job ads for a given position.

While social media gurus, and sometimes professors, broadcast that all recent graduates must master every software, our analysis tells a different story. Soft skills dominated the landscape. Communication, problem-solving, and leadership led the list, even in analytically heavy roles. This makes inherent sense; SCM is a "team sport," and even the most rigorous data analysis is worthless if not communicated clearly.

Technical skills like ERP systems (SAP, Oracle), along with basic analytics (KPIs, dashboards), appeared often without clear context. Many ads simply listed software or buzzwords without explaining how those skills would be used.

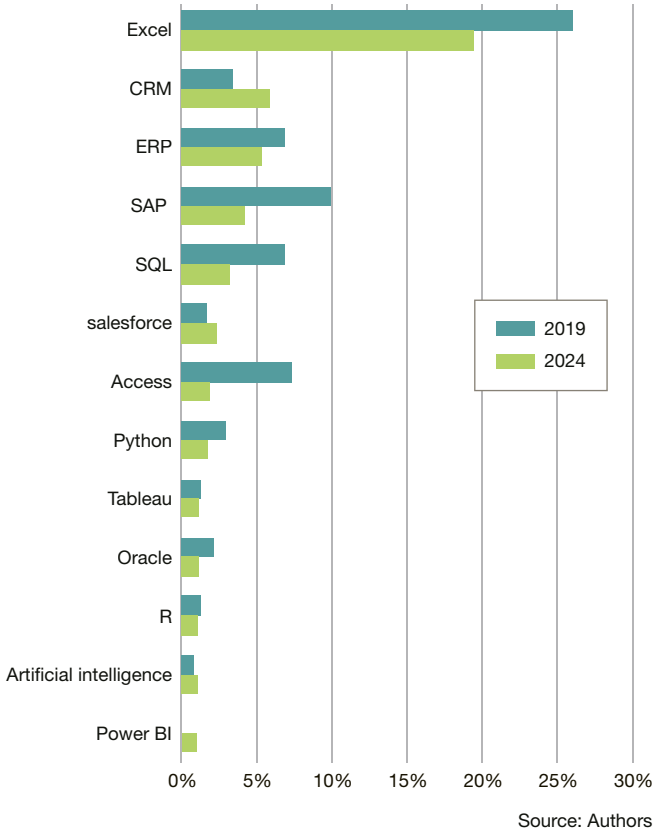
References to supply chain-specific knowledge, such as inventory control, procurement cycles, or transportation planning, were inconsistent. Some ads directly highlighted these as essential. Others did not, perhaps assuming candidates infer these skills or learn on the job.

For Gen Z job seekers raised in a world of constant information, lack of clarity is a major barrier. Listing every skill without discerning essential versus nice-to-have only confuses. Most ads don't explain skills in context. "Strong communication skills" sounds good, but does it mean emailing dashboards or presenting insights? "Python preferred" helps, but only if you say why.

Gen Z isn't avoiding technical challenges; they just want plain language. What's essential on day one?

FIGURE 2

Percent of job advertisements mentioning



Source: Authors

What's trainable? What tools actually get used? A bloated, jargon-heavy qualifications list does not impress; it confuses. Be specific, or risk deterring the talent you need.

Key responsibilities: Tools of the trade

Gen Z is tech-savvy, but also overwhelmed. Gen Z reports higher levels of anxiety than any other generation, according to the National Social Anxiety Center. Typical Gen Z individuals spend hours on social media, not only following their friends but also engaging with influencers who confidently offer contradictory advice. Should they learn Excel? Tableau? Python? AI? SAP? Most job ads do not clear the confusion. We analyzed the frequency of all software mentioned in our sample (see Figure 2).

One thing stands out. Excel still dominates, appearing far more often in job ads than Python, R, Tableau, or AI. Even in the data scientist cluster, Excel remains the industry standard, appearing more frequently than other tools with more advanced capabilities.

We also found notable growth in mentions of CRM platforms like Salesforce, not just in ads for sales roles. CRM mentions show up frequently in listings for specialists, coordinators, and analysts, suggesting a deeper transformation. As supply chains move closer to the end customer, even traditionally "back-office" roles require service-minded communication, responsiveness, and awareness of customer impact. For Gen Z, who values purpose, connection, and impact, this closer link to impact is a welcome fit.

The takeaway for Gen Z? Excel remains a staple. AI and automation are rising, but not required, yet. Customer-facing tech, especially CRM, is growing for entry-level roles. The takeaway for employers? Be specific. Don't just name-drop tools; explain how they fit into the job. Otherwise, the list becomes just another wall of noise.

TABLE 1

SCM job clusters

Role	Description
Buyer/Planner	Detail-oriented professionals managing purchasing, inventory, and suppliers; skilled in ERP, forecasting, and negotiation.
Category and brand manager	Blend marketing and supply chain to drive growth through customer insights and category management.
Supply chain consultant	Analytical experts who optimize strategies using data, process mapping, and change management.
Coordinator/ specialist	Early-career professionals supporting logistics, planning, and purchasing through strong organizational skills and cross-functional coordination.
Data scientist	Highly analytical, using Excel, SQL, and Python for forecasting, inventory, and KPI reporting.
Developmental programs	Rotate through various functions (i.e., logistics, procurement, and analytics) to develop leadership and cross-functional skills. These are "pipeline positions," not permanent roles.
Engineer	Apply engineering knowledge to improve processes and support production and distribution systems.
SCM manager	Oversee transportation, warehousing, and distribution with leadership and strategic planning skills.
People manager	Lead teams, coach staff, and align operations with organizational goals through strong leadership.
Project manager	Manage cross-functional projects like ERP and facility expansion; focus on budget and timelines.
Sales	Manage service levels and post-sale interactions with strong interpersonal and internal coordination skills.
SCM analyst	Analyze data for inventory, transportation, or procurement to drive decisions and improvements. Focused on reporting and decisions, rather than models/algorithms.

Source: Authors

Logistics

Gen Z cares about more than job titles. According to Handshake's class of 2024 survey, most want learning and development (87%), job security (76%), and high starting salaries (72%). Of course, flexibility matters. This generation learned on Zoom during formative years, why should work differ? Nearly 70% report they are more likely to apply if schedules are flexible, and 78% say work-life balance is essential. Most (65%) won't even apply if an employer's values don't align with theirs.

In most job ads, the logistics section covers basics like location, work model, compensation range, and schedule expectations. But in much of our sample, this information is either vague, incomplete, or missing altogether.

That's a missed opportunity. Gen Z pays close attention to details that signal transparency and respect. No location? Red flag. A "competitive" salary without numbers? Swipe left. A full-time role with zero mention of flexibility? Scroll past. Gen Z isn't unrealistic; they expect clarity; where they'll show up, the hours they'll work, and whether pay reflects expectations.

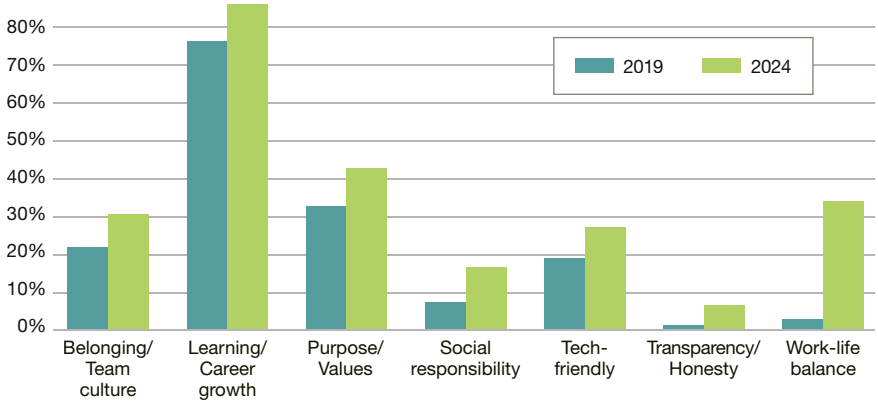
We also analyzed the job ads for Gen Z "attraction themes," phrases aligned with Gen Z value, including "work-life balance" (e.g., remote), "purpose" (e.g., impact), and "career growth" (e.g., learning). Table 2 shows the full list. Mentions of these themes rose from 2019 to 2024, suggesting that employers are beginning to adapt, albeit slowly.

There's still room to improve. Many postings

FIGURE 3

Gen Z themes in job descriptions: 2019 vs. 2024

% of job descriptions



Source: Authors

TABLE 2

Gen Z "themes"

	Gen Z theme	Keywords/Phrases searched	What it indicates
	Purpose/ Values	Mission-driven, make a difference, impact, social responsibility, ethics, DEI, diversity, inclusive	Alignment with company purpose, social justice, and values-driven work
	Work-life balance	Flexible work, hybrid, remote, work-life balance, mental health	Flexibility, autonomy, and mental well-being
	Learning/ Career growth	Learning, development, career path, growth opportunities, mentorship, training	Development opportunities and career advancement pathways
	Tech-friendly	Digital tools, automation, technology-driven, innovation	Modern, efficient, and digitally savvy workplaces
	Transparency/ Honesty	Transparency, open communication, feedback culture, and clear expectations	Clear and open communication, honest culture
	Social responsibility	Sustainability, climate, ethics, community service, and volunteer	Environmental and civic engagement; ethical reputation
	Belonging/ Team culture	Collaborative, inclusive, belonging, team-oriented, authentic	A sense of inclusion, authenticity, and interpersonal connection within teams

Source: Authors

read like legal disclaimers or recycled templates. To attract Gen Z, job ads should sound like real people wrote them. Use plain language, highlight mentorship, be transparent about pay and growth. Gen Z wants a future, not just a job. Knowing where a current role could lead helps with that. Reusing the same job ad from 2018 is certainly easier for hiring managers, avoiding HR friction. But a bland, outdated description may deter applicants and, eventually, impact outcomes.

Now hiring: A new approach to job ads

This section of most job ads strikes a hopeful tone, "Help us shape the future." But Gen Z is the present, not just the future. Missing the mark with Gen Z is more than just a lost opportunity; it is a giant, Gen Z-sized risk to your bottom line.

Ready to attract the next generation of supply chain talent? Skip vague titles, marketing speak, and empty promises. Craft job ads that clearly explain the role, how success is measured, and what candidates will learn and do. Gen Z is career-focused, digitally fluent, and values-driven. They're not scrolling past because they're lazy—they're looking for roles that speak their language. Meet them there. •

How to develop the next generation of supply chain planning professionals

Look beyond traditional talent development to build future-ready planning skills

By Marisa Brown, APQC and Dan Pellathy, University of Tennessee

Supply chain planning is in need of a reboot. Planners are increasingly expected to take a leading role in managing complex cross-functional processes, driving automation, and building more agile supply chains. As a result, the competencies that today's planning professionals need are very different than what was needed just a few years ago.

Invest in your talent to thrive during disruption. In addition to hiring new employees with the skills needed, provide training to upskill/reskill current employees to keep pace with today's dynamic environment. Effective supply chain planning enables companies to adjust operations to avoid disruptions while capitalizing on opportunities. It is precisely during times of uncertainty that companies need to invest in planning capabilities.

Many supply chain leaders recognize the need to develop a new type of professional equipped with both strong soft skills (e.g., critical thinking) and technical skills (e.g., demand planning/forecasting) to contribute strategically to the organization.

To identify these critical skills, assess how well organizations are helping employees develop them, and evaluate the current state of investment in planning talent, APQC and Dan Pellathy from the University of Tennessee collected data and insights from 462 global supply chain planning professionals. Our findings suggest that the evolution of supply chain planning demands a set of competencies that extend beyond traditional technical skills to include a broad array of deep work and social skills. The results also indicate that while most organizations rely on traditional talent development approaches, the most effective organizations use an innovative mix of approaches to develop the planning skills of tomorrow.

Talent development is a strategic imperative

Organizations participating in APQC's research shared that many senior leaders are on board to invest in the next generation of supply chain planning talent. For 49% of organizations APQC surveyed, senior supply chain leadership sees training as a priority for supply chain planning at least to some extent (Figure 1).

While good news, there is room here for

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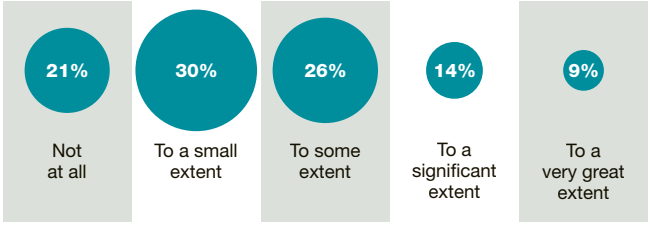
Dan Pellathy is faculty of practice leading graduate courses and executive education with a focus on Supply Chain Planning and Supply Chain & Finance at the University of Tennessee - Knoxville. He is also director of operations for UT's Global Supply Chain Institute's Advanced Supply Chain Collaborative, a collaborative think tank that connects industry leaders with faculty to explore advanced concepts in supply chain management.

FIGURE 1

Extent to which training for supply chain planning staff is a priority for senior supply chain leadership



Source: APQC

improvement. One technique for supply chain planners to get executives to support talent development is to change the conversation from the costs and time required for training to value generation and risk mitigation. Many leaders are conflicted; they want to invest in training and education, but they fall into the trap of taking short-term and tactical actions focused on cutting costs and reacting to the news of the day. It's important to keep an eye on long-term survival versus only short-term gains or there will be no long-term.

APQC also found that most organizations have talent management programs available for supply chain planning professionals. Leading organizations (19%) have talent development programs in supply chain planning specifically. An additional 23% have a program at the level of supply chain management. Most organizations (58%) have a program at the enterprise level (Figure 2). This represents both a challenge and an opportunity. Our research suggests that broad-based corporate training programs are not enough to fill or meet the competency needs of planners. Supply chain planners have unique demands placed on them and therefore need unique development programs. Planning leaders need to actively engage in shaping these programs.

Experiential learning is critical to competency attainment. One way to create a more responsive talent development program that better meets the needs of planning professionals is to locate tailored experiences within the supply chain or supply chain planning function. Locating the program closer to the front lines can enable faster, more responsive adjustments based on the changing reality on the ground. Classroom experiences that send participants back into their organizations to assess planning processes are also critical. Our research found that some components of a talent development program are larger in scope and more commonly located at the enterprise level versus at the level of supply chain or supply chain planning.

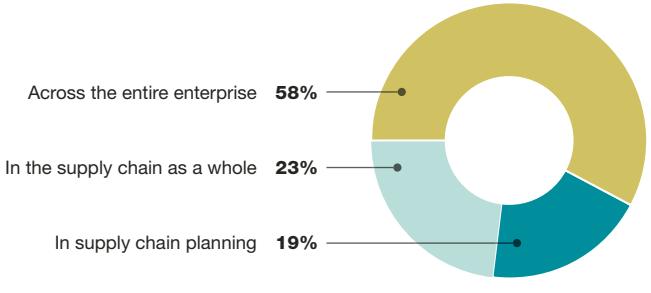
Common location of talent development components

Enterprise Level

- Learning paths
- High-potential leadership development program
- Workforce planning
- Learning profiles/resumes
- Formal knowledge capture/transfer program

FIGURE 2

Location of formal talent development program



Source: APQC

Supply Chain/Supply Chain Planning

» Career paths
» Succession planning
» Talent reviews
» Formal skills assessment program
» Internal hiring/talent mobility strategy
» Learning portal

Align critical skills and focus of talent development

One purpose of this research was to identify the key skills needed for future roles in supply chain planning and evaluate how well organizations were helping employees develop those skills. First, respondents identified the most important skills needed in supply chain planning across three categories:

1. ***Deep work skills:*** indicative of being able to focus without distraction on cognitively demanding tasks.
2. ***Social skills:*** help us collaborate, set strategic direction, and manage change.
3. ***Technical/job specific skills:*** relevant specifically to supply chain planning as well as some general business skills relevant in and beyond supply chain planning.

Respondents then rated their organization's effectiveness in training and development for each critical skill along a five-point scale from not at all effective to extremely effective. For each of the top skills, there is a sizable gap between the importance of the skill and effectiveness in development, and some gaps are particularly notable. For example, 66% say critical thinking is important, but only 28% of organizations are very or extremely effective at helping employees develop this skill (Figure 3).

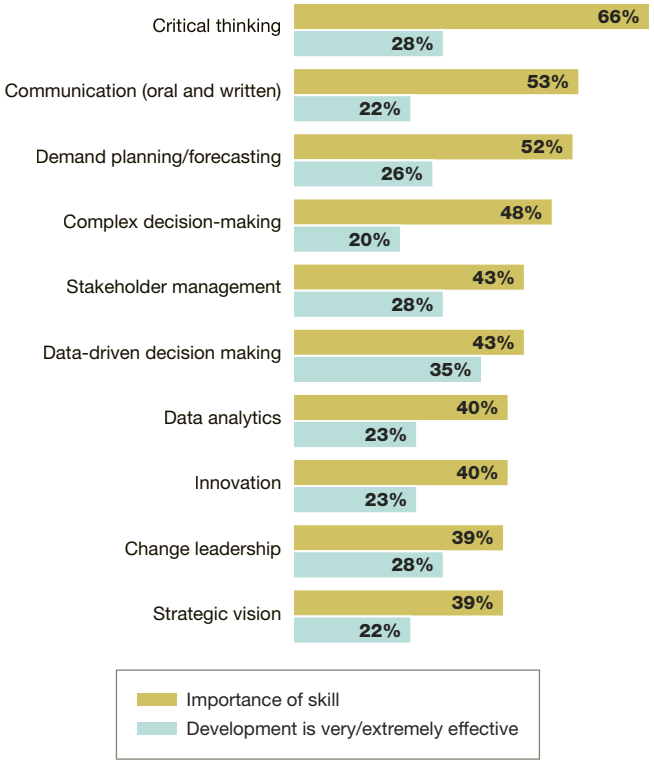
The values for "Importance of skill" do not add up to 100% because it was a "please select the top three" question. The values for "Development is very/extremely effective" do not add up to 100% because only the top two options are displayed for each skill.

This gap shows a distinct disconnect between the skills identified among the top 10 and the organization's effectiveness in developing those skills. These gaps may reflect the distance between corporate-level training programs and the evolving needs of planners. Accordingly, many organizations will need to realign—or even completely overhaul—their supply chain planning talent development approaches to focus on a mix of high-priority deep work, social, and technical skills.

The consequences of not addressing these gaps are considerable. If organizations cannot develop these skills in-house, they will be forced to secure them through external hires and/or consultants. In an increasingly competitive labor market, over-reliance on external hires will likely prove costly and slow critical planning transformation.

FIGURE 3

Gaps for top 10 skills: importance vs. effectiveness



Source: APQC

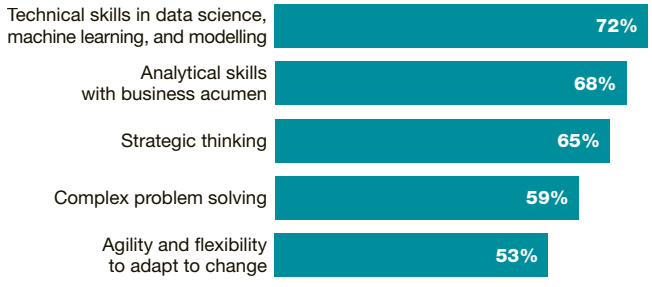
But the only other option is to simply not develop these skills—and that's even more dangerous. Organizations may be able to rely on a handful of experienced supply

chain planning professionals for now. But when those people retire (and they will), the function will be in the hands of people who lack experience with thinking critically in planning, communicating effectively, and demand planning and forecasting.

Additionally, leading organizations are interested in adopting new technologies and recognize the importance of having staff develop or enhance skills due to AI and other automation (Figure 4). We find that AI is still not widely adopted in supply chain planning. Only about one-third of organizations (31%) are currently implementing, operating, or optimizing AI for supply chain planning. Instead, the majority of organizations (61%) are in the piloting, consideration, or evaluation phases. As a result of AI, most respondents see the value of having planning team members with technical skills in data science, machine learning, and modeling (72%); analytical skills with business acumen (68%); and strategic thinking (65%). However, not everyone on the team needs to be an AI expert. For synergy to occur, it is important to have team members with complementary skills. Some planners likely will need deep data science and analytical skills to drive AI-based processes, but others will need to be highly capable users that can leverage AI for strategic thinking and project management.

FIGURE 4

Top 5 skills planning staff need to develop/enhance due to AI



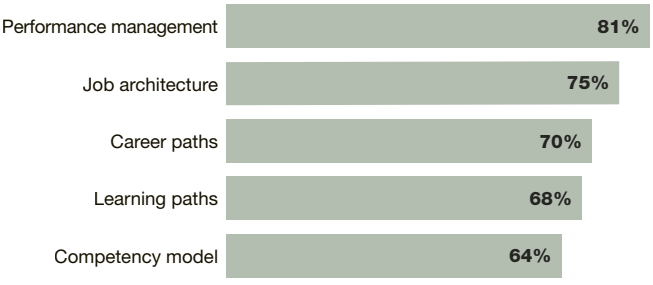
Source: APQC

Consider the components and approaches used

As part of this research, APQC asked organizations to describe the components of their talent development programs. Figure 5 shows the adoption rates of the most commonly used components. Performance management, a traditional approach, is most widely used by 81% of organizations in the research.

FIGURE 5

Top 5 components included in supply chain planning talent development programs



Note: The values above do not add up to 100% because it was a "select all that apply" question.

Source: APQC

Many of the components on this list have one thing in common: they're designed to benefit both the organization and the employee. While a career path focuses on job progression and the roles to achieve an employee's long-term career goals, a learning path emphasizes attaining specific skills and knowledge through structured learning. It is important to remember that developmental approaches tailored to the specific needs of employees typically lead to greater performance outcomes.

In addition to asking organizations which components they include in their talent development programs, APQC asked which approaches organizations use for talent development. As shown in Figure 6, we identified which approaches have the highest levels of effectiveness ("very/extremely effective") for the top five skills. Interestingly, this is not one-size-fits all, and a mix of approaches is necessary

FIGURE 6

Most effective talent development approaches for top 5 supply chain planning skills

Source: APQC

for developing the top skills, driving the need for a multi-faceted talent development program.

Many of the approaches needed for the top skills are internally focused (e.g., job shadowing, job rotations within supply chain), while other approaches extend beyond the planning or supply chain function—or even the organization altogether (e.g., collaboration with universities and other organizations).

Effectiveness of development efforts

Our research also examined how organizations rate the effectiveness of their supply chain planning talent development efforts as a whole. Across 19 talent-related goals, respondents indicated that their supply chain planning organizations are most effective at providing employees with time to learn (35%) and least effective at transferring knowledge (16%).

These findings suggest that many organizations see the value in training their supply chain planning employees but are less successful in implementing a formal program to capture the full value that planners create. For instance, knowledge sharing and organizational learning are critical for the adoption of new technologies. More broadly, knowledge sharing enables individuals and teams to tap collective insights to solve pressing issues. Other goals with higher levels of effectiveness include maintaining a pipeline of supply chain talent (31%) and manager development (30%). Figure 7 shows the percentage of respondents who rated their organizations very or extremely effective for the top five goals.

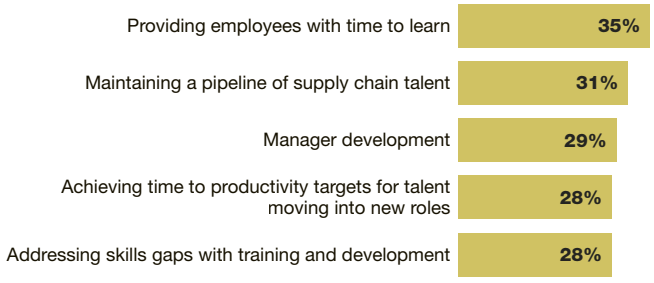
Effective organizations use a mix of approaches, such as job shadowing, formal mentoring, and participation in communities of practice or other collaborative working groups. Many effective organizations also use job rotations outside of planning and even outside of supply chain as a way of developing more well-rounded talent.

Moving forward

APQC recommends that organizations identify the skills and training that are most beneficial to the business and its future and then make an honest comparison against the skills and training that benefit their current supply chain planning professionals. By

FIGURE 7

Top 5 most effective talent-related goals in supply chain planning



Source: APQC

allowing focus on employee needs, organizations can create an environment that both attracts and retains top talent. At the same time, organizations must be aware that more talent development opportunities can lead to less time spent on the job. They must therefore plan accordingly to ensure that employees are not forced to choose between developing skills needed for the future and achieving today's productivity goals.

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. •

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

EXECUTIVE INSIGHTS ON TALENT

Built to Grow: Developing People, Not Just Filling Roles

Q&A with **Brad Brown**, Director of Marketing & Communications, Averitt

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

A: In a time of rapid transformation, one truth remains: people are the foundation of everything we do. At Averitt, our 54-year philosophy—"Our Driving Force is People"—continues to guide us. As supply chains grow more complex and technology accelerates, the need for skilled, dedicated individuals has never been greater. Tools evolve, but it's our people who drive success, create solutions, and move freight forward. That's not just a belief—it's our competitive edge.

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

A: The biggest challenge is twofold: finding people with evolving technical skills—and those whose values align with a strong team culture. At Averitt, we look for individuals who are service-driven, team-minded, and motivated to grow. Broader awareness is also critical. Young professionals often overlook supply chain careers, despite their real-world

impact on sustainability, safety, and quality of life. Our industry must do more to tell that story.

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: AI is transforming supply chain management—but its greatest potential lies in empowering people, not replacing them. When used well, AI handles repetitive tasks and delivers insights that help teams move faster and think smarter. The real opportunity is at the intersection of technology and human creativity. To unlock that, our industry must invest in talent development, foster cross-functional collaboration, and embrace AI as a tool that amplifies human strengths and sets the stage for long-term innovation and resilience.

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

A: Engagement and retention begin with hiring people whose values align with our culture. At Averitt, we invest deeply in growth, providing training and mentorship that support personal and professional advancement. Our team thrives when they see their impact—on customers, each other, and the world. Programs like Averitt Cares for Kids and the Team Up Community Challenge connect associates to something greater than themselves, building purpose, camaraderie, and a workplace where people want to grow and stay.

AVERITT

EXECUTIVE INSIGHTS ON TALENT

Beating the talent shortage with a stronger HR function

Q&A with **Lisa Yankie**, CHRO, Odyssey Logistics

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

A: It's well-known that there's a significant talent shortage in logistics — not just drivers, but roles such as operations managers and account coordinators. We've worked hard to build a strong team at Odyssey and continue investing in internal talent development. As a mid-size company, we've made a point to hire agile, versatile talent — people who believe in hard work and want to make an impact — and then help them grow.

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

A: Too many companies underestimate the importance of employer brand. This is not the same as simply being a good company. Candidates want to know not just what they'll do, but what the company stands for — and whether it aligns with what matters to them. Are there opportunities for growth? Is safety a priority? In logistics, where opportunities are

plentiful, first impressions must reflect the culture and connect to what prospective employees value.

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: For AI to deliver real value, it can't sit in a silo. It needs to be integrated into how people work — which means HR and IT must be aligned from the start. At Odyssey, we've focused on building that partnership. In the past, HR has often worked most closely with Finance — but as technology becomes a bigger driver of workforce strategy, it's just as important to be working side by side with the CIO.

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

A: Employees want to grow, but in logistics, their day-to-day responsibilities leave little room for long training sessions. We introduced a manager training program built around microlearning modules designed to be practical and easy to fit into a busy workday. We also launched a formal talent review process, including succession planning, to give senior leaders clear development paths and identified successors. Together, these efforts have strengthened our bench, reduced risk, and prepared our organization for long-term growth.

Odyssey®

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EXECUTIVE INSIGHTS ON TALENT

Advancing talent strategy in a shifting industry

Q&A with **Christina Fletcher**, Senior Vice President of Human Resources, Penske Logistics

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

A: The supply chain industry continues to face competition for key roles across all levels, influenced by geography and specialization. At Penske Logistics, we attract top talent through a centralized hiring approach and a strong focus on building high-performing teams. We invest in developing our workforce through functional training, safety education, professional development, and leadership programs. This commitment helps us stay ahead in a competitive talent market and ensures our associates are equipped to grow and succeed within our organization.

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

A: Our most pressing challenge is staying market-competitive in compensation and benefits. We proactively evaluate each market where we operate to ensure our pay structures remain attractive and effective in retaining top talent. A dedicated team continually analyzes compensation trends for existing operations and future business opportunities. This discipline helps us

avoid falling behind in key markets and reinforces our commitment to being a top employer in logistics, where retaining skilled associates is critical to long-term success.

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: At Penske Logistics, AI is helping us elevate talent by reducing manual work and boosting productivity. One area we've invested in is AI-powered route planning, and we continue exploring more tools that optimize operations. Our goal is to use AI to enhance – not replace – human capability, allowing associates to focus more deeply on customer service. We're also working to evaluate training and development programs to support this transition, ensuring our workforce is prepared to use AI meaningfully in their day-to-day work.

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

A: We've made strategic improvements in associate communications to strengthen engagement and retention. This includes monthly team meetings, digital signage and quarterly business updates from leadership. Associates want to understand how their work contributes to our success. In warehouse operations, where retention can be most challenging, we introduced dedicated check-ins between new associates and managers, providing space for early feedback and support. These efforts create stronger connections between our people and the business, ensuring every associate feels valued and informed from day one.

EXECUTIVE INSIGHTS ON TALENT

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.

SMC³®

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

A SPECIAL SUPPLEMENT TO:
SUPPLY CHAIN MANAGEMENT REVIEW

Top 50 3PLs

3PLs Under Pressure: Growth collides with global disruption

As tariffs rise, labor tightens, and supply chain costs climb, 3PLs are reworking operations across warehousing, transport, and value-added services to stay competitive.

BY **KAREN E. THUERMER**, CONTRIBUTING EDITOR

Since President Trump took office, sweeping import tariffs, temporary pauses, and a reassessment of trade exemptions have added significant uncertainty for global businesses and consumers.

The impact is certainly being felt by today's largest companies that have long-standing trade relationships and supply chains that stretch across multiple countries. "So, when tensions rise, it adds complexity and cost to cross-border trade," says Herman Guzman-Carranza, logistics and transportation advisor at Accenture.

"Ongoing tariffs and trade wars are likely to slow global economic growth," says Evan Armstrong, president, Armstrong & Armstrong (A&A), a leading third-party logistics (3PL) advisory firm. "Outcomes will hinge on which businesses and industries secure exemptions. So far, larger, well-capitalized U.S. companies with robust lobbying efforts are likely to fare better than their smaller counterparts."

Of note, on April 2, President Trump announced changes to the *de minimis* rules for shipments from China. This will eliminate exemptions from specific tariffs for small shipments, such as those in e-commerce. Given these factors, Armstrong projects 2025 3PL

revenue will reach $316.2 billion—a 4.5% increase—driven largely by early-year growth.

Multiplying impacts

Meanwhile, geopolitical tensions, such as trade disruptions caused by the Russia-Ukraine war, Red Sea blockage, and the recent reciprocal tariff announcements, are forcing companies to rethink and redesign their supply chains. Each part of the 3PL business, including transportation, warehousing, and value-added services are facing its own set of challenges amid economic shifts, regulations and evolving consumer demands.

"Rising costs and inflation are squeezing margins, making it harder for logistics providers to stay profitable," says Sarah Banks, global lead, freight and logistics, Accenture. "It's a complex and evolving landscape, and most 3PLs are working closely with their clients to assess the business impact."

Guzman-Carranza emphasizes how volatile fuel costs, labor shortages, and geopolitical risks are disrupting shipping routes. "Regulatory pressures and infrastructure constraints are also driving up costs," he says. "Even though tools like AI and route optimization are helping, many tasks are still manual, making it harder to react fast."

Labor shortages and fierce competition for skilled workforce, especially in warehousing and transport, compounded by pressure to speed up order fulfillment for growing e-commerce demands, continue to remain a key concern to 3PLs.

"This can potentially be made worse by stricter immigration policies," adds Banks. "At the same time, many ports and rail systems are facing congestion and aging infrastructure, making the movement of goods slower and more unpredictable."

Warehousing and distribution continue to deal with fluctuating demand for space, as inventory levels keep shifting unpredictably.

The inventory buildup ahead of the Trump-era import tariffs has resulted in 3PL warehouses nearing full capacity, which will take time to draw down. Because of this inventory buildup, air and ocean freight forwarders have seen substantial increases in volumes and revenue.

"Advancements in automation are easing some pressures, but smaller 3PL players struggle to invest in warehouse management systems, AI, and robotics because of the high costs, placing them at a disadvantage as compared to their larger peers," says Guzman-Carranza. "On top of that, rising operational costs to maintain service levels, real-time inventory visibility, and regulatory compliance are eroding profitability."

For value-added services, like packaging, demand keeps changing. "Direct impacts are seen where raw material supply is disrupted due to trade uncertainties," says Guzman-Carranza. At the same time, 3PLs need to keep up with new rules around sustainability and packaging.

"With the rise of omni-channel retail, clients want more personalized and greener packaging, which requires a balance of creativity, efficiency, and environmental responsibility," adds Guzman-Carranza.

U.S. 3PL market growth by segment

3PL segment	2024 Gross revenue (turnover) (US$ billions)	2024 vs. 2023 Gross revenue (YOY %)	2024 Net revenue (US$ billions)	2024 vs. 2023 Net revenue (YOY %)
DTM	118.4	-4.2% ▼	19.2	-2.0% ▼
ITM	78.8	6.5% ▲	26.9	-4.0% ▼
DCC	31.5	6.0% ▲	31.5	5.3% ▲
VAWD	69.7	2.3% ▲	53.9	3.9% ▲
TOTAL*	298.4	1.1% ▲	131.2	1.6% ▲

* Total 2024 gross revenue (turnover) for the 3PL market in the U.S. is estimated at **$302.7 billion**. **$4.3 billion** is included for the contract logistics software segment.

Source: Armstrong & Armstrong

2024 3PL market figures

While no one will know the full impact on the 3PL industry this year, data compiled by A&A for 2024 indicates that the overall 3PL market remained stable after being hit hard in 2023.

According to current estimates from A&A, the net revenues of the U.S. 3PL market in 2024 grew by 1.6% to reach $131.2 billion in 2024, following a decline of 12.8% in 2023. Meanwhile, the gross revenues across all four segments of the 3PL market increased by 1.1% year-over-year, recovering from a significant drop of 26.1% in 2023.

"This brings the total value of the U.S. 3PL market to $302.7 billion in 2024," says Armstrong.

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Armstrong & Associates Top 50 U.S. 3PLs

(Largest U.S. 3PLs Ranked by 2023 Logistics Gross Revenue/Turnover)

2024 Rank	Third-party Logistics Provider (3PL)	2024 Gross Logistics Revenue (USD Millions)*
1	Amazon**	156,146
2	C.H. Robinson	16,848
3	GXO Logistics	11,709
4	J.B. Hunt	11,403
5	UPS Supply Chain Solutions	11,165
6	Expeditors	10,601
7	Ryder Supply Chain Solutions	7,746
8	Kuehne + Nagel (North America)	7,156
9	Total Quality Logistics	6,884
10	DSV (North America)	5,534
11	Lineage Logistics	5,400
12	DHL Supply Chain (North America)	5,250
13	Uber Freight	5,141
14	Beon (Transportation Insight & Nolan Transportation Group)	5,010
15	RXO	4,550
16	WWEX Group	4,380
17	Schneider	4,314
18	Penske Logistics	4,308
19	Hub Group	3,946
20	Echo Global Logistics	3,700
21	NFI	3,650
22	CEVA Logistics (North America)	3,580
23	GEODIS (North America)	3,167
24	Landstar	2,900
25	DB Schenker (North America)	2,850
26	Americold	2,667
27	AIT Worldwide Logistics	2,598
28	Maersk Logistics (North America)	2,400
29	MODE Global	2,320
30	Knight-Swift Transportation	2,260
31	Werner Logistics	2,154
32	Flexport	2,100
33	PSA BDP	2,068
34	Arrive Logistics	2,040
35	Forward Air	2,020
36	KLN (Americas)	1,952
37	Capstone Logistics	1,840
38	TFI International (North America)	1,822
39	Scotlynn (North America)	1,725
40	Ruan	1,704
41	Universal Logistics	1,611
42	FedEx Logistics	1,590
43	ArcBest	1,553
44	Kenco	1,537
45	Ascent Global Logistics	1,327
46	Allen Lund	1,316
47	Priority1	1,310
48	SEKO Logistics	1,300
49	Redwood Logistics	1,240
50	ITS Logistics	1,200

*Revenues cover all four 3PL Segments (DTM, ITM, DCC, and VAWD) and are company-reported or A&A estimates. Currencies have been converted to US$ using the exchange rate on December 31, 2024. **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.

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management (ITM)—which encompasses air and ocean freight forwarding, customs brokerage, warehousing, and inland transportation—and domestic transportation management (DTM)—which includes freight brokerage, managed transportation, intermodal transportation management, and last-mile—both experienced significant gross revenue declines in 2023, with double-digit reductions reported.

DTM saw an additional decline of 4.2% in 2024, while ITM experienced a 6.5% increase last year—the most significant year-over-year increase of all 3PL segments.

A&A attributes the growth in the ITM segment to shipping uncertainties in the Red Sea and a decrease in ocean traffic through the Suez Canal as well as concerns regarding tariffs and trade wars—especially in late 2024, as importers were eager to receive their goods before tariff increases.

In contrast, the non-asset-based DTM segment experienced gross and net revenue declines of 4.2% in 2024, or $118.4 billion. Net revenue fell by 2%, reaching $19.2 billion. "Despite this decline, it marked an improvement compared to 2023, which saw double-digit revenue drops," Armstrong says.

A&A figures indicate that the asset-heavy dedicated contract carriage (DCC) 3PL market saw the second largest year-over-year gross revenue growth in 2024 for all 3PL segments, up 6% to $31.5 billion, and the largest in year-over-year net revenue growth, up 5.3% to $31.2 billion.

"DCC has an advantage when truckload capacity increases due to softer demand and declining rates," says Armstrong. "Because traditional DCC contracts have one- to three-year terms with specific trucking assets dedicated to customers, this makes DCC contracts much 'stickier' than standard shipper/carrier trucking contracts and less susceptible to declines in the truckload spot market."

The value-added warehousing and distribution (VAWD) market was the third best-performing segment in 2024, growing 2.3% to $69.7 billion in gross revenue. In 2024, VAWD experienced the second-highest net revenue increase among the four 3PL segments, growing

3PLs adopt new technology

While the environment remains uncertain, 3PLs are evolving, becoming more adaptive, tech-savvy, and resilient to supply chain shifts, consolidation, and geopolitical change.

Third-party providers are also seeking ways to be vital partners by assisting with Customs, duties, smarter sourcing, and inventory strategies.

"AI and machine learning are helping to forecast demand better, price freight dynamically, and match with the right carriers—all of which is leading to cost savings and better service," says Herman Guzman-Carranza, logistics and transportation advisor at Accenture.

For example, warehouses autonomous systems, and robotics are speeding up order picking and improving accuracy. By accessing real-time data and analytics from the cloud, robots can optimize their routes, reduce idle time, reduce human transport/travel time, and prioritize tasks based on demand.

IoT and telematics are giving real-time visibility into shipments and vehicle performance, while AI is optimizing routes to save fuel and reduce delivery times.

For international transportation management (ITM) 3PLs, digitalization and compliance management use AI powered customs clearance platforms to ensure accurate documentation and avoid penalties.

"And on the last-mile front, innovations like drones and smart lockers are cutting down costs and speeding up deliveries, especially in the fast-growing e-commerce space," says Guzman-Carranza.

Armstrong & Armstrong (A&A) finds that four of the top five freight brokers—C.H. Robinson, Total Quality Logistics, WWEX Group, and Echo Global Logistics—are some of the 3PLs driving industry automation along with the newer tech-first digital freight brokers such as Uber Freight.

"At this point, most of the top freight brokers are strategically digitalizing operations to add value through improved carrier management and customer and carrier experiences," says Evan Armstrong, president, of A&A.

"Digital freight platforms such as Freightos, Flexport, and Windward and digital solutions from traditional freight forwarding 3PLs facilitate real-time booking, tracking, and cost optimization," says Armstrong. "Predictive analytics are being used to forecast and adapt to tariff changes and supply chain visibility solutions are helping companies adjust shipments based on new tariff regulations."

Meanwhile high warehouse labor demand, turnover, and wage increases are driving significant interest from value-added warehousing and distribution 3PLs to automate warehouses with autonomous robots from manufacturers such as Fetch, Locus, and 6 River Systems, Armstrong adds.

—Karen E. Thuermer

Armstrong & Associates Top 50 Global 3PLs

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9	Maersk Logistics	14,920
10	Sinotrans	13,062
11	GEODIS	12,300
12	GXO Logistics	11,709
13	J.B. Hunt	11,403
14	UPS Supply Chain Solutions	11,165
15	Expeditors	10,601
16	DACHSER	8,360
17	DP World Logistics	8,199
18	Ryder Supply Chain Solutions	7,746
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20	Total Quality Logistics	6,884
21	CJ Logistics	6,150
22	LX Pantos	5,900
23	Lineage Logistics	5,400
24	Kintetsu World Express	5,199
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32	WWEX Group	4,380
33	Schneider	4,314
34	Penske Logistics	4,308
35	CIMC Wetrans Logistics Technology (Group)	4,293
36	Hub Group	3,946
37	Hellmann Worldwide Logistics	3,860
38	Echo Global Logistics	3,700
39	NFI	3,650
40	AWOT Global Logistics Group	3,470
41	ID Logistics Group	3,439
42	Mainfreight	3,230
43	Savino Del Bene	3,120
44	SAIC Anji Logistics***	2,986
45	Landstar	2,900
46	Gebruder Weiss	2,818
47	Arvato	2,700
48	Americold	2,667
49	Culina Group	2,662
50	AIT Worldwide Logistics	2,598

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by 3.9% to $53.9 billion.

"For VAWD 3PLs, most warehouses are full, and higher interest rates have kept a lid on new warehouse development," says Armstrong. "There has been increased focus on fine-tuning warehouse pricing and improved bid performance. Shippers see this as a good time to put out RFPs and work to mutualize some of the one-sided agreements entered into during the post-shutdown demand surge."

Armstrong adds that many shippers are examining their supply chain networks and providers to improve inventory management and on-time delivery performance. "We anticipate a continued focus on supply chain network flexibility and warehouse optimization," he says.

3PL merger and acquisition activity

In 2024, 18 merger and acquisition (M&A) transactions occurred, including five acquisitions valued at more than $1 billion. "This year has started strong, with eight pending deals for more than $100 million as of January," Armstrong notes.

The industry is seeing significant consolidation as well. "Large 3PLs are expanding their capabilities, technologies and reach through M&A, affecting both the industry and its customers," says Banks.

For example, DSV's acquisition of DB Schenker and CMA CGM's purchase of CEVA Logistics, Ingram Micro, and GEFCO are helping them scale up freight, warehousing, and value-added services and let them invest more in advanced tech like automation, IoT, AI and analytics—which is great for shipper customers.

"But there's also a risk of fewer choices in the market, which could increase prices or limit service options,"

"Rising costs and inflation are squeezing margins, making it harder for logistics providers to stay profitable…It's a complex and evolving landscape, and most 3PLs are working closely with their clients to assess the business impact."

—Sarah Banks, Accenture

says Banks. She predicts that in the future, fewer, but stronger 3PLs are likely to dominate, and smaller firms will survive through specialization.

"Large 3PLs' tech-driven platforms will likely raise entry barriers, fueling international growth and last-mile improvements," says Banks. "But while the consolidation unlocks benefits for 3PLs and their customers, 3PLs will not realize these benefits without a clearly defined and well-executed integration strategy that considers customers, culture, and technology."

In for a landing

Given multiple uncertainties in today's volatile market, Armstrong advises 3PL customers to compare their current operations against prevailing market prices.

"If their existing pricing for 3PL services, such as warehousing, was established during the peak demand period following the pandemic shutdowns, they should consider reviewing these agreements," advises Armstrong. "Customers should plan to create an RFP with updated pricing and contract terms well in advance of their contract renewal."

Investing time in developing a comprehensive dataset of product items, orders, and shipments is crucial in preparing a successful 3PL RFP. "The RFP should be structured to ensure comparable bids, facilitating both the contracting and implementation processes with the 3PL providers," Armstrong says.

In addition, customers need to assess their domestic and international operations and identify where 3PLs can add value—whether that's in a specific region, through a certain capability, or both, and more.

"Second, resilience is key," adds Banks. "Look at your operations. Where can you diversify suppliers, shift inventory, optimize inventory mix, or reinvent inventory management strategies? A strong 3PL partner can help you do that and provide the tools and insights to navigate whatever comes next." •

—Karen E. Thuermer is a contributing editor for Supply Chain Management Review

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