Innovation Insight: Leverage Uncertainty With Probabilistic Planning

1 September 2025 - ID G00828420 - 16 min read

By: Joe Graham, Pia Orup Lund, Jan Snoeckx

Initiatives:Supply Chain Planning Digital Transformation; Supply Chain Planning

In today's supply chain landscape, fragile single-number supply chain plans create risk and divert resources. It's vital for supply chain planning leaders to account for uncertainty and risk by leveraging probabilistic approaches, enabling supply chains to adapt, recover and thrive during disruption.

Overview

Key Findings

- Supply chain organizations are being blindsided by volatility: 76% of organizations in a recent survey report that disruptions of different magnitudes frequently forced them to take action outside their S&OP plans. This frequency of "plan busts" erodes stakeholder confidence and drives costly, unplanned interventions across the business.
- Traditional, deterministic, single-point plans provide a false sense of precision; only 30% of supply chain leaders say their current planning process effectively manages uncertainty that impacts supply chain operations. As a result, planners spend excessive time refining deterministic plans rather than preparing for variability, leaving operations ill-equipped to pivot when assumptions fail.
- A recent Gartner survey found that 46% of respondents that use range-based planning say their plans effectively steer actions under volatility, compared with only 13% of those relying on single-point plans. By explicitly modeling uncertainty and embedding predefined guardrails, these organizations can proactively adjust forecasting, replenishment and capacity decisions, reducing reaction time and improving overall operational stability.

Recommendations

To build probabilistic capabilities, supply chain planning leaders should:

- Select SCP platforms with native probabilistic engines — such as Monte Carlo simulation and automated scenario analysis — for forecasting, replenishment, capacity and inventory. Simultaneously, establish strong data pipelines and governance for reliable probability inputs and train planning teams to interpret distributions and make risk-aware decisions.
- Pilot probabilistic methods in high-uncertainty areas, such as long-lead-time SKUs and capacity bottlenecks, to benchmark against deterministic approaches. Use expected value analysis to guide decisions and measure success by improvements in service levels, inventory costs and responsiveness to disruptions. Leverage quantified results to build the business case and secure executive sponsorship for broader adoption.
- Integrate range-based planning — defining upper and lower bounds for key variables — into supply chain processes to transition from deterministic to distribution-driven plans. Assign ownership for monitoring adherence to planning ranges, updating through performance reviews and institutionalizing lessons learned to ensure continuous improvement and sustained value.

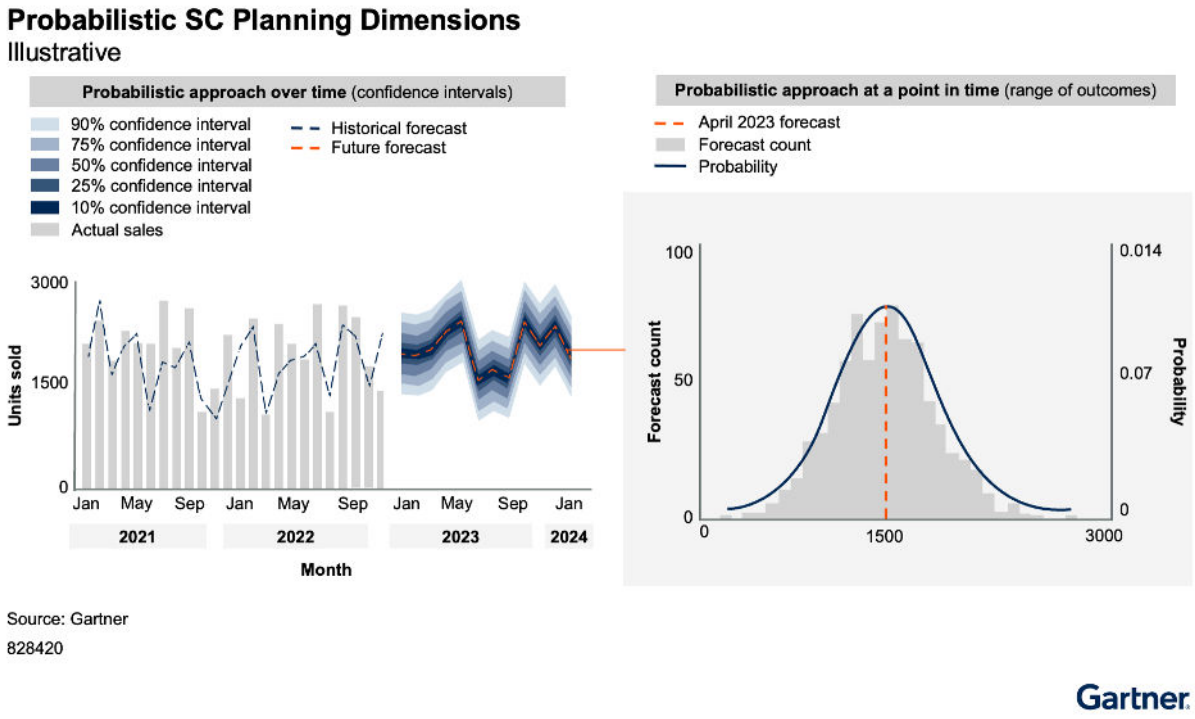
Introduction

Today's supply chains face relentless disruption with geopolitical shocks, unstable trade agreements, supplier failures and volatile demand swings that erode plan accuracy. Despite this volatility, most SC planning organizations still rely on deterministic, single-number plans that assume the most likely outcome and disregard the full spectrum of possibilities. This narrow approach overlooks real-world variability, leading to firefighting, inflated forecast errors, excessive safety stocks, frequent stockouts and missed revenue opportunities during demand surges.

Probabilistic planning reframes uncertainty as a strategic input, empowering leaders to make decisions based on expected value and the quantified business impact across a range of possible futures, rather than relying on deterministic estimates. Figure 1 illustrates two critical dimensions of the probabilistic approach: the range of outcomes at a specific point in time and how these ranges evolve over the planning horizon.

At any given point, the graph displays a probability distribution, revealing the full spectrum of potential outcomes for a forecast, rather than a deterministic value. This distribution quantifies both the most likely result and the probability of higher or lower outcomes, enabling planners to assess risk and opportunity with greater precision. Over time, the graph's confidence intervals demonstrate how uncertainty can widen or narrow as new information is incorporated, providing a dynamic view of forecast reliability.

Figure 1: Probabilistic SC Planning Dimensions

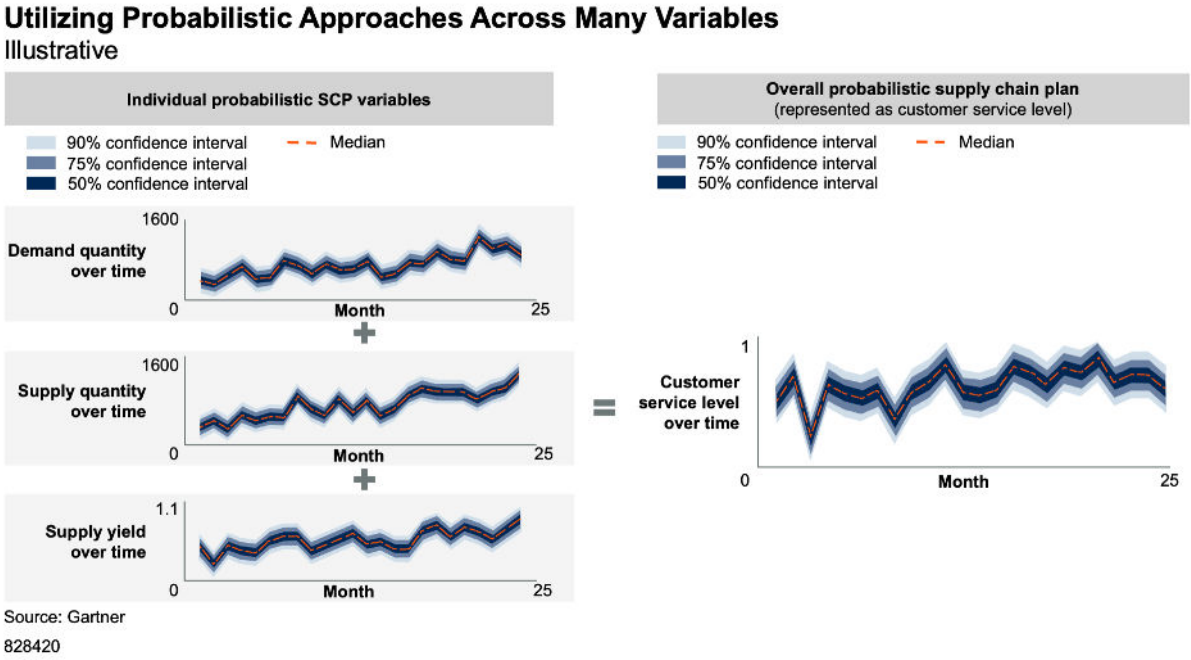


Source: Gartner
828420

Gartner

Building on this foundation, Figure 2 demonstrates how chaining probabilistic approaches across multiple variables, such as demand, lead time and supply, produces a composite probabilistic output. By integrating the probability distributions of these interconnected variables, planners can more accurately model end-to-end uncertainty and its impact on outcomes like inventory requirements or service levels. This enables organizations to move beyond isolated forecasts and adopt holistic, risk-aware planning strategies that reflect the true complexity of supply chain operations.

Figure 2: Utilizing Probabilistic Approaches Across Many Variables



By leveraging these insights, organizations can set dynamic inventory and capacity targets, proactively plan for best-case, worst-case and most-likely scenarios, and implement automated triggers when performance deviates from expected ranges. This enables faster, more informed responses to volatility, supporting the development of adaptive, antifragile supply chains.

Description

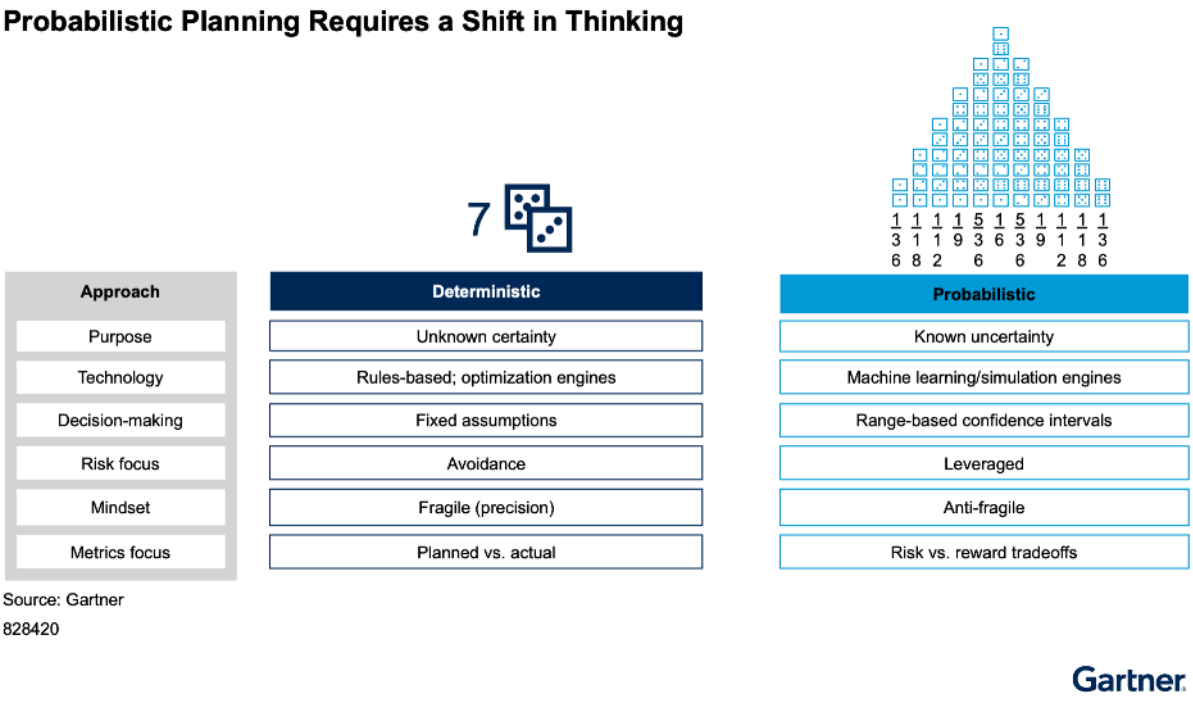
Probabilistic supply chain planning (SCP) refers to the application of probability distributions to represent variable inputs and parameters (e.g., lead times) and to construct supply chain plans (e.g., demand plans, replenishment plans, manufacturing plans and maximum and minimum inventory levels). These plans take into account uncertainty in the physical supply chain.

Benefits and Uses

Dynamic Supply Chains Require Probabilistic SC Planning

Organizations adopting probabilistic planning are realizing significant operational and financial gains, at a time when 77% of organizations report losses exceeding $1 million per disruption and 57% see at least a 30% increase in cost-to-serve when plans break. [1] By moving beyond deterministic plans, companies use probability distributions to inform every level of supply chain planning, from designing antifragile networks and configuring capacity, to optimizing inventory policies and dynamically adjusting production and replenishment in response to real-time events (see Figure 3). This enables more value-added scenario modeling and risk-adjusted decision making in supply chain planning processes, allowing organizations to align resources with likely outcomes, proactively manage disruptions and seize upside opportunities.

Figure 3: Probabilistic Planning Requires A Shift In Thinking



Eighty-six percent of supply chains reported experiencing a revenue loss when faced with high uncertainty exposure. [2] Probabilistic planning directly addresses this gap by building plans with a quantifiable, higher probability of being successfully executed and proactively modeling and managing variability and risk, rather than waiting for variance to surface in broken plans.

By transforming variable supply chain planning inputs such as demand, lead-time and yield uncertainty into structured probability distributions (as visualized in Figure 3), organizations can:

- **Gain early risk visibility.** Probabilistic planning uses statistically defined planning corridors to make known variability explicit, exposing supply instability and demand swings before they escalate. For example, if actual demand for a product consistently approaches or exceeds the upper bound of its forecast corridor, planners receive an early warning to investigate and adjust inventory or production, preventing potential stockouts or service failures. This early risk identification allows organizations to act, not just react.
- **Turn uncertainty into opportunity.** Probabilistic planning enables organizations to anticipate and capitalize on unexpected increases in manufacturing output. For example, when probability models signal a higher likelihood of producing more units than forecast, planners can quickly deploy strategies such as reallocating surplus inventory to high-demand regions, advancing shipments to key customers or coordinating with commercial on revenue-generating opportunities, ensuring that excess output drives business value rather than becoming a costly liability.
- **Enable confident, agile decision making.** By establishing statistically defined planning corridors and probability-based thresholds, organizations empower teams to make rapid, localized adjustments, such as modifying production schedules, when conditions remain within agreed risk limits. This approach supports greater automation and local autonomy, allowing planners to respond to variability and minor disruptions without triggering cumbersome, organizationwide replanning or multiple layers of approval. As a result, decisions are made faster and closer to the point of impact, ensuring supply chain agility while keeping actions aligned with overall business objectives.
- **Enable expected value-based scenario planning.** Probabilistic planning empowers organizations to evaluate and compare planning options by calculating the expected value of each scenario, factoring in both the probability and impact of a range of possible outcomes. For example, when deciding how much inventory to hold ahead of a new product launch, planners can weigh the potential costs of overstocking against the risk and lost revenue from stockouts, and choose the inventory level that delivers the highest average financial return over time. This approach enables leaders to make more informed, risk-aware choices that optimize for long-term business value, rather than relying on deterministic estimates or intuition.

By adopting probabilistic planning, organizations transform uncertainty into a strategic asset, gaining earlier risk detection, greater agility and more confident, data-driven decisions across the supply chain. This approach not only helps SC planning leaders proactively manage volatility and capitalize on unexpected opportunities, but also enables more precise planning for hard-to-predict items and supports smarter scenario choices using expected value. The result is a supply chain that is not just resilient, but increasingly antifragile, consistently improving performance, efficiency and business outcomes in the face of ongoing disruption.

These benefits arise across core functional planning domains, for example:

- **Demand planning and sensing:** Generate probabilistic forecast bands using historical error distributions or machine learning models to anticipate demand variability across channels and key accounts, enabling more accurate production planning, optimized inventory placement and improved service levels for retail partners and distributors.
- **Replenishment and inventory optimization:** Replace fixed safety stock formulas with risk-weighted inventory corridors, automatically triggering purchase orders when projected consumption moves outside these bounds. This ensures more responsive replenishment and reduces both stockouts and excess inventory.
- **Capacity and production scheduling:** Plan within capacity planning corridors, informed by inputs such as yield variability and maintenance-window uncertainties, dynamically recalibrating shift patterns or line allocations in response to real-time performance.
- **Spare and service parts planning:** Model failure probabilities over multiyear horizons to optimize multitier depot and warehouse inventory, reducing emergency shipping and ensuring service continuity.
- **Scenario analysis and simulation:** Replace random, gut-feel scenario planning with data-driven, probability-weighted simulations, ensuring that supply chain strategies are evaluated against the most plausible and impactful future outcomes.
- **Planning hard-to-predict SKUs:** Model both the likelihood and timing of demand for items with sporadic or highly variable usage — such as spare and service parts — to fine-tune stocking strategies, schedule replenishments more accurately and reduce stockouts and excess inventory, improving service continuity and working capital efficiency.

By integrating probabilistic engines into core planning processes, organizations transform uncertainty from a source of disruption into a lever for competitive advantage. This shift enables supply chains to move from reactive crisis management to proactive, policy-driven resilience.

As adoption accelerates, industries characterized by high variability and complex networks are at the forefront of leveraging probabilistic planning to address their unique challenges:

- **High-tech manufacturing (semiconductors, electronics):** Balancing wafer starts and process yield variations to maximize fab utilization under shifting demand.
- **Industrial and automotive OEMs:** Applying range-based scheduling to align paint shop capacity with volatile sales mix and supplier lead times.
- **Life sciences and pharma:** Managing regulatory and raw material lead-time uncertainties through scenario corridors linked to capacity and inventory policies.
- **Retail and consumer packaged goods:** Adapting inventory corridors to seasonal demand swings, promotional spikes and omnichannel fulfillment dynamics.
- **Industrial equipment and service:** Optimizing spare parts forecasts for long-tail SKUs with sparse demand history and high service penalties.

> **Case in Point: How A Top Retail Organization Navigated COVID-19 With Probabilistic Planning (JD.com)**
>
> During the 2022 COVID-19 lockdown in Shanghai, JD.com set itself apart by using probabilistic supply chain planning to manage unpredictable spikes in demand for essential goods. By leveraging probabilistic forecasting with explainable AI and a digital supply chain twin, JD.com was able to simulate a range of demand scenarios, stress-test its supply chain and make real-time, policy-based adjustments. This approach allowed the company to maintain product availability and stable pricing while competitors struggled. JD.com's use of probabilistic planning turned uncertainty into a strategic advantage, enabling agile and resilient supply chain operations throughout the crisis.

Risks

Probabilistic SCP, while offering significant advantages by embedding uncertainty into plans, also presents risks and challenges that organizations must address to ensure successful implementation and utilization. Without disciplined adoption, these innovations can introduce new pitfalls that undermine decision quality, inflate costs, and erode stakeholder trust. Planning leaders must proactively manage these risks across several categories:

- **Organizational and skill gaps:**
  - **Probability illiteracy:** Planners unfamiliar with statistical concepts may struggle to interpret confidence bands, select meaningful triggers or distinguish noise from true risk. This can lead to inappropriate buffer settings or false alarms. A significant risk is the lack of a basic understanding of what probabilistic planning is and how it differs from traditional deterministic plans. Deterministic plans provide a false sense of precision, often assuming the most likely outcome while ignoring alternative possibilities. Training planning teams on interpreting distributions, triggers and risk-aware decision making is crucial.
  - **Lack of trust in probabilistic outputs:** Even with the right tools in place, planners who do not fully understand probabilistic methods may distrust the results, questioning forecast ranges, scenario probabilities or automated triggers. This lack of trust can lead to overrides, underutilization of new capabilities or a fallback to familiar deterministic approaches. Building trust requires not only technical training but also clear communication of the business rationale, transparency in model logic and demonstration of real-world impact through pilots.
  - **Change resistance:** Teams and executives accustomed to one-number plans may resist multi-scenario workflows, risking reversion to brittle deterministic methods under pressure. This highlights a broader challenge in transitioning from a “fragile mindset” that tries to keep uncertainty outside the supply chain. Organizations need to drive framework changes to embrace uncertainty and move toward antifragility

- **Data quality and governance:**
  - **Garbage-in, garbage-out:** Probabilistic approaches leverage probability distributions to represent variable inputs like demand, lead times and yields. If the historical data used to generate these distributions is sparse, inaccurate or of low quality, it can produce misleading probability distributions. This can lead to suboptimal decision making, such as over- or under-buffering of safety stocks, which can in turn result in bloated safety stocks, stockouts or missed revenue. Organizations must build robust data pipelines and governance for high-quality probability inputs.

- **Vendor and solution limitations:**
  - **Limited E2E support:** Many SCP platforms still lack comprehensive end-to-end probabilistic support beyond demand forecasting, often forcing clients to cobble together bolt-on tools and manual workarounds. While several vendors support probabilistic demand forecasting, a strategic goal for some is to expand probabilistic analytics across all planning activities, ensuring every input has an associated measure of variability and every output presents a probability distribution of outcomes. True probabilistic engines feature capabilities such as Monte Carlo simulation and scenario analysis across various planning functions (such as forecasting, replenishment, capacity and inventory).

- **Decision complexity:**
  - **Actionable planning ranges:** If planning corridors are defined too broadly, they lose their effectiveness as actionable guardrails, making it unclear when planners should intervene. In probabilistic planning, the challenge is to establish dynamic planning ranges that trigger timely decisions. Unlike deterministic approaches, where thresholds are fixed and action points are clear, probabilistic planning requires careful calibration of ranges to ensure that alerts and interventions remain meaningful. This added complexity underscores the importance of ongoing review and adjustment to maintain decision relevance and drive effective outcomes.

Adoption Rate

Probabilistic planning remains an emerging capability, with adoption concentrated among organizations managing inventory risk, facing the highest volatility and possessing strong analytics maturity. Gartner positions probabilistic planning in the “Trough of Disillusionment” on the Hype Cycle for Supply Chain Planning Technologies, 2025, as initial proofs of concept deliver value but broad, repeatable implementations remain limited. As technology and organizational capabilities mature, probabilistic planning is poised to cross into mainstream adoption. Adoption is strongest in sectors with long lead times, complex networks and high variability, especially semiconductor and electronics manufacturing, automotive OEMs, industrial equipment, and service and spare parts industries.

Recommendations

To build probabilistic capabilities, supply chain planning leaders should:

- Select SCP platforms with native probabilistic engines — such as Monte Carlo simulation and automated scenario analysis — for forecasting, replenishment, capacity, and inventory. Simultaneously, establish strong data pipelines and governance for reliable probability inputs, and train planning teams to interpret distributions and make risk-aware decisions.
- Pilot probabilistic methods in high-uncertainty areas, such as long-lead-time SKUs and capacity bottlenecks, to benchmark against deterministic approaches. Use expected value analysis to guide decisions, and measure success by improvements in service levels, inventory costs, and responsiveness to disruptions. Leverage quantified results to build the business case and secure executive sponsorship for broader adoption.
- Integrate range-based planning — defining upper and lower bounds for key variables — into supply chain processes to transition from deterministic to distribution-driven plans. Assign ownership for monitoring adherence to planning ranges, updating through performance reviews, and institutionalizing lessons learned to ensure continuous improvement and sustained value.

Representative Providers

Flowlity, Hexight, Kallikor, Lokad, PTC (ServiceMax), Throughput.AI, ToolsGroup, Zebra

Evidence

2024 Planning for the CSCO and Supply Chain Under Volatility Survey. The objective of this survey was to assess approaches to improve the alignment and resilience of supply chain plans across strategic, tactical and operational horizons, ensuring effective disruption management and the achievement of strategic goals. The survey focused on two key issues: (1) sales and operations planning (S&OP) and financial misalignment and (2) disruption management. The research was conducted online from April through May 2024 among 264 respondents from North America (n = 159), Latin America (n = 9), Western Europe (n = 61) and Asia/Pacific (n = 35). Respondents were from organizations with $500 million or more in 2023 enterprisewide annual revenue. Industries surveyed included manufacturing (consumer products, industrial, high tech and life sciences; n = 140), transportation and logistics (n = 16), retail (n = 52), healthcare providers (n = 31), energy and utilities (n = 18), wholesale trade (n = 6) and natural resources (n = 1). To qualify for the survey, respondents had job roles tied to the supply chain planning and inventory management (n = 86), supply chain center of excellence (CoE) (n = 36), end-to-end supply chain (n = 114) and supply chain performance management and metrics (n = 28). They are involved with both supply planning and demand planning and have been either solely/jointly responsible or a key contributor to the decision-making process in the S&OP/IBP. Disclaimer: The results of this survey do not represent global findings or the market as a whole, but reflect the sentiments of the respondents and companies surveyed.

[1] **2023 Gartner Risk and Resilience Survey.** This survey was conducted to determine the best way for supply chain organizations to meet demand with supply profitably, despite disruptions. This research was fielded online from 2 November through 29 December 2023. In total, 606 respondents were surveyed across North America (n = 297), Latin America (excluding Brazil; n = 68), EMEA (n = 114) and Asia/Pacific (n = 127). Of the respondents, 243 were leaders, while 363 were staff; 138 respondents were from organizations with more than 25,000 employees, and 587 respondents were full-time salaried employees. Respondents were screened for whether: (1) their organization had experienced at least one high-impact disruption that was rare or different (2) that they had a personal role in responding to and (3) that the response had already concluded. The aim of the survey was to determine the impacts of two approaches: proactive mitigation and disruption response on supply chain outcomes. Proactive mitigation is a combination of three factors: visibility, agility and resilience. Disruption response consists of enabling operational talent to mobilize through strong institutional knowledge, governance clarity, a culture of autonomy and trust, personal contribution, and individual skills and attributes. Disclaimer: Results of this survey do not represent global findings or the market as a whole, but reflect the sentiments of the respondents and companies surveyed.

[2] **2023 Gartner Anti-fragile Supply Chain Management Survey.** This study was conducted to assess how supply chains cope with uncertainty. We sought to explore how they cope with different types of uncertainty, what measures and metrics they use, and what tactics and approaches they employ and to what effect. The research was conducted online from March through June 2023 among 164 respondents from North America and Western Europe. Qualifying organizations reported enterprise wide annual revenue for the most recent fiscal year of at least $500 million. Qualified participants were employed as full-time supply chain professionals in roles with primarily a business focus or a blend of IT and business focus. Disclaimer: Results of this survey do not represent global findings or the market as a whole, but reflect the sentiments of the respondents and companies surveyed.

Disclaimer: The organization (or organizations) profiled in this research is (or are) provided for illustrative purposes only, and does (or do) not constitute an exhaustive list of examples in this field nor an endorsement by Gartner of the organization or its offerings.

Recommended by the Authors

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

Hype Cycle for Supply Chain Planning Technologies, 2025

Use Range-Based Planning to Manage Supply Chain Uncertainty

Supply Chain Brief: What Antifragile Means for Digital Supply Chain Technology

Magic Quadrant for Supply Chain Planning Solutions