The 2022 Strategic Supply Chain Technology Themes

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Initiatives: Supply Chain Technology Strategy and Selection; Supply Chain Strategy

Global supply chains must deliver responses to disruptions, supply shortages and security incidents. Supply chain technology leaders can use this research to explore innovative technologies to help architect responsive and robust infrastructures across their supply chain.

Overview

Impacts

- Business disruption, as can be seen by recent events, is becoming the new normal. Supply chain leaders are eager to return to growth and re-establish business momentum, but are challenged at every turn. Adopting and adapting new innovative technologies and technology themes (groupings) is helping establish a robust and resilient infrastructure for weathering business disruptions and keeping focus on business outcomes.

Recommendations

Supply chain technology leaders responsible for technology strategy and selection should:

- Identify key critical business areas that are constraining business achievements and develop a combined business-IT group to explore where technology themes could apply.
- Use the combined business and IT resources to run rapid proof of concept projects to validate a technology's use in supply chain.
- Target your efforts around integration, visibility and data to address these three key weaknesses during periods of disruption.

Introduction

This document was revised on 7 April 2022. The document you are viewing is the corrected version. For more information, see the Corrections page on gartner.com.

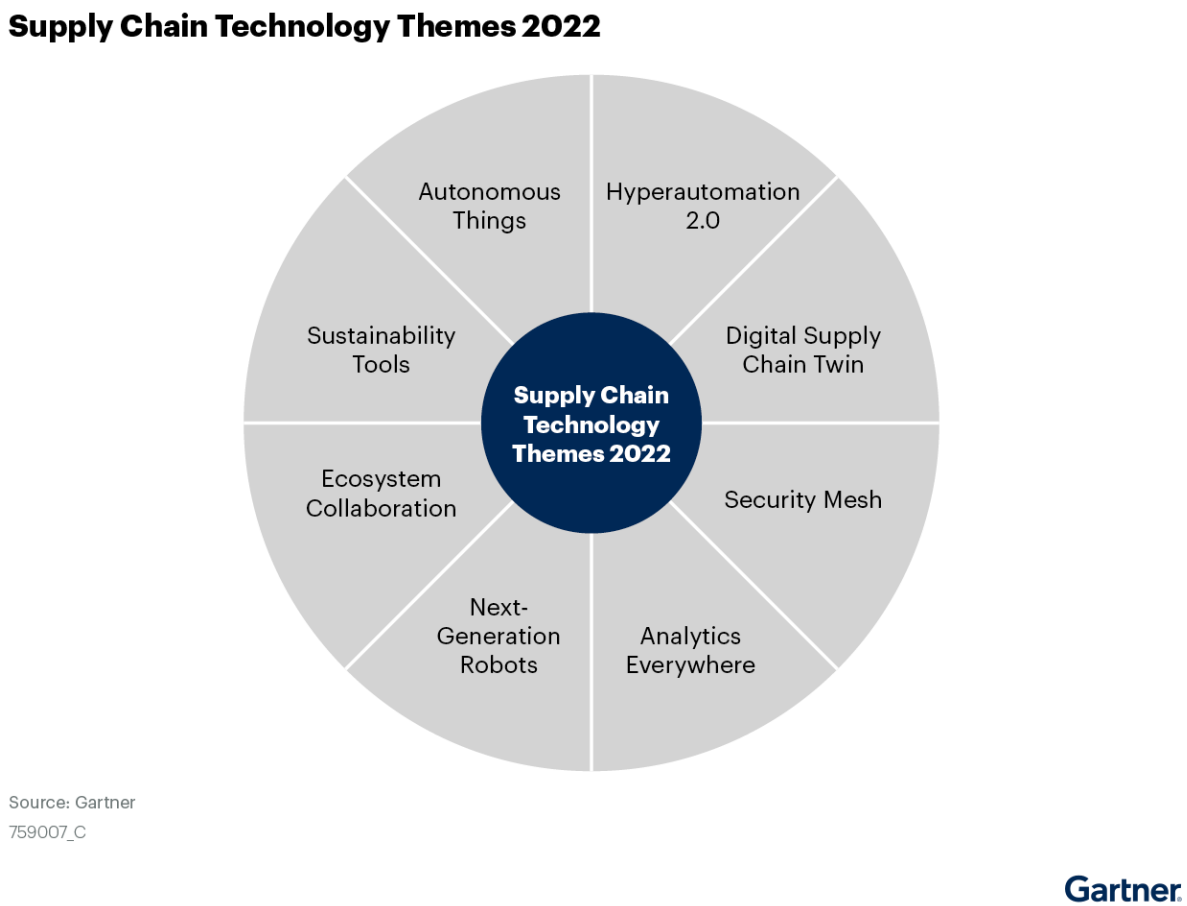
2022 is a watershed moment for supply chain technology leaders with increasing responsibilities to deliver solutions to address global impacts and risks resulting from the COVID-19 pandemic and other major events, such as climate change and increased threats posed by security incidents. These new events should not preclude ongoing digital business objectives and goals such as cost optimization, automation and enhanced customer experiences but rather may reprioritize efforts underway. Supply chain technology leaders must carefully plan and construct phased sequences of technologies that justify investments for immediate business demands while maximizing opportunities to position technologies' role in transforming supply chains of the future. This is a great opportunity to shift perceptions on the value that breakthrough technologies can have by integrating or augmenting existing technology architecture or combining to rapidly solve specific supply chain business challenges.

This year's report highlights technology themes that exploit a wide pool of technology enablers that combine to deliver more agile solutions to business objectives (see Figure 1).

- Themes center around smart and responsive technology combinations or augmentations while embracing major global events or drivers that impact the ability of an organization to maintain business continuity and grow. These might elevate the supply chain's role in meeting objectives tied to climate change, safe workspaces and security threats, or greater levels of transparency and autonomy. For example, tailored combinations of sensors, diagnostics and barcoding solutions (such as RFID) can be integrated with logistics and transportation management platforms to provide real-time status of key parameters across a shipment's journey such as location, temperature, status and ownership. In this specific use case the key differentiator of a themed approach is the agility to configure it for a single B2B interaction but it could be equally effective when deployed across a network of stakeholders including the customer/consumer.

- Themes are both interchangeable and agile in their own right. Future supply chain use cases are expected to adopt multiple different themes expressed in sequence or together. For example, hyperautomation 2.0 establishes foundations for developing ecosystem collaboration or next-generation robots connecting with autonomous things to optimize autonomous workflows in manufacturing, warehousing and final mile logistics.

Figure 1. Supply Chain Technology Themes 2022



While this report focuses on the top eight themes for 2022, supply chain technology leaders should not rule out contributions that can be made through other technology innovations. This report also includes notable mentions with additional insights to seven further themes. Additionally, we take a retrospective assessment of recent technologies trends and 2021 themes that should be considered complementary in a toolbox of enablers to be leveraged for specific business needs or objectives.

Theme Profiles: Click links to jump to profiles

Hyperautomation 2.0
Digital Supply Chain Twin
Security Mesh
Analytics Everywhere
Next-Generation Robots
Ecosystem Collaboration
Sustainability Tools
Autonomous Things
Notable Mentions

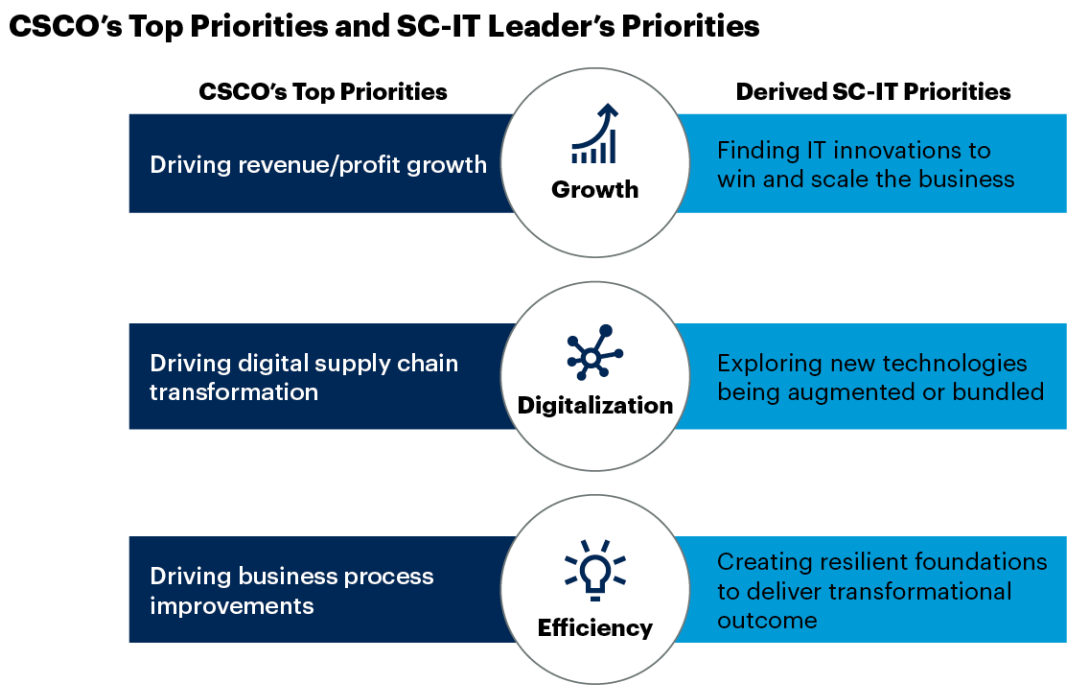
Impacts and Recommendations

Explore Innovative Technologies to Weather Infrastructure Disruptions and Focus on Business Outcome

CSCOs and senior C-suite leaders increasingly are taking a more hands-on approach to understand the full dynamics of their supply chains, both within the enterprise and across the end-to-end value chain (see Note 1).

The central role supply chains play has been elevated as a result of pandemic disruptions and have sent a message of critical importance of having a unified and digitized network of stakeholders, people, processes and things. Even the most mature organizations will have gaps, critical paths and immaturity in certain areas of the value chain that need to be addressed in supply networks, outsourced production or final mile logistics. Results from Gartner's 2021 Supply Chain Technology User Wants and Needs Survey [1] indicate the multidisciplined approaches for identifying innovative technologies senior supply chain leaders should take to orchestrate the right technology investments at the right place and right time. CSCO's top priorities where they look for guidance from their IT counterparts are growth, digitalization and efficiency (see Figure 2).

Figure 2. CSCO's Top Priorities and SC-IT Leader's Priorities



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Time is a precious commodity for supply chain technology leaders in making accelerated, yet assured, decisions for progressive technology investments. Supply chain leaders must make assured decisions that demonstrate technologies can be robust in smarter and more agile ways. Themed approaches provide supply chain leaders with options for more accelerated decisions on technology investments with an open portfolio of technologies in which to trial and pilot. A renewed companywide focus on due diligence being placed on mapping across the full value chain should be carefully balanced with business continuity and replan for the future.

Given the highly extended and dynamic nature of supply chains, there are always opportunities to prioritize compact pilots that:

- Concentrate on critical paths, risks, gaps and areas of immaturity
- Demonstrate the value of investments of clusters or combinations of technologies

For example, service or contract transactions between two key 3PL providers as part of product handovers may be the bottleneck impacting an entire logistics workflow that may have relied on spreadsheets or semimanual process of exchanging information. By taking a themed approach to accelerated technology discovery, a solution can be deployed from within the supply chain in collaboration with the two partners that can automate, optimize and secure transactions as well as update status in real time. This might include a combination of tools that focus on edge computing, real-time visibility, advanced IoT applications and blockchain as a service. The compact nature of the ecosystem introduces accelerated opportunities for shared value creation and onboarding of partners who may have their own levels of immaturity around digitalization or connectivity.

Supply chain technology leaders should sponsor new approaches to rapid but robust value assessment for technologies by ensuring process and governance steps are also addressed as prerequisites such as segmentation, risk assessments, mapping and digital maturity assessments.

Hyperautomation 2.0

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Client Challenge: How can supply chains exploit advanced technology deployments to supplement and optimize more automated tasks, transactions, and operations at scale across the value chains?

Definition: Hyperautomation is a business-driven, disciplined approach that organizations use to rapidly identify, vet and automate as many business and IT processes as possible. Hyperautomation involves the orchestrated use of multiple technologies, tools or platforms. Hyperautomation 2.0 extends potential further in assessing all innovative technologies migrating away from an early focus on artificial intelligence (AI), machine learning (ML) and robotic process automation (RPA). Targeted combinations can agnostically (and retrospectively) complement and deliver optimization tools for digitalization, collaboration and shared value creation roadmaps across dynamic networks such as in supply, manufacturing or product distribution. “Processes” refers to not only tasks and activities in the execution, working or operational environment, but also in planning, analysis and discovery.

Outlook: Fresh approaches to implement faster, more accurate and informed decision making and trust across digitally connected networks supports organizations migrating away from traditional "projectized" or siloed technology deployments. Hyperautomation 2.0 reinforces urgency in remote management and monitoring, fully or semiautonomous operations, visualizing, mapping and optimizing digital workflows across zones and domains that have high data processing traffic or that have traditionally observed large transactional workloads, like logistics of manufacturing.

A disciplined approach to exploiting hyperautomation 2.0 can provide supply chain technology leaders with agile approaches to delivering discovery opportunities and infrastructure for unified digitally-connected networks of stakeholders. By exploiting themed approaches, hyperautomation 2.0 provides mechanisms and tools to adopt robust responses to legacy supply chain applications reliant on distributed and fragmented inputs of human judgment.

During the next five years, we expect hyperautomation 2.0 to underpin initiatives that address optimized responses to warehousing, transport, production, supply chains and others. Solutions will include intelligent remote fulfillment networks in warehouse or yard management domains, virtual training through personalized/tailored services in digital workspaces or personalized e-commerce applications. Other examples include autonomous vehicles (AVs), delivery robots or autonomous chassis (for yard management). Hyperautomation 2.0 will also provide continued resources for progressive process orchestration like automating multiple processes to execute workflows around complete life cycles. For example, this would include pharmaco-vigilance in life sciences or assuring greater levels of predictive demand planning for more resilient and accurate forecasting.

Use Cases:

- Extended levels of visibility across diverse groups of assets (including human resources) in healthcare networks. Connected networks for real-time alerts of critical shortages or potential shelf-life incursions for tools, components, kits and consumables. Automating traditional manually intensive tasks in checking and assigning inventory and medical services for scheduled surgical procedures.
- Optimized product and logistics workflows in extended distribution and multienterprise networks, autonomous and connected networks of smart robots, drones and machines that map, analyze and refine the product workflow across its entire chain of custody. This can include warehouses, yard environments, fulfillment centers, remote parts depots and distribution centers.

- AI, ML and analytics applications in augmenting traditional manually intensive tasks in CRM and customer services environments and creating a more inclusive and immersive customer environment. Tools for locating, capturing and consolidating customer profile data points and making customized recommendations. Automated services to support agents in accessing fully populated profiles in a single click, without the need to switch across different applications or landing pages relating to purchases, orders, returns or historic CRM interactions.

Recommendations:

- Extend communications to explore the value of hyperautomation 2.0 to address long-standing legacy or supply chain maturity issues such as tools for network visualization, mapping, transparency and real-time visibility. This might include technologies such as API interfaces, ML, graph technology, robotics, edge computing and smart machines.
- Apply hyperautomation 2.0 as a key tool and reference framework to support future planning in developing roadmaps in three key steps — automation, augmentation and autonomy — against initiatives such as digital workspaces, contactless transactions, supply chain planning, capacity planning, network reconfiguration and exception management.

Research References:

Beyond RPA: Build Your Hyperautomation Technology Portfolio

Top Strategic Technology Trends for 2022: Hyperautomation

Emerging Technologies: Research Roundup on the Hyperautomation Opportunities Ahead

Sample Vendors: Alteryx, BJSS, Interlake Mecalux, OMP, rapidMATION, ThinkIQ

Digital Supply Chain Twin

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Client Challenge: How can I mature toward higher quality and faster decision making and drive supply chain convergence?

Definition: The digital supply chain twin (DSCT) is a high-fidelity digital representation of the physical (often multienterprise) supply chain. It is a dynamic, real-time and time-phased representation of the various associations between the data objects that ultimately make up how the physical supply chain operates. It is the basis for local and end-to-end (E2E) decision making for the supply chain that ensures that this decision making is aligned horizontally and vertically throughout the supply chain. The DSCT is derived from all the relevant data across the supply chain and its operating environment.

Outlook: DSCTs are part of the digital theme that describes an ever-increasing merger of the digital and the physical world, yet this is aspiration for the time being and will take years to mature. With the impact of the DSCT being transformational, it focuses on creating the appropriate digital representation of the physical supply chain. It creates end-to-end visibility and supports end-to-end decision making. Through this linkage to the real world, situational awareness and supply chain decision making are greatly enhanced. Organizations would use a DSCT for supply chain decision making, connecting from strategic through to executional level systems. Appropriate predictive and prescriptive analytics (including ML and AI) would be applied to the DSCT, enabling aligned — and to various degrees automatic — decisions to be made across the variety of supply chain domains. By being a truer representation of the real-world physical supply chain, these decisions would be faster and of a higher quality. Also note that at the later stages of a digital supply chain journey, a company will want to converge E2E decision making with E2E supply chain visibility. This will result in the coalescence of its digital supply chain twin initiative with its control tower initiatives. At this stage of maturity, there will no longer be a separation between the digital supply chain and the E2E control tower — just the DSCT.

Use Cases:

- In general, use a digital twin for enhanced decision making. Appropriate predictive and prescriptive analytics, including ML and AI, should be applied to the digital supply chain twin, enabling aligned — and to various degrees automatic — decisions to be made.
- In warehouse management, warehouse and delivery execution analysis and optimization, simulation of alternatives due to change in demand or other influencing parameters.

- In inventory management, ingest data from internal and external sources, and run AI and ML models to generate predictive insights on where inventory risks are occurring in the network. This enables planners to act prior to risks materializing, like optimizing inventory positions across the network.

Recommendations:

- Develop a digital roadmap that enables aligned supply chain decision making. Put the notion of a DSCT at the center of this technology roadmap as is a prerequisite for Stage 5 supply chain maturity.
- Be prepared to experiment and/or go outside of your usual technology providers to get this capability. It is emerging and still underdeveloped.

Research References:

Innovation Insight for Digital Supply Chain Twin

Quick Answer: Will I Need Both a Digital Supply Chain Twin and a Supply Chain Control Tower?

Market Guide for Data Analytics and Intelligence Platforms in Supply Chain

Sample Vendors: Bluecrux, Blue Yonder, E2open, Kinaxis, o9 Solutions, Tada Cognitive Solutions

Security Mesh

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Client Challenge: How can I take immediate actions to leverage technologies to assure supply chain systems, tools, applications and people are safe and secure at all times?

Definition: Security mesh is a structured framework of governance, collaboration and applied technology applications that are orchestrated from within supply chain. Security mesh adopts a first principles approach to develop cohesive and collaborative approaches for preventative, predictive, automated and distributed security applications, and intelligence services across the extended end-to-end-value chain. Security mesh impacts also extend to people and customers in creating safe and secure working and client environments and protecting personal information.

Outlook: Security in supply chains is only as strong as its weakest link Supply chain security mesh embraces the reality of dynamic, interconnected and increasingly digitalized supply chains in addressing an evolving nexus of threats posed by cyber, digital and data. Compromised software, devices, data, portals or exposed systems in functional areas across the value chain can easily be exploited by criminals or hackers. Security events may also extend to people and customers by increasing safe and secure working and client environments.

The European Union Agency for Cybersecurity (ENISA) reported concern in August 2021 that supply chain attacks may increase by four-fold in the remainder of 2021. [1] A wave of publicly reported global supply chain security incidents has elevated security to the top of the agenda in many organizations. For example, the SolarWinds supply chain attack of late 2020 impacted around 18,000 organizations, [2] the CCleaner malware attack in 2017 [3] and the Equifax data breach. [4] COVID-19 pandemic disruptions have been a window of opportunity for criminal gangs to target organizations by exploiting the weakest links in networks or systems, often looking for easier targets outside of traditional IT organizations that have historically invested in security architecture.

With the complex and dynamic nature of modern supply chains coupled with greater levels of digitalization, distributed networks and precedents of more remote work supply chains present richer and easier opportunities for cybercriminals in exploiting weaknesses. Present threats to supply chain include but are not limited to:

- Security and data breaches from tools, applications and operational systems, either from internal or external agents
- Ransomware and malware attacks such as computer worms and trojan horse viruses
- People leaking sensitive data, intellectual property and personal information outside the business through hackers, third-party agents, stakeholders or even employees
- Corrupt or malicious code
- Firewall, interface and landing page breaches
- Legacy software vulnerabilities due to historic deployments that may not have undergone robust security screening
- Hardware attacks involving devices, packaging, spyware, assets and interfaces
- Identify theft or digital impersonation

Use Cases:

- Cyberthreat and security intelligence platforms, hubs and applications for digital networking and mapping across the supply chain, including third-party risk analytics, version control policies, threat alerts and collaborative intelligence across security peer and networking communities.
- In collaboration with the wider IT organization, progressive deployments of intrusion detection systems (IDSs) and intrusion prevention systems (IPSs) across targeted zones of the supply chain or in response to known, predicted or anticipated events.
- Cyber AI, machine learning and predictive analytics tools and applications to process and cleanse data and insights to support the development of a cyberthreat intelligence (CTI) hub that can ensure future business continuity and resiliency.

Recommendations:

- Establish a security governance council for supply chain that embraces holistic approaches to mapping out a “cradle to grave” approach on security vulnerabilities spanning the entire value chain. Embrace expertise by collaborating with IT architects, software engineering leaders, product development teams, engineering and risk and quality leaders to elevate supply chain’s prominent role in identifying, mitigating and preventing supply chain security incidents.
- Engage technology partners and specialist security integrators with established IT and cybersecurity pedigrees who are invested in extending and developing solutions for supply chains while addressing key differentiators and nuances that supply chain presents.

Research References:

The Importance of an Agile Cybersecurity Program: Lessons Learned From the COVID-19 Pandemic

How Software Engineering Leaders Can Mitigate Software Supply Chain Security Risks

Sample Vendors: Keeper, Interos, Orpheus, a McKinsey company, UpGuard, WhiteSource, XenonStack

Analytics Everywhere

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Client Challenge: How can I leverage big data — structured and unstructured, internal and external — to provide not only insights but also drive decisions and actions for delivering results?

Definition: Analytics are capabilities that deliver reporting, interactive data visualization and/or advanced analytics and intelligence — including ML, predictive and prescriptive analytics — either embedded directly into an enterprise business application or augmented as part of an intelligent data platform. The data is managed by the application or data platform, and the visualizations and reports are placed directly within the user interface to improve the context and usability of the data for supply chain business users and analysts.

Outlook: Companies are taking a bimodal approach when it comes to analytics, first using more embedded analytics in existing core supply chain applications and then complementing with intelligent data platforms. With the growth of data, analytics and AI could be applied to explore even further, transforming data into information and deeper insights. Business application platforms now provide a certain degree of integrated analytic functions — from reporting and dashboards to self-service analytics, alerts, collaboration, data preparation and ML on a unified, scalable architecture with common administrative and management functions. Lately, companies are not only leveraging analytics as embedded capabilities within core business applications but also complementing this with intelligent data platforms. These tools use real-time or near-real-time data from disparate sources and leverage rules, relationships and innovative technologies to drive anticipated business outcomes along certain use cases, all on the basis of more connected and correlated data as part of a digital supply chain twin.

Use Cases:

- In industrial manufacturing companies (such as automotive) embedded IoT, analytics and intelligence devices strategically applied to critical machine parts and connected management systems to continuously monitor performance, wear and tear and support optimized maintenance scheduling and optimized life cycle management.
- “Smart” assets can also integrate to support inventory replenishment fulfillment, greater levels of real-time visibility during processing phases, quality control and acceleration for new product development cycles.

- Smart energy devices, sensors and management systems (for example, smart energy grids) to enhance sustainability footprint, reduction of energy consumption in manufacturing and logistics (warehouse and transportation) operations.

Recommendations:

- Drive to integrate the analytics and intelligence into workflows where it can deliver more contextualized insights at the point of impact while performing specific tasks in the application.
- Look for solutions that not only support embedding of charts and visualizations, but also go deeper and integrate the data, analytics and intelligence into the fabric of the business application.

Research References:

Hype Cycle for Artificial Intelligence, 2021

Market Guide for Data Analytics and Intelligence Platforms in Supply Chain

5 Categories to Track the Benefits of Analytics Initiatives

Sample Vendors: Aera Technology, Blue Yonder, E2open, Google, IBM, Infor, Manhattan Associates

Next-Generation Robots

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Client Challenge: How can I evolve toward fully autonomous operations, proactively autonomous tasks and collaboratively autonomous missions where various robots, humans and other things work in consort with one another?

Definition: Emerging next-generation robots are a consolidation of several capabilities centered around mobility, sensory awareness and adaptive learning exploiting the use of AI to automate functions previously performed by humans. Robots are increasingly collaborative and their automation now goes well beyond the rigid programing models of the past. Robots now exploit the massive amounts of data generated from multiple forms of sensors used in advanced AI capabilities. These capabilities provide robots with behaviors that enable them to interact more naturally with their surroundings and with people within the four walls of an enterprise.

Outlook: Enterprise-centric next-generation robots are rapidly moving from science fiction to productive platforms transforming a wide range of industries. Such robots are more flexible and adaptive and now can be applied to a variety of tasks where previous generations of robots were highly specialized, requiring complex programming to do a single thing. The technologies behind next-generation robots are enabling rapid growth, which will accelerate as greater autonomy increases the applicable use cases while reducing the cost of deployment. The missions for which robots within the four walls are utilized are evolving. Uses range from semiautonomous machine-human collaborations to fully autonomous operations, proactively autonomous tasks and then collaboratively autonomous missions where various things work with one another to achieve a common objective. Demand is driven by the realization that robots can perform tasks much more cheaply than human labor. In the past, robots were programmed to do one thing and largely operated by themselves. However, increasingly, companies will have heterogeneous fleets of robots where work will have to be orchestrated across different robots — robots will have to interact with each other and they will need to communicate with other types of automated equipment like elevators and doors.

Use Cases:

- Industrial robotics manufacturing environments to enhance quality, processing precision and to supplement traditional complex or hazardous human-based tasks. Integrated robotics with virtual and augmented reality and workflow applications to supplement tasks requiring advanced levels of human skill and dexterity. For example, robots for dispensing adhesives, bonding agents or catalysts, handling and moving hazardous biological or chemical reagents, plasma or water jet cutting robots for precision machine parts or robot vision systems for continuous and 360-degree quality inspection.

- Multirobot orchestration platforms for integrating business applications and heterogenous fleets of operational robots, both mobile and stationary, within the four walls of the enterprise. They orchestrate and assign work, and monitor and coordinate the activities of diverse fleets of robots.
- Warehouse picking robots that pick up, handle and move goods using some form of reticulated arms and grippers. They employ advanced AI and vision systems to recognize and pick up items that are not in consistent places and orientations and are not the same sizes and shapes.

Recommendations:

- Identify enterprise-centric use cases where robots can deliver specific and immediate value that is aligned to your organization's level of maturity.
- Develop a robotics center of excellence (COE) to socialize robotics across the organization.
- Evaluate the use of robots as both substitutes and complements to the human workforce. Note that labor reductions seem the most likely drivers, but improvements in overall throughput and productivity will be the primary value.
- Explore the potential value of next generation robots when looking to build new automated facilities where some industries are further along in utilizing this technology.

Research References:

Hype Cycle for Supply Chain Execution Technologies, 2021

Emerging Technologies and Trends Impact Radar: Drones and Mobile Robots

Market Guide for Smart Robots in Retail

Chief Robotics Officer: A Top Automation Trend for 2022

Sample Vendors: IAM Robotics, KUKA, Rapyuta Robotics, READY Robotics, SVT Robotics, RightHand Robotics

Ecosystem Collaboration

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Client Challenge: How can a digital environment support a culture that fosters greater levels of communications, collaboration and shared value creation?

Definition: Ecosystem collaboration tools are digital technologies and services that create a collaborative work environment for people that generates new and continuous shared value opportunities. Collaboration ecosystems deliver tools to support continuous evolution for integrated and digital networks of stakeholders and partners including visualization, network mapping and redesign, business intelligence, security enhancements, real-time communications and continued intelligence feedback loops for further optimization and process improvements.

Outlook: Better collaboration, shared goals and value creation and trust are common aspirations shared across organizations — both within an enterprise and externally across the extended value chain. The pandemic impacts of 2020 and 2021 have brought attention to senior supply chain leaders that across critical regions of many supply chains even basic communications or digital connectivity may not be in place across key stakeholders (for example, multitier supply networks or outsourced processing and packaging networks). The absence of real-time connected networks of stakeholders working collectively can have big ramifications on decision making, such as customer fulfillment or remedial actions.

Establishing better collaboration across a predetermined or evolving ecosystem of stakeholders has proven challenging for many organizations. This is due in part due to functional approaches to technology investments, culture or digital maturity imbalances across key stakeholders. Historically, collaboration has often been viewed as a byproduct of broader initiatives such as traceability, digitalization or visibility as opposed to foundational in order for these objectives to be delivered. Integration and extended visibility as prerequisites for collaboration ecosystems can be viewed as a critical juncture in many supply chains in their ability to mature and make more informed collective decisions.

Ecosystem collaboration solutions and services establish foundational network visualization and mapping tools to support continuous maturity in advancing to real-time digital connections across people, data, machines, systems, processes and things. Evolving collaboration ecosystems explore the critical need for continuous improvement through collaboration and interoperability in digital ecosystems.

Use Cases:

- Voice of the customer, immersive applications and channeled data spearheading supply chain network redesign for global retailers, manufacturers and suppliers to collaborate closely to create transparency on a product's impacts to the environment, such as sustainability, ethical trade and provenance.
- In the life sciences and healthcare sector, stakeholder-led working groups representing manufacturers, wholesalers, logistics partners and healthcare providers working collaboratively with regulators and innovation partners to shape, model, influence and configure regulatory protocols for new generations of products.
- Advanced IoT and data capture technologies deliver an integrated connected network of critical assets and components on aircraft, communicating in real time with each other and with key supply and service stakeholders. Ensures business optimization and continuity for predictive maintenance, performance monitoring, rapid fulfillments of critical inventory and accelerated product development opportunities.

Recommendations:

- Establish collaboration ecosystems as a key pillar as part of multiyear, integrated digital supply chain strategy and roadmap to experiment, pilot and roll out technologies. Do not be overly ambitious with trying to establish a collaboration ecosystem in your initial effort.
- Target accelerated approaches to collaboration by exploring themed approaches to discovery in compact groups of stakeholders. Prioritize integration, extending visibility, data rationalization and functional interfaces across disparate or remote stakeholders.

Research References:

Industry Insights: Ecosystem Partnerships for Consumer Goods

Supply Chain Executive Report: Fostering a Digital Supply Chain Ecosystem

Consumer Goods Trend: Ecosystem Partnerships

Sample Vendors: Cloud Inventory, Blue Yonder, Generix Group, SAP (Signavio), Streamliner, VKS

Sustainability Tools

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Client Challenge: How can companies establish robust digital sustainability roadmaps and what roles do technologies play as part of balanced trade-off assessments?

Definition: Sustainability tools are an evolving spectrum of applications, services and capabilities. They provide digitized responses to use governance, data capture and predictive analytics for events associated with corporate, government or global directives for sustainability, environmental and circular economy impacts and mandates. Sustainability tools extend beyond a focus on just data collection and reporting in delivering technology architecture. They can enhance levels of digitalization, collaboration and visibility often critical in establishing foundations in which to formalize process and management disciplines needed for a progressive evolution of sustainability programs.

Outlook: Supply chains are increasingly positioned as important hubs in which to launch and establish environmental and sustainability centers of excellence and to differentiate their products and services. Sustainability has impacts that span the entire value chain — from plan, to source, to make, to deliver and, finally, to the service domain. This year's theme creates a clear distinction for the need for supply chains to be ready and mature in their response to sustainability impacts in areas such as environment, social and human rights, always correlated to different levels of maturity.

Specific to an individual organization and their product portfolios, sustainability criteria are often the initial catalyst for companies to establish broader governance programs supporting environmental, social and governance (ESG) mechanisms for evaluating and reporting on readiness and robustness to mandates and risks. Supply chain's key responsibility is reflected further in end consumers demanding to be continuously informed on products they are purchasing (for example, responsible sourcing or human rights impacts).

Organizations must develop closer relationships with and assess shared goals across key supply chain stakeholders and across the end-to-end supply chain to prioritize sustainability across their own processes. Global supply chains have an instrumental role to play in contributing to an enterprise's response and strategy to environmental commitments that may impact one or many of their products or services. Global initiatives on environmental sustainability including the recent COP26 with focus on climate change and the European Green Deal, have further elevated priorities. Failure to invest in tools that establish the digital foundations in which to meet obligations across a wide range of sustainability goals and metrics will have a significant impact on brand or company global image and consumer value perception. It also presents a risk of stranded assets, vulnerability to a carbon tax, unpreparedness for climate-related supply chain disruptions and, accordingly, shareholder value.

Use Cases:

- Sustainable, smart and connected packaging incorporating voice of the customer applications and information to end consumers pertaining to source, provenance, chain of custody for ethical/fair trade. Also biodegradable materials and robust reusable materials.
- Embedded and augmented route optimization tools in transportation using machine learning and artificial intelligence to compute optimal sustainability journeys across single delivery, multistop and across last-mile fulfillment networks.
- Network mapping, visibility and collaboration tools to report, track and monitor compliance and performance metrics across diverse stakeholders' networks such as in supply or manufacturing especially in sectors such as consumer products, apparel, automotive and food and beverages.

Recommendations:

- Determine the stakeholder and customer ecosystem impacted as a result of pressing sustainability objectives. Get the right foundations in place to invest in resources and services to establish foundational digital, unified visibility and mapping capabilities across these ecosystems prior to wholesale technology reviews.

- Invest in tools such as machine learning and analytics that can leverage data rationalization of retained and siloed data pertaining to sustainability and environmental impacts across the value chain. Focus on continuous data quality insights in maturing the sustainability infrastructure as well as real-time monitoring and sharing of new data, regulations, stakeholder feedback and global directives. This will equip leaders across the organization with real-time data to make informed decisions that align with sustainability goals but also allow for disclosure to stakeholders and customers.

Research References:

Research Roundup for Sustainability: Essentials to Inform the Supply Chain Response to Climate Change

Apply Digital Business to Sustainability

4 Supply Chain Sustainability Leadership Actions in Response to the IPCC Report

Sample Vendors: ABACO, Circulo Health, Greenplan, ImpactBuying, Sourcemap, Specright, Transparency-One

Autonomous Things

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Client Challenge: How can I utilize autonomous machines or tools to optimize workflows and enhance efficiencies and safety in key areas such as manufacturing, transportation, field-based operations or distribution?

Definition: A wide spectrum of physical machines, specialist hardware devices, robots, vehicles, drones and finished goods assets capable of independent movement and supported through AI applications to help them complete predefined transactions, missions or objectives. Autonomous things can augment traditional manually intensive physical tasks with greater efficiency, clarity and safety. Working independently or in networks they also enhance a new generation of immersive work and customer experiences through enhanced service efficiency and transparency.

Outlook: Autonomous things support safer, more efficient and optimized processes and operations across supply chains. Robots and smart machines have been familiar fixtures in domains such as manufacturing and warehousing for many years but often were limited in scope, being either tethered or physically fixed to a single location. Autonomous things exploit the next generation of robots as well advanced drones and specialist machines. They can be mobilized to address day-to-day transactions (for example, package sorting, fulfillment and delivery) as well as more targeted tasks (such as safety inspections of remote field-based assets or surveying inhospitable locations where it might not be viable or practical to consider human-based resources).

Autonomous things have evolved quickly with advances in new sensors, tracking, diagnostics, specialist transportation assets and data capture technologies. They will continue to offer significant potential in helping supply chain technology leaders transition traditionally labor- or time-intensive processes over to networks of "things." Autonomous things offer agility to configure delivery to high-risk/final-mile objectives or to integrate into existing multitask processing or fulfillment environments to augment manual tasks and operations (for example, for pick/pack or returns in distribution centers and warehouses).

While autonomous things can operate without data communications network coverage, it will be increasingly important for supply chains to localize more compute and decision making on the "thing" itself, such as with advanced IoT applications or edge computing capabilities. Advanced evolution in network communications (such as with 5G) provides greater data bandwidth for autonomous things to operate. This provides supply chain technology leaders with greater functionality to communicate with things over longer distances and opportunities to augment additional technologies such as smart cameras, video, machine learning or analytics.

Use Cases:

- Autonomous cars and trucks for improved fuel usage, enhanced safety and security for drivers and other road users and lower emissions for carbon.
- Independent immersive devices, machines and applications delivered across 5G data communications networks. Working virtually, intuitively and interactively with an operator in real time to navigate complex and intricate phased instructions in highly technical manufacturing phases.

- Digitized workflows of real-time visibility, monitoring tools and drones supporting the development, manufacturing and distribution cycles to ensure critical medical supplies (such as vaccines) are delivered optimally, securely and safely to end patients in regions that are remote or difficult to access.

Recommendations:

- Test autonomous things in small scale pilots and POCs to prioritize agile deployments focusing on smart machines, devices and objects that create immediate visibility in their application and viability as part of future scaling.
- Identify opportunities to address transactional, critical paths or data processing bottlenecks across operational and enterprise systems. Develop roadmaps to embed a continuous process review of autonomous things as part of enhanced automation, augmentation and autonomy.

Research References:

Emerging Technologies: The Future of Autonomous Things

Autonomous Things Deployment: 5 Best-Practice Stages That Require Manufacturing CIO Leadership

Lessons From Mining: 4 Autonomous Thing Benefit Zones for Manufacturers

5 Building Blocks to Achieve Autonomous Transportation

Market Impact: Regulation Is Making Way for Autonomous Deliveries

Sample Vendors: AGVE, Fetch Robotics, KUKA, Peloton, TuSimple, Zipline

Notable Mentions

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The following categories did not make this year's themes but should be considered close contenders for inclusion in a suite or portfolio of technology applications and solutions as part of a themed adoption. Across 2022, supply chain technology leaders have shown increased levels of interest in exploring (and re-exploring) the status and adoption of these technology areas in providing further bandwidth and agility in fulfilling immediate and strategic objectives.

Blockchain Renaissance

Blockchain in supply chains observed much hype peaking in the period 2017 to 2018. There was a noticeable decline in activity in 2019 and 2020, directly correlating with its position on the Peak of Inflated Expectations on the Gartner Supply Chain Hype Cycles. In 2021, interest has again significantly picked up for blockchain as companies react and adapt to disruptions and events related to the COVID-19 pandemic. Early trialists of blockchain in supply chain have exploited lessons and experiences through blockchain discovery especially in the areas of how technology is value assessed and clearly positioning its place in roadmaps.

Blockchain renaissance addresses a renewed but more realistic interest in exploring where and if blockchain has a role to play as part of a themed approach and alongside wholesale reviews of a range of available technologies such a control tower, visibility spectrum, IoT, automation and artificial intelligence. Blockchain will not be viable or needed in all use cases. But in the right use case, scenarios can have a role to play in elevating enhanced levels of verification, visibility, authentication or security in compact ecosystems founded around shared value creation opportunities. These could include brokerless supply chain transactions between trading partners, enhanced verification measures in virtual workplace environments or securing multiparty digital workflows in logistics or transportation.

Control Tower

Control towers capture and use data from across the business ecosystem to provide enhanced visibility and improve decision making in close to real time. They provide enhanced capabilities (such as advanced analytics and artificial intelligence/data science) on top of existing supply chain applications, leveraging the four-layer framework of "see > understand > act > learn." In other words, providing insights to drive decisions and actions for ultimately delivering results. However, as of today, such control towers are still often designed as "command center" environments that are focused heavily on visualization and dashboards and are still more functionally siloed in their setup.

Latest developments enhance the maturity of such towers toward being more predictive and autonomous. They facilitate more advanced data processing and allow for the delivery of insightful information, predictions and suggestions that are relevant and adaptive to user experiences toward more connected supply chain data. These developments provide a command center with data-powered innovation along specific use cases to add value without replacing existing apps.

Product and Asset Security

Supply chain security encompasses a continuous and expansive approach to embrace all security risks across the end-to-end supply chain. With imminent threats posed by cyber, data and digital threats (addressed through the security mesh theme), supply chain technology leaders must continue to be vigilant regarding broader security threats that originate or derive around physical goods and assets. Criminal gangs are becoming increasingly sophisticated in their approaches to theft, diversion, product safety and counterfeits and fakes, requiring companies even with established processes in place to continue to invest in tools and services that can eliminate, mitigate and prevent such attacks and events.

There are ranges of specialist and industry hardware and software applications that target physical security such as a IoT, asset tracking and serialization. With anticipated developing levels of digitalization across the end-to-end supply chain, convergence in delivery tools and solutions for security threats will be implicated increasingly through events associated with physical product and assets and vice versa. Supply chain technology future planning and strategy will inevitably need to map out the intricate relationships between physical goods and assets and their interface into digital systems in creating mature models that embrace the entire ecosystem of security threats.

Connected and Intelligent Packaging

This category is about the process or practice of embedding intelligent connected devices into otherwise improvident packaging assets with formats that can include both single use and reusable packaging assets. Packaging is an ideal medium in which to embed or establish robust technology solutions either at an adhered or embedded level that can capture and share valuable information across the life cycle of the goods and assets. This is a newly evolving market area with much interchangeability across terminology such as smart packaging, active packaging, connected packaging and intelligent packaging. There is also further innovation through reusable and sustainable packaging which can complement technologies to minimize waste and increase asset efficiency.

Technologies such as next generations of RFID, Near Field Communication (NFC), serialization and specialist IoT applications are among a wide range of technologies that are transforming packaging's role as a critical integration and digital connectivity hub that can provide digital connectivity and interoperability across stakeholders and end consumers. Use cases include voice of the customer applications through NFC or quick response (QR) codes; specialist IoT sensors for monitoring freshness, temperature or product condition; security applications deploying encrypted codes boosted with blockchain services and brand protection; and real-time inventory and asset management across distributed networks such as in healthcare or automotive. Not to forget the rising importance of end-to-end traceability — such as farm to fork — within the food supply chain driven by consumer needs for more information on the products.

Next-Generation Power and Energy Storage

Technology innovation for smart, clean energy sources combined with advances in energy storage will be a critical factor for building out robust technology infrastructures. Smart and sustainable batteries, power devices and battery management applications place less reliance on critical source materials such as cobalt or lithium by using alternatives such as sodium or hydrogen. There are new smart power options such as structural batteries which can complement lighter more efficient drones and electric vehicles, energy harvesting technologies that charge from the air via communications networks or nearby charged devices, or mobile hydrogen fuel cells.

There are several benefits by using these technologies, like energy sources being deployed in remote locations or because they can provide electricity supply resilience. Supply chain technology leaders must establish a comprehensive approach to assess developments in clean energy sources and energy storage technologies where appropriate. As these offerings are evolving quickly a recurring review needs to be established to stay up-to-date.

Synthetic Data

Data governance and continuous investments in technologies that can cleanse and enhance data quality are hot topics across many supply chain organizations. This is due to their ability to repurpose and promote legacy data, existing enterprise data and shared data and to establish stronger digital foundations. Unlike data quality insights, data itself is a limited asset. Synthetic data is a class of data that supplements activities for collecting and collating real-time data insights. It is artificially generated through rules and advanced analytics such as statistics, machine learning and simulation. Synthetic data deploys alternative methods to derive data insights (including statistically rigorous sampling from real data and semantic approaches), creating simulation scenarios where models and processes interact to create completely new datasets of events.

Synthetic data is set to be a valuable tool that can be leveraged by supply chains for use case scenarios where collection or capture of real data insights is not feasible when real data is too sparsely populated across the network to warrant investments. With increased deployments of mobile and automated solutions there are opportunities to transition greater levels of autonomy and intelligence to well-planned resources that can provide enhanced or alternate data insights on a continuous basis. Clients should be aware that synthetic data does not come without risks — for example, it may simply not reflect the real world — so rigorous testing becomes even more paramount. Also synthetic data may further increase solution complexity, and limit transparency and explainability.

Composable Supply Chain Applications

Within selected supply chain functions, such as transportation or warehouse management, we are increasingly seeing an acceleration of traditional application architectures being transformed into “composable” applications along with microservices. The composability of an application is defined by its business-focused modularity. This is similar to the characteristics of business-focused APIs for inter-application reuse/composition, incremental product-style delivery (where modules have autonomy to be delivered and versioned individually or modules may have multiple APIs) and productized modules offered as SKU-based commercial products. Composable applications also provide tools for some or all of composition, module creation and catalog management.

One key element is leveraging a microservices architecture, which arranges an application as a collection of loosely coupled services that are organized around business capabilities. Note that it is not a layer within a monolithic application, but rather a self-contained piece of business functionality with clear interfaces. There are numerous benefits of decomposing an application into a variety of smaller services, such as modularity, scalability and integration. However, simply having this architecture and these features does not mean that a vendor is providing an off-the-shelf solution. Incorporating these architecture principles is certainly simpler for vendors with newly built solutions. It is much more difficult to modularize older solutions and break them into components that can then be reassembled and enhanced according to a customer's needs.

A Retrospective View: Supply Chain Technology Trends and Themes

Back in 2017, we first introduced our key strategic technology trends research for the supply chain, closely working with our core-IT analyst community. This initial research identified the technology trends that supply chain leaders needed to track. Subsequent research in 2018, 2019 and 2020 focused on the actual trends and their impact and outcomes.

In 2021, we shifted to broader, overarching technology themes rather than individual technologies. This is because innovative, breakthrough technologies are often combined to solve specific supply chain business problems that come together to deliver anticipated business outcomes.

Table 1 provides a look back at the last three years of our leading supply chain technology trends and themes.

Table 1: Retrospective Supply Chain Technology Trends

2019 (Trends)	2020 (Trends)	2021 (Themes)
■ Artificial intelligence ■ Advanced analytics ■ Internet of things ■ Robotic process automation ■ Autonomous things ■ Digital supply chain twin ■ Immersive experience ■ Blockchain in supply chain	■ Hyperautomation ■ Digital supply chain twin ■ Continuous intelligence ■ Supply chain governance/security ■ Edge computing and analytics ■ Artificial intelligence ■ 5G networks ■ Immersive experience	■ Hyperautomation ■ Digital supply chain twin ■ Edge ecosystem ■ Supply chain security ■ Environmental social governance ■ Embedded AI and analytics ■ Augmented data intelligence ■ Immersive experience and applications

Source: Gartner (March 2022)

Evidence

[1] **2021 Gartner Supply Chain Technology User Wants and Needs Survey:** This survey was conducted to explore the roles digital and technology play in supply chain. It also supports supply chain technology leaders in their efforts to modernize legacy application landscape and generate a trustworthy business case for their digital journey. The research was conducted online from 26 October through 14 December 2021 among 354 respondents from North America, Western Europe and Asia/Pacific. Respondents were from organizations with $250 million or more in 2021 enterprisewide annual revenue. Industries surveyed included manufacturing (consumer products, industrial, high tech, healthcare products and life sciences), retail, wholesale trade, healthcare providers, natural resources, transportation and logistics. Respondents who had job roles tied to supply chain function and were involved in decision making regarding supply chain management processes/operations for more than two years qualified for the survey.

Disclaimer: Results of this survey do not represent global findings or the market as a whole, but reflect the sentiment of the respondents and companies surveyed.

Note 1: CSCO Priorities

Gartner surveys of supply chain leaders include C-suite and chief supply chain officers (CSCOs) and identify six priorities, strategies and challenges that impact decision making:

- Digital supply chain transformation decision-making enhancements and digitizing, tracking and managing assets at the edge were identified as key funded SC initiatives.
- Thirty-one percent of organizations support improving technologies to enhance end-to-end processes.
- Significantly greater focus toward value creation through innovation in 2021.
- Higher inclination of business outcome focus toward value creation through stakeholder integration.
- Ecosystem enablement emerged as a significant external concern across 2021.
- A significant number of respondents (62%) indicated that their role included supply chain strategy and/or leadership.

Senior supply chain and technology leaders need to quickly transition to much greater levels of responsibility in sponsoring and promoting technology investments ensuring that they recommend and secure the appropriate resources in key roles within the organization to drive adoption forward.

Document Revision History

The 2021 Supply Chain Technology Themes - 27 May 2021

The 2020 Strategic Supply Chain Technology Trends - 8 May 2020

The 2019 Top Supply Chain Technology Trends You Can’t Ignore - 11 March 2019

The 2018 Top 8 Supply Chain Technology Trends You Can't Ignore - 9 January 2018

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Use a Trendspotting Method to Identify the Technology Trends You Need to Track

Build a Balanced Portfolio of Initiatives With the Supply Chain Strategy Hype Cycle

Ten Cyber and IT Risk Fundamentals You Must Get Right

Hyperautomation 2.0
Digital Supply Chain Twin
Security Mesh
Analytics Everywhere
Next-Generation Robots
Ecosystem Collaboration
Sustainability Tools
Autonomous Things
Notable Mentions

Table 1: Retrospective Supply Chain Technology Trends

2019 (Trends)	2020 (Trends)	2021 (Themes)
Artificial intelligence	Hyperautomation	Hyperautomation
Advanced analytics	Digital supply chain twin	Digital supply chain twin
Internet of things	Continuous intelligence	Edge ecosystem
Robotic process automation	Supply chain governance/security	Supply chain security
Autonomous things	Edge computing and analytics	Environmental social governance
Digital supply chain twin	Artificial intelligence	Embedded AI and analytics
Immersive experience	5G networks	Augmented data intelligence
Blockchain in supply chain	Immersive experience	Immersive experience and applications

Source: Gartner (March 2022)