



## Whitepaper

# Supply Chain Digital Twin Strategy (SCDTS); an integrated approach using AI, IoT and data analytics

### Abstract

This whitepaper investigates how Supply Chain Digital Twin Strategies (SCDTS) integrate artificial intelligence (AI), Internet of Things (IoT) and advanced analytics to transform traditional supply chains. A digital twin is a virtual replica of a physical process; SCDTS extends this concept across the entire supply network, combining real-time sensor data with simulation and predictive models to create “living” supply chains. The study first clarifies where SCDTS is most valuable: in data-rich, complex and capital-intensive operations such as automotive, pharmaceuticals, high-tech manufacturing and regulated industries requiring precise traceability. It also notes applicability in continuous or batch production, hybrid manufacturing–logistics environments and last-mile service businesses.

Analyzing supply-chain functions, the report highlights typical cost drivers and explains how digital twins can reduce these costs through predictive planning, dynamic buffer management, routing optimization and proactive risk mitigation. The interaction between IoT and AI is examined. A step-by-step roadmap for adopting SCDTS is presented, covering strategic scoping, and a list of leading vendors. The conclusion underscores that SCDTS offers end-to-end visibility, resilience and sustainability, moving supply chains from unknown uncertainty to managed variability.

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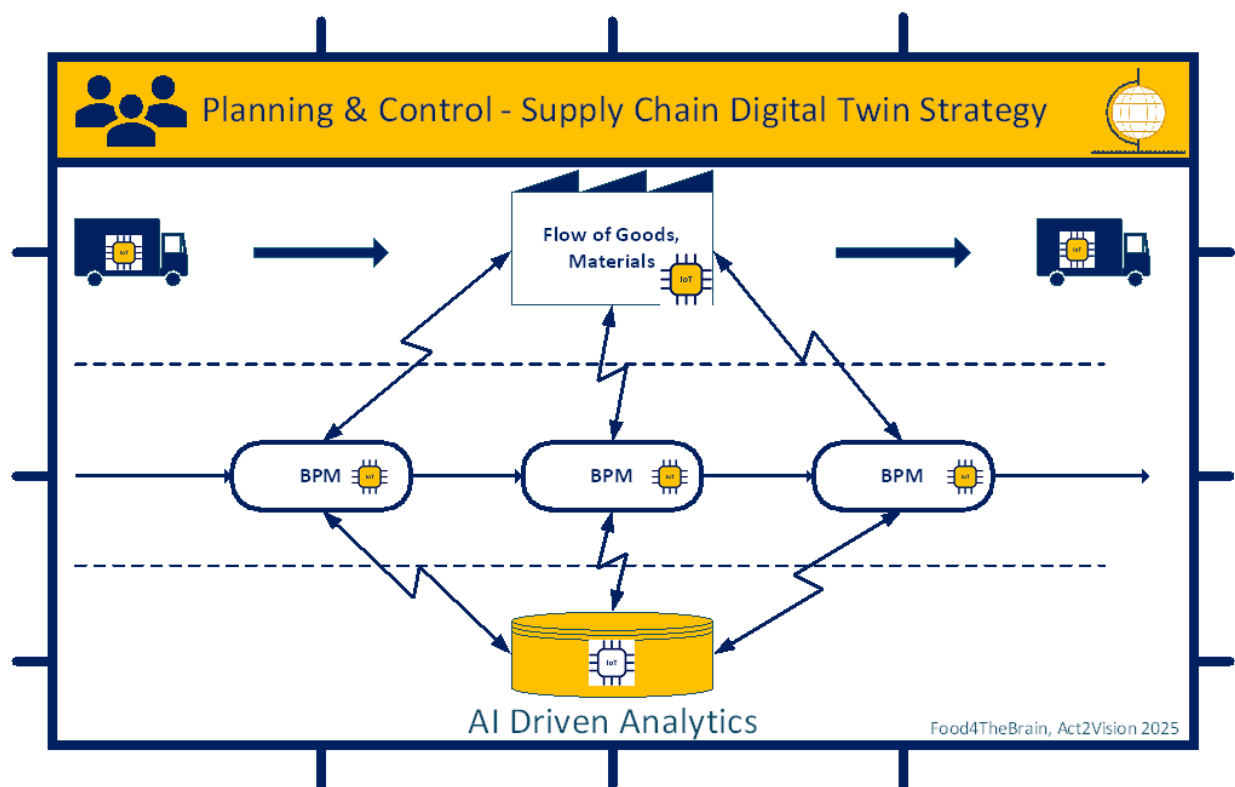
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## Introduction

Digital twins, sometimes called virtual twins, are virtual replicas of physical systems or processes. They mirror everything that happens in the real world by pulling data from sensors, machines and enterprise systems. The supply-chain digital twin (SCDT) extends this concept to the entire supply network.

Gartner defines a digital supply chain twin as a digital representation of the end-to-end physical supply chain used to drive understanding and decision making. It combines real-time data from warehouses, vehicles, IoT devices, suppliers and customers with simulation and predictive analytics to test “what-if” scenarios, anticipate disruptions and optimize buffers.

Digital twins are already transforming manufacturing, logistics, energy and healthcare, and the supply-chain twin market is forecast to grow with manufacturing as the largest adopter. Market analysis, volumes and value are not included in this whitepaper.



## Interplay between IoT data and AI-driven analytics

The digital twin “body” provides the contextual model of the supply chain, while artificial intelligence is the “brain” that interprets data and recommends actions. A digital twin is a data-driven digital replica of a physical system; AI can be embedded within a digital twin to enable predictive maintenance, automated scenario testing and anomaly detection. IoT sensors and cloud services collect streaming data from assets, pallets, vehicles and production lines; this data is stored in data lakes or cloud platforms (e.g., AWS, Azure). AI algorithms (machine learning, deep learning and reinforcement learning) process the data to forecast demand, detect anomalies and optimize decisions.

For example:

- **Data acquisition & integration.** IoT sensors generate real-time data on equipment conditions, location, temperature and utilization. This data is ingested into cloud platforms through messaging protocols (e.g., MQTT, HTTPS) and integrated with enterprise systems (ERP, MES, WMS). Building a digital twin requires access to real-time or historical data and integration into SCADA, ERP or MES systems.
- **Analytics and AI.** AI techniques such as probabilistic forecasting predict demand and supply variability, optimizing buffer levels. Predictive maintenance models use time-series data to predict equipment failures and schedule repairs. Deep learning models can analyze images or sensor data to detect quality issues. Reinforcement learning algorithms can learn optimal policies for dynamic routing and load balancing.
- **Simulation and optimization.** Simulation engines model interactions among supply-chain entities. DSCTs captures interactions through transactions (purchase orders, shipments) and adapt to evolving supply chain structures. Optimization algorithms (linear programming, heuristics, meta-heuristics) search for feasible solutions and trade-offs across cost, service and sustainability. Virtual twin solutions allow comparison of cost vs. sustainability scenarios.
- **Visualization & decision support.** Results are presented through dashboards, maps and KPI reports. Digital twin offers custom triggers and alerts for abnormal conditions. Secure components of digital twins can be shared with suppliers and partners, creating collaborative ecosystems with continuous realignment and AI-driven workflows.

## Where SCDTS fits – business characteristics

| <b>Business characteristic</b>                                  | <b>Why SCDTS is a good fit (with supporting evidence)</b>                                                                                                                                                                                                                                                                                                                              | <b>Examples/sectors</b>                                                                                                                                   |
|-----------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Data-intensive and information rich</b>                      | SCDTs need large volumes of real-time data. Digital twins rely on IoT sensors and systems to feed status information, conditions and events. A Gartner-recognized digital supply chain twin offers a single, highly detailed data model covering everything from sourcing to delivery.                                                                                                 | High-tech manufacturing, automotive, pharmaceuticals, electronics, food & beverage, healthcare – industries using sensors and rich transactional data.    |
| <b>Complex, multi-echelon supply chains</b>                     | Businesses with many nodes, products, suppliers and customers face dynamic variability. Digital twins let companies run simulations to anticipate risks, predict bottlenecks and allocate buffers dynamically. Digital twins must integrate numerous processes, gather data from various facilities and capture transactions like purchase orders, shipments and goods issue requests. | Global manufacturers (automotive, aerospace), consumer packaged goods (CPG), pharmaceuticals, fashion, semiconductor supply chains, e-commerce logistics. |
| <b>Capital-intensive operations where downtime is expensive</b> | Component/asset twins detect wear and predict failures to reduce unplanned downtime. For example, digital twins are used to anticipate machinery issues and reduce downtime.                                                                                                                                                                                                           | Process manufacturing (oil & gas, chemicals), power plants, mining, heavy equipment, airlines.                                                            |

|                                                                          |                                                                                                                                                                                                                                                                                                  |                                                                                                             |
|--------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| <b>Industries with strict regulatory compliance</b>                      | Digital twins provide traceability and compliance. In pharmaceuticals and biotech, virtual twins model cleanrooms, equipment behaviour and validation to ensure compliance. DSCTs enable better conformance and compliance by capturing performance variability.                                 | Pharma & biotech, food & beverage, medical devices, aerospace.                                              |
| <b>Continuous or batch production environments</b>                       | Process twins replicate entire workflows such as manufacturing lines or logistics flows and help run what-if scenarios and improve throughput without disrupting operations. Digital twins are used in continuous manufacturing (steel, aluminium) to optimize production plans and scrap usage. | Chemical and process industries, food processing, steel and aluminium plants, consumer goods manufacturing. |
| <b>Hybrid manufacturing/ logistics (single-product or multi-product)</b> | Digital twins are equally valuable in single-product manufacturing (to optimize the line) and in multi-product/batch industries (to balance capacity and sequencing). They enable simulation of layout changes, track performance and plan maintenance.                                          | Electronics assembly, packaging plants, contract manufacturing.                                             |
| <b>Service-oriented &amp; last-mile businesses</b>                       | Real-time supply-chain twins optimize transportation networks and last-mile deliveries. Digital twin monitors shipments and vehicle locations to plan transportation and manage risk. Materialize case studies show dynamic routing of shipments and proactive re-routing when cargo is stuck.   | Retail logistics, parcel delivery, third-party logistics (3PL), postal services, cold chain logistics.      |

## Supply-chain functions & cost breakdown

“Digital twin Supply Chain Strategy move supply chains  
from unknown uncertainty to known variability  
and support probabilistic planning”

### Cost Breakdown Structure

Supply chains typically include inbound logistics, warehousing & handling, inventory management, packaging, planning & control, outbound logistics and last-mile delivery.

- Research on value-added logistics (VAL/VAS) shows typical cost contributions: Warehousing & inbound logistics 15–20 %,
- CDC (central distribution center) handling and labor 15–18 %,
- CDC housing ~15 %, inventory 12–20 % (depending on product value density),
- planning & control 5–8 %,
- packaging 2 %.
- outbound logistics 25–30 %.

Although these numbers vary by industry, they underscore that warehousing, labour and outbound logistics are major cost drivers. Note that costs of customer returns, damaged goods, obsoletes, unsalable and slow-moving stock should also be taken into account (as might other cost drivers in your specific area of business).

### Digital twins bring value across all functions

*During this research many organizations claim successes with significant impact. As these numbers can't be validated they are removed from this chapter.*

- **Inbound & transportation** – Virtual twins map inbound flows, track shipments via IoT sensors and anticipate delays. Virtual twins allow companies to gather real-time production information from suppliers and sensors in the field, predict arrival times and even monitor containers and refrigeration units. They support proactive actions when trucks are late or equipment fails.
- **Warehousing & handling** – Warehousing labor can effect operating cost significantly. Digital twins simulate warehouse layouts, test routing and reduce transportation costs. They help plan labour and minimize space waste by identifying bottlenecks.

- **Inventory & buffer management** – Twins monitor inventory levels in real time using IoT sensors and RFID tags. Virtual twin uses AI-based probabilistic forecasts to improve planning and dynamic buffer allocation, resulting in improvements in forecast accuracy and reductions in delays and downtime. They help determine safety-stock positions and trade-offs between cost and service.
- **Packaging & value-added services** – Packaging operations can be simulated to optimize line setups and reduce waste. Digital twins are used to cut energy consumption and waste.
- **Planning & control** – Digital twins unify data from ERP, MES, WMS and IoT sensors for real-time planning. They enable scenario-based planning and scheduling, adjusting production and logistics based on predicted demand and capacity. Dynamic planning with digital twins can improve fulfillment and reduce labor cost.
- **Outbound logistics & last-mile** – Twins optimize routes, fleet utilization and last-mile delivery. Real-time alerts provide for abnormal situations and uses custom triggers to reroute shipments. Materialize’s case studies show dynamic route planning improved on-time delivery and reduced delays.
- **Predictive planning and preventive maintenance.** Digital twins transform planning from reactive to predictive. AI-enabled virtual twins provide probabilistic forecasts that allocate buffers dynamically and cut downtime. Component and asset twins monitor equipment health and detect wear, allowing predictive maintenance and reducing unplanned downtime. Digital twins are used to reduce downtime.
- **Workflow monitoring and pro-active control.** Creating digital twin models of supply chain networks enables real-time operational modeling and monitoring. Actionable intelligence anticipates problem scenarios, incorporates ground-truth data and automates responses. Deep data intelligence within digital twins allows organizations to monitor all assets—from containers and pallets down to vials—overcoming organizational silos and enabling partners to identify deviations and fix them quickly. Networks of digital twins support collaboration and continuous realignment across the ecosystem; AI/Machine Learning (ML) scripts drive predictive intelligence and automate workflows.
- **Flexibility and reduced bottlenecks.** Process twins replicate entire operations, allowing simulation of layout changes and testing of “what-if” scenarios without interrupting the real process. In warehouses and logistics, digital twins visualize bottlenecks before they happen and make operations more agile and efficient. Virtual twins, decision-makers can run simulations to stress-test the supply network and plan for disruptions.

- **Resilience and risk management.** Supply chain disruptions (pandemic, geopolitical events, Suez Canal blockage) expose fragility. Virtual twins provide visibility into events that might affect suppliers, giving stakeholders the power to predict and avoid disruptions. Supply chain digital twins require IoT sensors beyond manufacturing walls and into warehouses and suppliers, enabling real-time visibility of transit times and inventory. The ability to run scenario simulations helps companies prepare contingency plans and stress-test their supply chains.
- **Sustainability and circularity.** Combining virtual twins of product, sourcing supply chain and manufacturing can enable new value chains and optimize material flow. Supply-chain twin balances cost, sustainability and carbon emissions by comparing multiple scenarios. Virtual twins also underpin recycling and reuse strategies by tracing critical materials across their lifecycle and enhancing circularity.

## Plan of approach – implementing an SCDTS

*In “Data Driven Supply Chains, Digital Twin Supply Chain elements of a Modern Supply Chain” (Post:20 October 2020 [www.act2vision.nl](http://www.act2vision.nl)) a 7 steps approach is shared on how to create a digital twin. The plan of approach is complementary to the 7 steps approach.*

**Define strategic objectives and scope.** Identify critical pain points (e.g., frequent stock-outs, long lead times, high working capital) and decide which parts of the supply chain to “twin” (inbound logistics, manufacturing, warehouses, transportation). The foundation begins with a clear understanding of business objectives e.g. reducing downtime, improving efficiency, gaining visibility or enabling predictive planning.

**Assess data readiness and integrate IoT sensors.** Evaluate available data sources: ERP, MES, WMS, TMS, CRM, IoT sensors and partner data. Install or upgrade sensors (RFID, GPS, temperature, vibration) to capture real-time data across assets and environments. Extend IoT coverage beyond manufacturing walls into warehouses and supplier facilities.

**Choose the twin architecture (build vs. buy).** Decide whether to build the twin in-house or select a commercial SaaS/PLM solution. Building in-house offers customization but is expensive and time-consuming; SaaS solutions provide faster deployment and lower overhead. Consider integration with existing platforms and future scalability. Do not underestimate the required skills and expertise to actually set up the architecture and twin.

**Select appropriate software.** Evaluate digital twin software based on industry fit, simulation capabilities, AI integration, IoT connectivity and scalability vendors (see chapter: Selected SCDTS software suppliers and focus areas). Ensure the platform supports integration with existing systems (ERP, SCADA, analytics) and handles multi-echelon networks.

**Model the supply chain.** Create a digital representation of the physical network, including facilities, equipment, inventories, transport modes and policies. Capture interactions through transactions (orders, shipments) and define constraints and parameters (capacities, lead times, costs). Start with a pilot area (e.g., one product line or region) and validate the

model with historical data. Digital twins use live data feeds (shipment schedules, vehicle locations, inventory levels) and can test design changes, monitor risks and plan transportation.

**Embed AI and analytics.** Develop predictive models for demand forecasting, maintenance, risk detection and dynamic routing. Use scenario simulation to stress-test the supply chain and evaluate alternative policies. DSCTs must handle variability and provide probabilistic planning. Define KPIs such as service level, cost, carbon emissions, labour productivity and inventory turns.

**Implement control tower and alerts.** Create dashboards and control towers to monitor real-time operations and trigger alerts when deviations occur. For integrated networks consider empowering partners and suppliers to collaborate and coordinate operations at all stages, aligning planning and execution with ground truth.

**Continuous improvement and scaling.** After validating the twin, scale across the network, refine the model with new data and integrate additional AI algorithms. Use the twin to support strategic decisions (network design, sourcing strategy, sustainability initiatives). Plan for regular updates to reflect changes (new products, mergers, macroeconomic shifts).

## Selected SCDTS software suppliers and focus areas

The table is not exhaustive; many other vendors (e.g., Infor Nexus, OMP, Llamasoft–Coupa, Alteryx) offer components of supply-chain digital twin solutions.

| Vendor / Platform                                                                              | Specific area and strengths                                                                                                                                                              | Alignment with SCDTS                                                                                                                                              |
|------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>BAP Software</b> (Vietnam)                                                                  | Provides custom digital twin solutions across industries; uses IoT and AI to replicate physical systems and optimize operations.                                                         | Flexible partner for bespoke twin implementations and simulations.                                                                                                |
| <b>Siemens Digital Industries Software</b> (e.g., Tecnomatix, Plant Simulation and MindSphere) | Strong in manufacturing and product lifecycle. Plant Simulation models production lines, logistics and material flows; MindSphere connects IoT devices for real-time data and analytics. | Suitable for discrete manufacturing, assembly lines and smart factories; integrates with PLM systems and supports predictive maintenance and layout optimization. |
| <b>General Electric – GE Digital</b>                                                           | Focuses on asset-centric industries (power, aviation, energy). Predix platform collects operational data,                                                                                | Applicable to capital-intensive supply chains with critical assets; emphasizes asset                                                                              |

| <b>Vendor / Platform</b>                        | <b>Specific area and strengths</b>                                                                                                                                                                                                                                                                                         | <b>Alignment with SCDTS</b>                                                                                                                                        |
|-------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                 | builds digital twins for equipment and optimizes performance and reliability.                                                                                                                                                                                                                                              | management and predictive maintenance.                                                                                                                             |
| <b>Dassault Systèmes – DELMIA &amp; Quintiq</b> | Offers virtual twin experiences that go beyond mirroring physical objects to simulate behavior and evolution. DELMIA Quintiq enables supply-chain virtual twins for optimized planning; scenarios balance cost and sustainability. Their virtual twin approach supports circularity and collaboration across value chains. | Ideal for end-to-end supply chain planning, manufacturing operations and circular economy initiatives; provides advanced optimization and scenario planning tools. |
| <b>Microsoft Azure Digital Twins</b>            | Cloud-based IoT platform that models environments using digital twin definitions; integrates with Azure IoT Hub, Event Grid and Time Series Insights.                                                                                                                                                                      | Suitable for organisations seeking scalable, cloud-native digital twins integrated with IoT devices and analytics services.                                        |
| <b>PTC ThingWorx</b>                            | Industrial IoT platform combining augmented reality and digital twin technologies. Enables remote monitoring, asset optimization and predictive maintenance.                                                                                                                                                               | Good fit for manufacturers needing remote service, condition-based maintenance and integration with PLM and CAD.                                                   |
| <b>IBM Digital Twin Exchange</b>                | Provides a marketplace for digital twin models and integrates with IBM Maximo for asset management. Emphasises equipment maintenance, utilities and facilities management.                                                                                                                                                 | Suited for industries requiring strong asset management and maintenance (utilities, facilities, industrial equipment).                                             |
| <b>Bosch.IO</b>                                 | IoT and digital twin software for manufacturing, logistics and building technologies; integrates with sensors and cloud.                                                                                                                                                                                                   | Useful for industrial IoT deployments, especially in smart buildings and connected factories.                                                                      |

| <b>Vendor / Platform</b>                                          | <b>Specific area and strengths</b>                                                                                                                                                                                               | <b>Alignment with SCDTS</b>                                                                                                           |
|-------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| <b>Oracle Digital Twin &amp; IoT Cloud</b>                        | Integrates IoT data with supply chain applications (Oracle SCM Cloud). Supports asset monitoring, logistics management and predictive maintenance.                                                                               | Suitable for companies using Oracle ERP/SCM seeking to extend into digital twin capabilities.                                         |
| <b>Ansys Twin Builder</b>                                         | Engineering simulation platform that creates physics-based digital twins for predictive maintenance and system optimization.                                                                                                     | Valuable for high-fidelity simulations of equipment and complex systems; integrates with system engineering and mechanical design.    |
| <b>SAP Digital Supply Chain (DSC) &amp; Digital Manufacturing</b> | Provides supply chain planning, network design and asset management; SAP Intelligent Asset Management creates digital twins of equipment; SAP IBP and SAP Analytics Cloud support scenario planning.                             | Ideal for companies already using SAP; integrates across finance, logistics and manufacturing modules.                                |
| <b>Kinaxis RapidResponse &amp; Maestro</b>                        | Cloud-based supply chain planning platform. RapidResponse uses in-memory computing to build digital supply chain twins for concurrent planning; the AI-powered <b>Maestro</b> orchestrates scenarios and infinite digital twins. | Best suited for complex, high-speed planning where multiple scenarios need to be evaluated quickly (e.g., aerospace, consumer goods). |
| <b>Bluecrux Axon</b>                                              | Software for digital supply-chain twin with probabilistic simulation. Offers use cases like inventory reduction, value-stream mapping and network performance monitoring.                                                        | Suitable for companies seeking SaaS digital twin platform with supply chain-specific features and quick pilot deployment.             |
| <b>anyLogistix</b>                                                | Simulation and optimization software for supply chains; builds digital twins using real-time data to forecast                                                                                                                    | Good for network design, risk analysis and transportation planning;                                                                   |

| Vendor / Platform  | Specific area and strengths                                                                                                              | Alignment with SCDTS                                                                    |
|--------------------|------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
|                    | dynamics, plan transportation, optimize inventory and cost-to-serve.                                                                     | integrates with existing ERP/BI systems.                                                |
| <b>Simio</b>       | Simulation modeling software enabling digital twins of manufacturing and logistics systems; supports risk-based planning and scheduling. | Suitable for modelling discrete event systems, such as production lines and warehouses. |
| <b>Logivations</b> | Digital twin solutions for warehouse and logistics optimization; uses AI for slotting, routing and workforce planning.                   | Ideal for logistics, warehousing and intralogistics improvements.                       |

## Conclusion

Supply-chain digital twin strategies allow businesses to see, simulate and steer their supply networks. By combining IoT-enabled data acquisition, AI-driven analytics, simulation and optimization, SCDTs provide end-to-end visibility, predictive foresight and decision support.

The technology is particularly valuable for data-rich, complex and capital-intensive operations where disruptions and variability threaten performance. It delivers value across inbound logistics, warehousing, inventory management, planning and last-mile delivery by reducing downtime, improving buffer management, optimizing resource utilization and enabling proactive responses to disruptions. Implementing an SCDTS requires a structured approach—defining objectives, assessing data readiness, choosing the right software, modelling the network and embedding AI and analytics. Leveraging the expertise of specialized software vendors can accelerate deployment and ensure scalability.

The integration of supply-chain digital twins with circular economy principles further expands their strategic role. Virtual twins enable sustainable sourcing, optimize material flows and support new regenerative value networks. As businesses continue to navigate volatile markets, supply-chain digital twin strategies will underpin resilience, agility and sustainable growth.