The New Competitive Edge

Analytics-Driven Supply Chain Design

An Executive Guide

MIT Center for Transportation & Logistics

coupa

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Executive Summary

Supply chain design is the pillar of strategic supply chain planning and a key source of value creation for organizations. As supply chains become more global and focused on the end customer, the design of supply chains plays an increasingly important role as a competitive differentiator. Furthermore, with global supply chains competing in an increasingly complex environment, tactics for managing and mitigating risk, building resilience, and supporting growth and sustainability are more important than ever.

To align their supply chains with the requirements and challenges of today's markets and gain a competitive edge, companies need to adopt new supply chain design paradigms. These new approaches require refocusing decision-support tools with an eye toward four primary opportunities:

1. Extending the scope of supply chain design beyond its traditional focus on cost minimization to incorporate a larger set of considerations. These include, for example, design for global and diverse markets, design for value creation, and design for sustainability.
2. Integrating more granular, tactical components into strategic decision-support tools to reduce gaps between anticipated and actual performance of supply chain networks. This is relevant to a number of tactical planning areas, such as sourcing optimization, production planning, inventory decisions, and transportation planning.
3. Putting greater emphasis on the consideration of various sources of risk and uncertainty in supply chain design and structurally incorporating risk-mitigation and resilience measures into analytical decision-making support tools.
4. Embracing new design methods and practices that incorporate new technologies and business models, supporting the design of digitally enabled, customer-centric supply chains that are both flexible and profitable.

A new generation of analytical tools in the field of optimization, simulation, and data science provide an unprecedented opportunity to implement a data-driven supply chain design process. In order for these tools to inform and drive business decisions in a real-life business context, however, companies must rethink how these tools are incorporated into a broader decision-making process around supply chain design. Their adoption must go hand in hand with a redesign of organizational processes related to supply chain design to promote a collaborative, cross-functional planning process, ensuring that all relevant perspectives are considered, the framing of the problem reflects organizational priorities, the analyses are fully understood and trusted, and the resulting solutions are implemented. Furthermore, organizations must implement a continuous redesign process that allows the alignment of designs with evolving supply chain strategies and the ability to adapt to a dynamic business environment.

About the Report

This white paper is the fruit of a collaboration between the Massachusetts Institute of Technology's Center for Transportation & Logistics (MIT CTL) and Coupa, the provider of artificial intelligence (AI)-powered supply chain analytics software. New trends and challenges are reshaping the role of supply chains in enabling companies to compete successfully in changing markets. The paper addresses the growing need to rethink how companies approach supply chain design in this context.

So much is changing in the commercial environment where today's supply chains compete. Global supply chains are becoming increasingly complex. The number of actors involved is increasing, consumer expectations are rising, and industry trends such as the growth of omnichannel marketing and direct-to-consumer services are redefining supply chains, especially over the last mile.

As a result, tactics for managing and mitigating risk, building resilience, and supporting sustainability now play a more important role in the design of supply chain networks than was the case just a decade ago. From a strategic perspective, supply chain design has become a major source of competitive advantage. But to capitalize on this advantage, companies must adopt and implement design practices that meet the demands of today's competitive environment.

As markets and technology continue to evolve at a rapid pace, traditional supply chain design methods have become outdated, and companies that follow them risk putting themselves at a competitive disadvantage. The challenge for supply chain leaders, therefore, is not just to respond to market developments; they must also acquire the tools and flexibility to keep up with the accelerating speed of change.

MIT CTL and Coupa have combined the knowledge and experience gained from state-of-the-art academic research and many hours working with companies to establish a vision for future-proof, analytics-driven supply chain design and planning approaches. This vision is elucidated in the following paper. We present an overview of the current state of practice in supply chain design and offer specific strategies—supported by real-world examples—for putting our vision into practice.

About the MIT Center for Transportation & Logistics

Founded in 1973, the MIT Center for Transportation & Logistics (MIT CTL) is a dynamic, solutions-oriented research center where students, faculty, and industry leaders pool their knowledge and experience to advance supply chain education and research. Through its Global Supply Chain and Logistics Excellence (SCALE) Network, MIT CTL sits at the heart of an international network of six centers of excellence, with over 80 researchers and faculty members from multiple disciplines, and more than 150 corporate partnerships.

About Coupa

Coupa is the cloud-based Business Spend Management (BSM) platform that unifies processes across supply chain, procurement, and finance functions. Coupa empowers organizations around the world to maximize value and operationalize purpose through their business spend.

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Foreword

For supply chain professionals, there has never been a time in history like the past two years. Virtually every supply chain worldwide has had to contend with supply, production, labor, and logistical bottlenecks caused (or at least exacerbated) by the Covid-19 pandemic. Strategies like Just-in-Time and low-cost-country sourcing—for decades, the unquestioned building blocks of global commerce—are coming under fresh scrutiny as companies consider whether their current supply chain networks are resilient enough to withstand ever-growing risks.

The speed with which disruptions upended operations made it painfully clear that successful supply chains must be flexible and adaptable. But being able to quickly respond to changing markets and competitive priorities is not solely a pandemic-era concern. Increasing supply chain complexity, the exponential growth of e-commerce and omnichannel fulfillment, and the mandate for sustainability are not new, but successfully managing them requires similar capabilities.

For all these reasons and more, traditional supply chain designs and methodologies have become outdated, creating risk for today's businesses. To model a new world, you need new thinking and new tools. We hope this timely paper will help you to reconsider and reshape your network design strategy at a time when it's never been more important.

Professor Yossi Sheffi

Director,

MIT Center for Transportation & Logistics

Foreword

Nowadays supply chains are under significant stress. The high variability of demand, the customer behavior shifts prompted by the Covid-19 pandemic and geopolitical instability, the ever-growing risks from supplier networks, and the heightened interest worldwide in achieving sustainability goals as soon as possible are some of the top agenda items for CSCOs around the globe. There is a global need to redefine supply chain decision-making processes, to move from network designs that are no longer the result of a historical accident but rather an engineered reality, and to connect various C-suite decision-makers through supply chain initiatives that positively impact not only costs, but more importantly, revenue and sustainability priorities.

It has been clear for some time now that those much-needed changes and improvements are heavily dependent on supply chains' number one asset: people. Organizational silos can hinder the speed at which we can drive change and enhance our performance.

Now is the time to learn from the mistakes of the past, to connect C-suite stakeholders so that decisions that move from strategy to execution, vertically and horizontally, happen in unison. We are in a business environment where purchasing decisions are considering margin to serve, not just price or cost, and where cash flow is being driven not only by cost improvement in supply chains but also by revenue increases through strategic positioning of inventory, clever tactics in last-mile delivery, and smart returns management. Understanding how to create and design these decision processes, how to enhance the ones that already exist, and, more importantly, how to accelerate their impact through democratizing them, are core capabilities that organizations need to develop in order to succeed in this era of reimagined, next-generation supply chain design.

I invite all of you to take up this challenge, and to try to achieve this connection throughout your organization. Empower your teams with robust decision-making processes and technology that can support them, elevating the management of your supply chain's complexity through the simplicity of scenario building, multi-tier discussions, and probabilistic decision-making paradigms. Only through embracing this challenge can we shift our thinking, influence our future, and enable supply chains to be all that they can be: an engine for positive change and impactful decision-making.

Carlos Valderrama

Vice President,
Customer Services &
Value Management
Coupa Software

Authors and Contributors

Milena Janjevic

Research Scientist, MIT Center for Transportation & Logistics

Milena Janjevic is a Research Scientist at the MIT Center for Transportation & Logistics. Her current research focuses on the design of supply chain networks. Her work, performed in collaboration with multiple global organizations, focuses on improving decision-making in supply chain design through the use of data-driven optimization and simulation models and their integration into interactive visual tools. In addition, her research focuses specifically on distribution network design in the context of urban logistics and last-mile delivery, urban freight policy, and infrastructure design.

Dr. Janjevic received her doctorate and master's in Engineering with specializations in Logistics at Université libre de Bruxelles in Belgium. During her doctoral studies, she was a Visiting Scholar at the Center of Excellence for Sustainable Urban Freight Systems at Rensselaer Polytechnic Institute in New York. Her doctoral research focused on the optimal design of urban logistics systems based on multi-tier distribution networks, electric vehicles, and policy measures. Dr. Janjevic's previous professional work includes working with McKinsey & Company in Belgium and France on various projects in the telecommunication, insurance, and retail sectors.

Carlos Valderrama

Vice President, Customer Services & Value Management, Coupa Software

Carlos Valderrama is an entrepreneur and specialized supply chain design and planning expert leader with broad experience in venture start-up strategic planning, supply chain management, customer success function development and optimization, and business development and growth in global markets in high tech. Carlos has over 20 years of experience working with executives in the top 1,000 companies globally, influencing their supply chain and sourcing transformations for the better. He is currently Vice President of Customer Services & Value Management for Emerging Solutions at Coupa Software, supporting more than 500 customers globally connecting executives to help improve their decision processes on business spend management.

Michael Bucci

Senior Director, Solutions Delivery, Coupa Software

Since joining LLamasoft in June 2011 and now Coupa Software, Michael Bucci has worked on a variety of projects as a Solutions Manager and Engagement Lead. In his current role, Mike manages all aspects of projects from kick-off to completion. His scope of responsibility includes project management, model design, scenario analysis, customer support, and training.

Prior to joining LLamasoft, Mike worked for 10 years in a variety of consulting, engineering, and management roles. His prior work experience includes developing strategic network design solutions, starting a consulting practice focused on lean supply chains, working as a plant manager, and leading process improvement projects at IBM.

Mike earned his doctorate in Industrial Engineering from North Carolina State University. His studies focused on the development of solution methods for complex supply chain network designs.

Walid Klibi

Research Affiliate, MIT Center for Transportation & Logistics

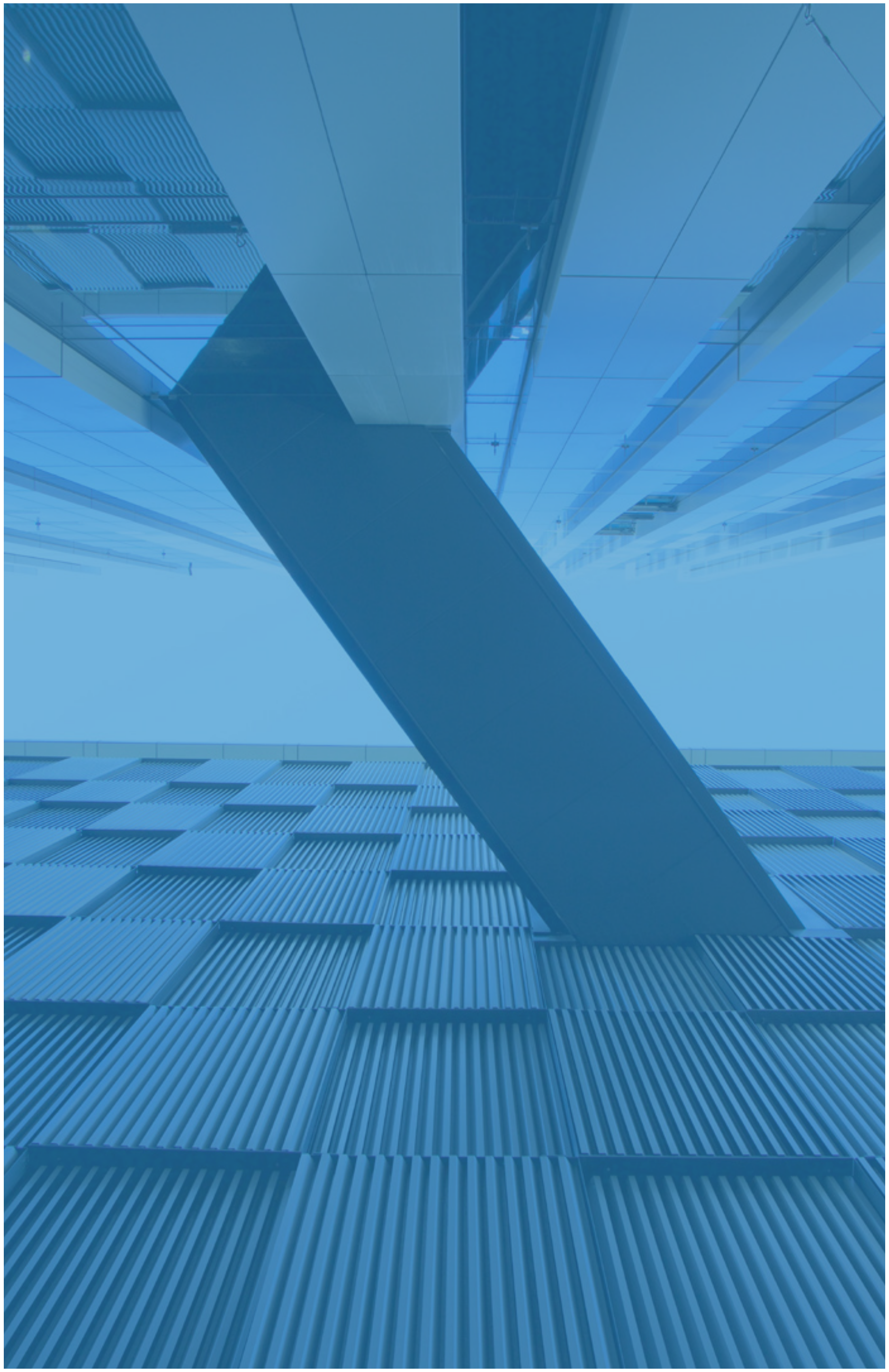
Walid Klibi is currently a research affiliate at the MIT Center for Transportation & Logistics. Since 2011, Walid has been a Professor of Supply Chain and Operations Management at KEDGE Business School in France, and a co-founding member of the Center of Excellence in Supply Chain (CESIT) at KEDGE. He served as the director of the CESIT from 2015–2019. Walid obtained his doctorate in Supply Chain Design from the Faculty of Business Administration at Laval University in 2009. And in 2020, he earned a habilitation degree in Applied Mathematics from the University of Bordeaux.

Walid's research focuses on supply chain design, resilience, omnichannel distribution, and urban logistics, carried out in partnership with several international companies. He has also co-authored more than 30 articles in international academic and professional journals and a book, *Designing Value-Creating Supply Chain Networks* (Springer, 2016). Most of his work is carried out in collaboration with affiliated schools and international colleagues.

Contributors

Jarrod Goentzel, Director, MIT Humanitarian Supply Chain Lab

Matthias Winkenbach, Director, MIT Megacity Logistics Lab



Supply Chain Design

In supply chain design, also called strategic supply chain planning, senior management makes decisions regarding the resource investments, business policies, and deployment issues involved in redesigning their supply chains. Not surprisingly, these decisions have a major impact on operational efficiency, and hence, competitiveness.

The supply chain design field is rooted in conventions developed through research carried out in the 1990s. These studies focused on the physical structure of supply chains (i.e., decisions related to the number, location, capacity, and mission of the company's production-distribution facilities and flows between different parts of the network). Designs were typically reviewed every few years over a long planning horizon and were usually the responsibility of the supply chain or logistics department or entrusted to a dedicated supply chain analytics or modeling team.

But the commercial environment in which today's supply chains compete is very different from the one that existed three decades ago—and it continues to evolve at a rapid pace. Consequently, traditional design methods have become outdated, and companies that follow them risk putting themselves at a competitive disadvantage. However, there are tremendous opportunities for enterprises that take a more enlightened path. Just as markets have evolved rapidly over recent decades, so too have supply chain design practices and tools. By taking advantage of these advances and updating the way they approach supply chain design, companies can capture significant gains in operational efficiency and competitiveness.

The following sections show how these gains can be realized.

Current Approaches to Supply Chain Design

Supply chain design is supported by analytics approaches that can be embedded in decision-making tools and fed by relevant supply chain data. The following is a brief overview of the state-of-the art and state-of-practice in these areas.

Analytics Approaches

Supply chain design has typically been supported by two prescriptive analytics approaches: *optimization approach* and *simulation approach*. In practice, a combination of the two approaches can be beneficial.

The *optimization approach* typically employs mixed-integer linear programming (MILP) models to establish network configurations (e.g., number and location of facilities or structure of flows between different parts of the network) that aim to maximize some measure of performance while taking into account certain business constraints (e.g., limitations with regard to the capacity of different facilities). These models can either be used to perform a “greenfield” optimization, where the objective is to determine an optimal design for a new network that does not incorporate existing infrastructure, or a “brownfield” optimization, where the focus is on adjusting the design of an existing supply chain network while keeping some of the existing design intact.

The *simulation approach* aims to assess the expected performance of a supply chain design based on various inputs, such as by establishing total cost to serve for a given network configuration. While the simulation approach (unlike the optimization approach) does not guarantee that the optimal network performance will be reached with respect to a specified performance metric, it typically is significantly less expensive from a computational standpoint. This allows decision-makers to incorporate more refined input data and more complex relationships between different elements of the network.

Data and Decision-Making Tools

To harness the full potential of supply chain design, organizations can rely on huge amounts of data and employ decision-making tools of various degrees of sophistication. We find, however, that collected data is not always used to support supply chain decision-making, and that the decision-making tools that are employed vary widely across organizations. In the following paragraphs, we describe how the data and tools organizations use differ according to their level of decision-making maturity.

At the most basic level of decision-making maturity, relevant data is dispersed throughout the organization and basic tools (such as spreadsheet analysis) are employed. The decision-making process is typically siloed and limited to the supply chain functions.

As the decision-making maturity grows, organizations recognize the need for end-to-end decisions and cross-functional collaboration. They invest in tools that allow them to gain visibility across the organization and enable collaboration between different teams.

In highly mature decision-making environments, we witness a move toward a single data repository, which serves as a common source of truth and is embedded into more sophisticated and widely distributed planning tools. These serve as a major enabler of collaboration between different teams. Supply chain design decisions are no longer confined to one part of the organization, but instead emerge from a multi-stakeholder decision-making process.

Using Planning Optimization for End-to-End Supply Chain Decisions

The typical pharmaceutical supply chain is long and complex. It often includes multiple stages of production that are interdependent across many locations around the world. A slight change resulting from a decision in one area, which might improve operations locally, could trigger unexpected impacts elsewhere, leading to higher costs and lower efficiency in the supply chain as a whole.

For example, to avoid the cost of additional shifts, a packaging team might decide to smooth out their production plan by pre-building some volume at a time when demand is lower, which might be weeks or months ahead of when it will be needed. This means the assembly and filling teams must also adjust their plans to provide the input materials, which might increase their production costs. Moreover, because of a large minimum order quantity (MOQ) for the batch size, they will have to make much more packaging than usual and hold excess inventory—while bearing the added inventory holding cost.

Consider the example of one pharmaceutical manufacturer. The company used to manage production planning with spreadsheets and emails. Different stages of production had their own planners, who would submit their individual plans in the third week of each month. Then the supply chain planning team scrambled to negotiate with the production teams and piece the different plans together for a feasible plan in time to make a decision before the end of the month. Because this process was very manual and prone to error, it typically resulted in suboptimal plans.

To avoid such errors and improve planning, Coupa's Supply Chain Design and Planning (SCDP) team worked with the company to set up a repeatable optimization planning solution that covers the end-to-end supply chain, including primary and secondary manufacturing facilities as well as the distribution network to the company's markets. This solution considers the dependent demand among different stages and recommends feasible solutions. More importantly, it can find a holistically and mathematically optimized production plan that balances production costs, inventory holding costs, and transportation costs. Each production team now only needs to provide the refreshed inputs, such as run rates and capacity, in an agreed format. This feeds an automated data-processing workflow that validates and cleans the input data, then triggers the optimization and visualizes the recommendation of the optimized plan. The time required to refresh the production plan has been shortened from weeks to days. Planners can also run multiple "what-if" scenarios concurrently. As a result, rather than being tied up with spreadsheets and emails, the supply chain planning team can spend most of their time understanding the optimization results and making crucial decisions.

The Opportunities

There are many ways in which companies can improve how their supply chains are designed. But drawing on our extensive research and hands-on experience in the field, we have identified **four primary opportunities** for leveraging the latest supply chain design methods and practices to gain a competitive edge.

Supply Chain Design

Extend the scope

Move beyond cost minimization and facilities management

Incorporate the tactical

Integrate tactical decisions into strategic decision-support tools

Account for risk and plan for resilience

Use technology to mitigate risk and make optimal decisions

Adapt new technologies and business models

Embrace digitalization for customer-centric supply chains

Opportunity 1:

Extend the Scope of Supply Chain Design

As supply chains become more global and focused on the end customer, they play an increasingly important role as a competitive differentiator. Furthermore, companies are under pressure from consumers and regulators to improve the sustainability of their supply chains. With this in mind, supply chain design must move beyond its traditional focus on cost minimization and decisions about the physical configuration of networks (e.g., the number and location of facilities). Models and decision-making tools for supply chain design should incorporate a larger set of considerations. In this section, we describe several strategies for expanding design horizons in this way.

Design for Global and Diverse Markets

Cross-border supply chains that span multiple jurisdictions and support channels serving diverse markets are prime candidates for a more expansive approach to supply chain design. In these supply chains, objectives tend to vary and lack alignment in areas such as offshoring, onshoring, postponement, stocking, and last-mile delivery.[1] To overcome such inconsistencies, supply chain design must holistically integrate decisions from sourcing to go-to-market channels across multiple countries and geographies. The objectives must be expanded to explicitly consider global differences in upstream factors such as labor costs, tariffs, taxes and financial incentives, inventory value of products in transit, and transfer pricing. Likewise, the supply chain's distribution and delivery channels must incorporate objectives spanning a diverse customer base to effectively serve market segments.

Design for Value Creation

Supply chain design choices are directly related to company service objectives and product offerings.[2] For example, the configuration of logistics facilities and their proximity to the customer affect a company's ability to capture market share. Therefore, supply chain design involves making complex trade-offs to create value while keeping operating costs under control. However, in many organizations, the supply chain function is still predominantly seen as a cost center rather than a value-creation center, and there is still a lack of awareness of the relationships between supply chain decisions and return on investment for shareholders. Supply chain design models should incorporate a larger set of financial objectives, such as capital expenditure, working capital, market share, price, growth, and an extended set of decisions (e.g., product assortment, product launch).

Design for Sustainability

Sustainability has become a high priority for organizations worldwide, putting supply chains squarely in the spotlight. One reason is that global operations tend to increase transportation distances, which leads to greater environmental impact. Another is that adding more echelons to a supply chain can reduce transparency, a source of social sustainability concerns. In addition, growth in direct-to-consumer sales results in more fragmentation of deliveries and increased environmental impact in terms of emissions and packaging waste. While it is common for industries to compute the CO_2 emissions for various transportation modes, these assessments need to be expanded and refined to include the social and environmental impact of end-to-end supply chains, incorporating all production and warehousing facilities as well as the upstream energy sources, to achieve the "triple bottom line" of sustainability"[3]: economic prosperity, environmental quality, and social justice—or, more simply, people, planet, and profits.

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[1] Cohen, M. A., & Lee, H. L. (2020). Designing the Right Global Supply Chain Network. *Manufacturing & Service Operations Management*, *22*(1), 15–24.

[2] Martel, A., & Klibi, W. (2016). *Designing Value-Creating Supply Chain Networks*. Springer.

[3] Elkington, J. (1998). *Cannibals with Forks: The Triple Bottom Line of 21st Century Business*. New Society Publishers.

Cases

Value-Based Supply Chain Design

When a chemical company needed to adapt to customers' changing delivery requirements, MIT CTL worked with the company to redesign its US distribution network. The company's customers were increasingly seeking short delivery lead times, meaning that the proximity to demand was driving market share and profit. One possible solution was to densify the company's network of warehouses—that is, add more warehouses located close to customers—to increase sales, but it was necessary to also keep logistics costs under control. To support the company with this network redesign, the MIT research team first analyzed the exact relationship between distance to the customer and observed service time, then developed a distance-based service model. Additionally, the team analyzed historical market data to develop a model of price elasticity, which the company integrated into a network optimization model. This resulting model proposed a redesigned network that represented the profit-optimal trade-off between the expected additional logistics costs and the resulting growth in market share and revenue captured.

Supply Chain Design Integrating Profit and Sustainability

Coupa had been working with the supply chain team at a mining company on an end-to-end network design model that included production; material handling at plants, terminals, and transloads; storage at terminals; and transportation—truck, rail, and barge. After a few years, the project had advanced to a point where the model was optimizing across the entire network to maximize profit in a supply-constrained business environment. The supply chain team was then tasked with helping to determine the amount of CO_2 emissions in the company's supply chain. Their Coupa modeling solution allowed them to add to the model CO_2 emissions per ton of product produced, handled, or shipped for all nodes and lanes in the network. This provided an easy means of identifying the total amount of CO_2 emitted across the supply chain as well as calculating the CO_2 emissions totals by customer and product.

Sustainable Last-Mile Distribution Network Design

When a major global parcel carrier wanted to rethink its future last-mile delivery models, it called on MIT CTL for help. CTL built large-scale optimization models informed by representative samples of the carrier's parcel demand data for various urban and non-urban service areas. The MIT research team was able to make recommendations on which future vehicle technology (including drones, electric cargo bicycles, and electric delivery vans) the carrier should deploy, in which service areas they would be most beneficial, and which customers and parcel volumes would be best suited for service by these new delivery solutions. To maximize both the economic benefit from introducing these delivery model innovations and their environmental benefits to the carrier's last-mile operations, the team deployed an integrated modeling approach that considered tactical route planning, strategic facility location, and capacity planning dimensions. For example, some new delivery models would be viable only if their deployment would be accompanied by changes in the carrier's facility network.

Opportunity 2:

Incorporate Tactical Decisions

Strategic supply chain design decisions and tactical planning are closely interconnected. To reduce complexity, the latter is typically approximated and aggregated at the strategic decision-making level, leading to gaps between anticipated and actual performance. While this is acceptable in some planning areas, it can yield significant financial losses in those areas that drive supply chain performance. In recent years, data availability and computational power have increased, making it possible to integrate these more granular, tactical components into strategic decision-support tools. The following are examples of areas where these integrated applications can be particularly useful.

Sourcing Optimization

In many industries, sourcing optimization has become more important owing to the adoption of multi-sourcing practices as well as rising concern over supplier risk, the sustainability of sourcing practices, and the impact of sourcing on corporate responsibility. Most recently, disruptions during the Covid-19 pandemic have shed light on sourcing as a major point of failure and have confirmed the need to look at this issue in finer detail. For that reason, there is a vital need for analyses that integrate these more immediate, shorter-term tactical planning decisions with strategic, long-term decisions that are relevant to product flows and network structure.

Production Planning

In the manufacturing space, strategic production planning decisions, including facility location and machine capacity, are directly interrelated with tactical decisions on the utilization of those assets—i.e., choice of facility and production line, and lot and batch-size optimization. These tactical decisions, which have a direct impact on sourcing decisions and the downstream supply chain, are major drivers of overall efficiency. Hence, analytical tools in this space should jointly consider strategic and tactical decision-making levels, as gaps between these levels lead to suboptimal designs, which in turn lead to supply chain underperformance.

Replenishment and Inventory Decisions

Inventory and replenishment decisions are directly related to strategic planning aspects that are relevant to sourcing and to the locations and sizes of various facilities in the network. This is particularly relevant for global, multi-tier supply chains and industries characterized by a high value of inventory, where decisions about cycle and safety-stock deployment can have substantial financial impacts. Extending the current supply chain design models to incorporate inventory and replenishment aspects is crucial to capture trade-offs between facility, transportation, and inventory capital costs.

Transportation Planning

In parcel delivery and retail industries, transportation planning has a strong influence on strategic planning. This applies especially in inbound transportation and last-mile distribution, where decisions about the allocation of transportation resources and carrier or mode selection need to be aligned with the design of the network. For example, deciding on the configuration of logistics facilities without accounting for the last-mile transportation routes can dramatically increase distribution costs. Hence, design of distribution networks should incorporate a more granular estimation of the transportation and routing costs, accounting for elements such as customer density, logistics infrastructure, and the expected service level.

Integrated Last-Mile Network Design

MIT CTL collaborated with a major Brazilian omnichannel retailer to redesign its last-mile distribution network. The company serves thousands of customers each day in São Paulo and other major cities in Brazil and offers various delivery speeds, including next-day, same-day, and immediate delivery to customers' homes or to brick-and-mortar stores. Decisions relevant to network configuration, such as location and number of logistics facilities, are typically dealt with at the strategic level, while decisions about fleet and route optimization tend to be tactical and operational. However, last-mile delivery operations require a balance of both of these areas in decision-making.

To address this problem, the research team developed an integrated network design model incorporating these multiple levels of decision-making. The integrated model also accounted for the company's various distribution channels and delivery services. Proprietary and external data were used to perform a highly granular analysis of the company's last-mile distribution operations and the properties of the entire service area.

The resulting design was a three-tiered, last-mile distribution network that leverages diverse transportation modes (e.g., vans, cargo-bikes, motorbikes, crowdsourced shipping) depending on the delivery speed, the demand characteristics, and the infrastructural properties of each neighborhood in which the company operates.

Integrating Strategic and Tactical Planning

A large international food and beverage company wanted to further integrate its strategic models, which were based on forecasts for annual periods looking out several years, into the tactical space—monthly periods looking out 12–18 months. The company's enterprise resource planning (ERP) system had tactical sales and operations planning (S&OP) functionality; however, it lacked the sophisticated optimization logic and rules planners wanted, and it was difficult to move between the strategic model and tactical solutions. The Coupa SCDP team worked closely with the company to leverage the strategic model data foundation (~75% of what was needed) and augmented it with more detailed data within its ERP system and elsewhere to add detailed manufacturing data (production line capacities by month, changeover times, inventory capacities, and demand seasonality).

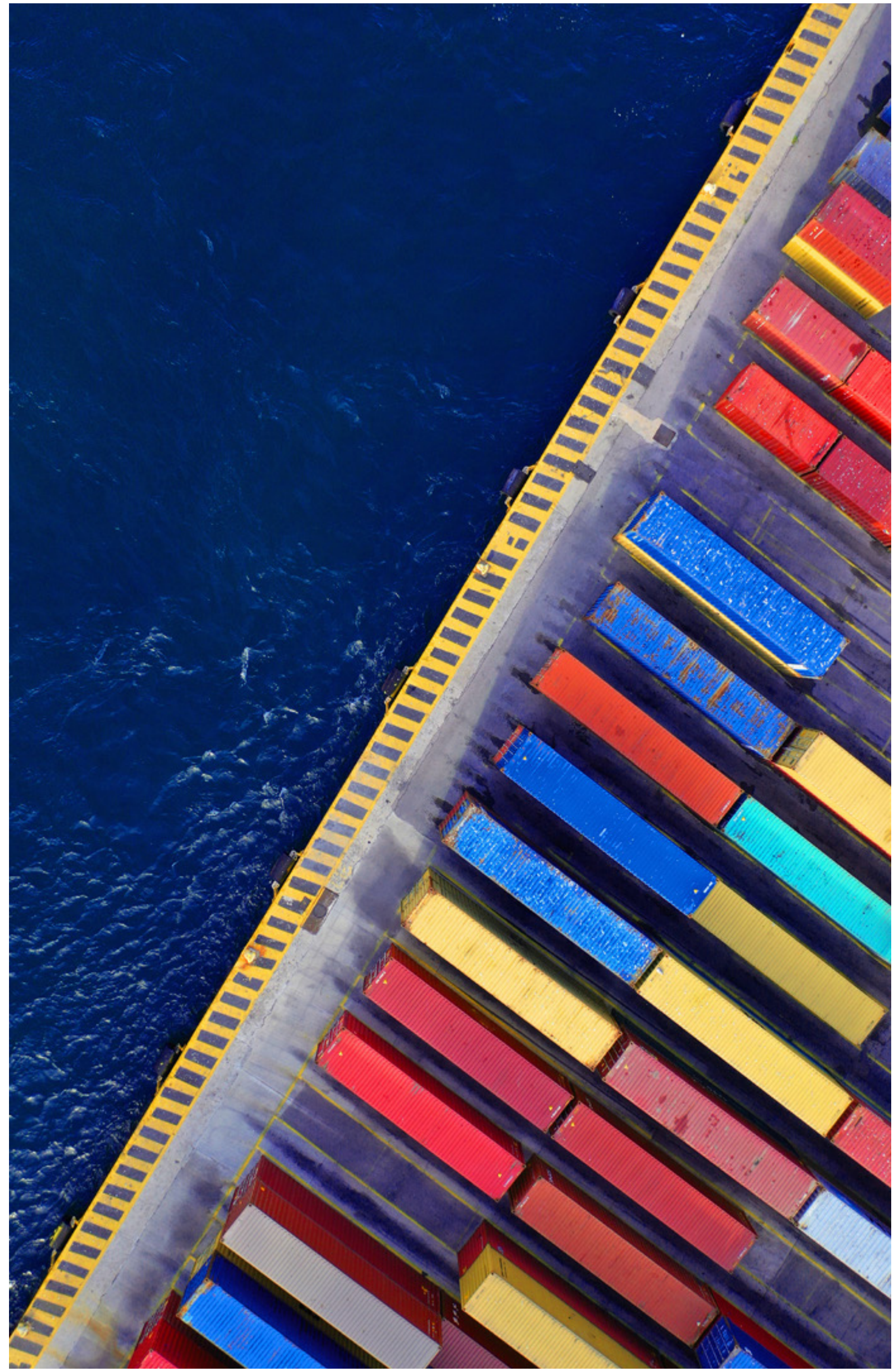
A key goal was the ability to move quickly between the strategic and tactical space, using the same data and assumptions, to validate strategic scenario results at a tactical level and to revert from tactical solutions to strategic models as challenges were identified.

With a common data foundation enabling data to be analyzed in both strategic and tactical contexts, planners gained access to new tools like user-controlled selections and toggles that changed the level of granularity, the types of constraints applied, and the model periods and horizon. Consolidating data inputs and assumptions and automating data transformation took several months, but the result was an end-to-end solution that could be updated in a few hours as opposed to a few weeks. This allowed the company to significantly expand its usage of the new tools. Additionally, planners could now answer many more questions for the management team in a time frame that met their expectations.

Opportunity 3:

Account and Plan for Risk and Resilience

One thing has become abundantly clear to supply chain managers in recent years: Disruption, uncertainty, and risk have all increased. Product demand, costs, freight transportation rates, lead times, exchange rates, and capacity requirements are naturally exposed to various sources of uncertainty. In addition, demand and capacity are subject to shocks, mainly due to natural disasters and accidents, but also to supplier failures, strikes, and, of course, epidemics and pandemics. In light of the increased pace of change on the demand and supply sides and the growing relevance of major disruptive events, it is imperative that companies mitigate risk to achieve optimal performance in challenging environments. Accordingly, supply chain decision-makers are seeking methods for integrating risk and resilience into their supply chain designs. Here are some ways technology can help.



Embedding Uncertainty into Supply Chain Design

To account for uncertainty (e.g., future demand), organizations typically design supply chains to operate optimally under expected conditions (e.g., average demand) and perform sensitivity analyses to assess that design's performance across a range of scenarios. This approach can help to validate that a given design performs sufficiently well in a given scenario range, and it can help to foresee and prevent big deviations from the expected results. But because it is agnostic of the likelihood and impact of various scenarios, it typically leads to more variability and does not guarantee an optimal outcome. A more effective method is to structurally embed uncertainty into supply chain design. For instance, stochastic programming methods optimize designs by explicitly accounting for a range of likely outcomes associated with the main sources of uncertainty. This approach creates designs that achieve higher overall performance in a wider range of risk and uncertainty scenarios.

Using Scenarios to Account for High-Impact Risk

Low-probability, high-impact risks require more complex decision-making support. First, the lack of historical data makes it extremely difficult to associate probabilities with this risk type. Second, even if such probabilities can be established, given their extremely low likelihood, the potentially catastrophic impact of such events will likely not be captured by traditional methods, and therefore, will likely not affect the design choices. To incorporate these types of risks in supply chain design, a scenario planning approach can be useful. In such cases, scenario planning allows users to understand potential outcomes and steer decision-making away from reaction and toward proactive preparedness.[4]

Incorporating Risk Mitigation and Resilience

Companies need to structurally incorporate risk-mitigation and resilience measures into analytical decision-making support tools. Risk-mitigation measures can translate to "rules" embedded in the underlying models. Examples include limitations on the share of total volume that can come from a single supplier and prioritization of customers according to their strategic importance in case of capacity shortages. Resilience can be achieved through redundancy, such as inventories dedicated to serve as buffers in critical situations and back-up centers to ensure business continuity for customers, or through flexibility, such as flexible production and distribution capacity and the ability to substitute components.[5] A proactive, data-driven approach to resilience, deploying risk-mitigation strategies ahead of time, will result in an increased return on investment on risk and resilience expenditures—much better than reactively incorporating such measures after a disruptive event.

[4] Scenario Planning Builds a Resilient Future. (2020, April 17). *.org Community*. https://orgcommunity.com/scenario-planning-builds-a-resilient-future/

[5] Sheffi, Y., & Rice, J.B. (2005). A supply chain view of the resilient enterprise. *MIT Sloan Management Review,* 47(1), 41.

Cases

Incorporating Uncertainty into Supply Chain Design

Demand uncertainty was a top concern for a major fast-moving consumer goods (FMCG) manufacturer in Colombia that fulfills millions of orders per year. Short delivery times are often requested by the tens of thousands of customers the company serves daily, leading to significant variations in daily demand. Working with a team of researchers from MIT CTL, the company aimed to design a network that minimizes costs and risks. To achieve this, the MIT CTL research team first established a range of scenarios that best represent the distribution of the observed demand uncertainty. The team then developed a stochastic network optimization model that considered different demand scenarios and their probability of occurrence. The model incorporated a series of flexibility measures (e.g., flexible facility capacity and possibility of fleet outsourcing) that the company can use to mitigate the effects of demand fluctuations. Compared to the company's traditional network planning approach, which was based on average demand assumptions only, the new design yielded a more robust network with a lower expected operational cost and significantly reduced financial downside risk.

Risk Mitigation with Scenario Capabilities

The ever-increasing pace of change requires companies to be able to adjust their supply chain designs quickly to remain competitive. Early in the Brexit process, a pharmaceutical company with plants in the UK needed to understand the impact of an anticipated change in a drug product testing regulation on its production plan and distribution network. The company knew that certain UK-produced products might need to be tested separately in the EU before they could be released to the EU market. This would add extra transportation cost and increase lead times and inventory levels. The supply chain model Coupa's SCDP team built for this client acted as a "sandbox" where historical production and distribution rules were modified to test different options for accommodating the new, post-Brexit rules. The company then compared the total cost, service level, and inventory implications of the different scenarios in the virtual model and quickly prepared Brexit supply chain strategies. When Covid-19 hit, the manufacturer used similar models to evaluate whether its current supply chain could survive various scenarios of Covid-19's impact on its demand profile and workforce availability.

The analysis helped the company decide to adjust the safety-stock levels and production run rates of certain products to improve its supply chain's resilience to the most likely Covid-19 scenarios.

Opportunity 4:

Adapt New Technologies and Business Models

In recent years, the digital transformation of supply chains—the alignment of digital information flows with physical and financial flows through new technological platforms—has generated dramatic changes in business models, including the way companies reach their customers, organize internal processes, and collaborate with supply chain partners. Companies can leverage these changes in the design of their supply chains by embracing practices that support and enhance the benefits of digitalization. The following examples explain some of these opportunities.

Digital transformation has enabled more companies to customize their products and services in line with market demand; it also has enabled them to move toward direct-to-consumer business models and omnichannel retail and distribution. The resulting fragmentation of distribution channels and shipments, combined with rising customer expectations for delivery responsiveness and service flexibility, can increase fulfillment costs.[6] However, these digitally enabled capabilities offer an opportunity to promote customer loyalty and lifetime value through customized distribution channels. To capture these trade-offs, the associated costs and benefits must be included in supply chain design. Including these costs helps companies to ensure that customized services are profitable and efficient.

Complex Organizational Relationships

To fully exploit the more complex forms of collaboration made possible by digitalization, supply chain design exercises should reflect the key relationships that link the different actors involved. These include various forms of outsourcing and subcontracting, different types of vertical collaboration (e.g., revenue-sharing contracts or vendor-managed inventory), and various forms of horizontal collaboration (e.g., asset sharing and resource pooling). It is especially important to incorporate the risk- and benefit-sharing rules used by the supply chain partners in the network. In addition, design exercises should take into account new business models that allow on-demand utilization of resources rather than investment in assets. These flexible models enable companies to revisit their design decisions more frequently—a key advantage in today's fast-changing markets.

New Technologies in Production, Warehousing, and Transportation

The introduction of technologies such as robotics, drones, and autonomous vehicles is accelerating the evolution of production, warehousing, and transportation processes. These technologies fundamentally change the premises on which supply chain designs are based. For instance, design features such as warehouse throughput and storage capacity are dependent on the shipping and receiving resources (e.g., number and type of docks), storage space, and storage technology that are available. Similarly, production or assembly workstations can employ dedicated or shared technologies, and in last-mile distribution, the use of drones or autonomous vehicles with a limited range impacts the location of logistics facilities. The lesson here is that decisions relating to the selection and implementation of new technologies should be part of the supply chain design process to maximize the benefits gained and avoid costly mistakes.

[6] Janjevic, M., Merchán, D., & Winkenbach, M. (2021). Designing multi-tier, multi-service-level, and multi-modal last-mile distribution networks for omni-channel operations. *European Journal of Operational Research*, *294*(3), 1059–1077.

Case

Digitally Enabled, On-Demand Fulfillment for a Fashion Delivery Service

A global sports-fashion brand asked MIT CTL for recommendations on how to enhance the company's distribution and retail store network in New York City and other major cities around the world. The objective was to provide highly responsive, on-demand delivery services for online orders in the brand's most valuable customer segments. The project team identified which network facilities and store locations could support the service and the amount of inventory required for each product, down to the SKU and physical location levels. The support needed from store-based, decentralized fulfillment processes, in-store personnel, and courier services were also mapped out. The team used large amounts of historical order data, publicly available traffic and road network data, and other sources of information to develop a simulation-based optimization model. The model combined traditional optimization and simulation models with advanced machine learning methods to create an accurate representation of complex, real-world network configurations. Moreover, the analysis yielded key insights into the optimal network design and expected performance while keeping computational costs to a minimum.

Armed with this information, the enterprise leveraged its existing brick-and-mortar stores and other distribution facilities to meet its service goals. It was also able to identify areas where the existing network would need to be complemented by new, dedicated facilities. In addition, the tool generated more accurate inventory-positioning plans across the distribution and store network. It also provided more accurate numbers for the total cost per delivery of the new premium service based on the location of the order and its surrounding demand and infrastructure characteristics.

Toward Value-Added Supply Chain Design in Organizations

As the preceding opportunities and case examples show, a new generation of supply chain design tools and practices can deliver significant cost savings, operational efficiencies, and competitive gains for those companies able and willing to apply them.

In this section, we help executive leaders understand the significance of these advances by explaining why and how they are applied.

Tapping into the Full Power of Analytics

Thanks to the rapid growth in computational power and major advances in operations research, it is now possible to build enhanced optimization and simulation models that capture the business constraints that characterize contemporary supply chains. In addition, major advances in data science provide new tools for the study of complex supply chains. Here are the main opportunities that spring from these developments.

AI and Machine Learning to Enhance Input Data

This is the most common application of data science in supply chain management; it is particularly interesting for modeling the behavior of actors outside the control of the organization, such as customers and indirect suppliers. These techniques are especially relevant in market environments defined by a large number of customers (e.g., forecasting e-commerce retail demand) and a fragmented supplier base (e.g., modeling supplier risk in the automotive industry), where it is not possible to model each individual actor.

AI and Machine Learning to Facilitate Scenario Building

In supply chain design studies, a potentially infinite number of possible scenarios can be incorporated in a given analysis. Running each scenario incurs a significant computational cost. Therefore, scenario selection is a crucial step that can drive the quality of analytical insights and the speed at which they are derived. In order to select the most relevant scenarios to be included in the analysis, companies can use historical data and AI or machine learning methods to identify primary sources of uncertainty, empirical probabilities, and potential correlations between the scenarios.

AI and Machine Learning to Reduce Model Complexity

The complexity of analytical models grows with the integration of more granular, tactical components, multiple scenarios, and new technologies or business models. For example, including inventory-deployment decisions quickly increases problem complexity, making it difficult to solve the problem using classical optimization techniques. To address this challenge, data science can be used to reduce the complexity of the model by performing aggregation, such as through the use of clustering rules, or by replacing certain parts of the model—for example, by approximating certain tactical or operational decisions sufficiently well rather than explicitly modeling them.

Network Science Perspectives for Studying Complexity

Network science, which studies complex networks like telecommunication, social, or biological networks, is an emerging discipline that has seen dramatic advances in recent years. In the field of supply chain management, this discipline offers new perspectives on the study of complex networks of facilities, assets, actors, and relationships. For example, network topology analysis can be used to assess the relative position of different elements of the network and highlight those that present the most favorable position (a candidate cross-dock facility with the most advantageous location in terms of distance and cost relative to other facilities in the network, for instance). These analyses can also be used to pinpoint parts of a network that are most vulnerable to disruptions, such as a supplier that represents a critical link in the network.

Case

Network Topology and Machine Learning for Network Redesign

An MIT CTL research team worked with a global manufacturer on the redesign of its network. The team applied network science methods to identify and analyze tens of thousands of subnetworks for each of the manufacturer's several thousand products and customer clusters. For each of these subnetworks, the team computed network topology metrics describing the relative position of different facilities within the network. The exercise identified those facilities positioned most favorably to serve target markets and the upstream supply chain. A freight-cost prediction model incorporated many features, including customers' purchasing behavior (delivery quantity and frequency), product characteristics, direction of the flow relative to global and regional trade flows, GDP per capita and labor costs of origin and destination country, and indicators of logistical performance in origin and destination countries. The machine learning algorithm then performed a realistic estimation of logistics costs in a highly complex network composed of hundreds of logistics facilities and tens of thousands of individual clients.

Adopting New Decision-Making Frameworks for Supply Chain Design

Adopting the data-driven supply chain design methods described in this paper is not enough; these methods must also align with a company's managerial and organizational culture if the opportunities described are to be realized. To achieve such an alignment, it is necessary to rethink the decision-making frameworks that underpin these new design approaches. In this section we present some key aspects to consider when developing new decision-making frameworks.

Reframing the Design Problem

Supply chain design and supporting models have traditionally focused on standard problems and objectives, such as cost minimization, decisions about where facilities should be located, and capacity constraints, and scenarios for factors such as average demand. The first step in reframing decision-making is to translate the dimensions where supply chain design creates value into specific design objectives. For example, in the retail industry, key dimensions could include market share and revenue growth, whereas in the pharmaceutical sector, factors relevant to patient well-being should be considered. Second, key value-generation levers must be translated into design decisions (changing product mix or employing a crowdsourced delivery model in retail, for example), while realistically capturing critical industry and organization-specific constraints (regulatory constraints limiting the structure of physical flows in the pharmaceutical sector, for example). Finally, primary sources of uncertainty should shape the implicit stochastic modeling and/or the scenario-building process.

Choosing the Right Level of Customization

Supply chain design studies have traditionally employed generic models and general-purpose tools. For example, facility location and network flow models were often agnostic of the specific industry or market in which organizations operate. Given the key role that supply chain design plays in corporate strategy, a more customized approach to supply chain design is needed. While these targeted solutions increase the relevance of tools and models used to support decision-making in supply chain design, they also require the maintenance of custom-developed code. Therefore, while reframing the decision-making problem, it is necessary to adopt a more customized approach only in those areas that act as key levers of performance.

Choosing the Right Level of Complexity

The complexity of models used to support supply chain design should account for trade-offs between the need to collect and maintain data, the computational time required, and the ability of those models to generate relevant insights. Here, the complexity of tools used to describe different planning components should directly reflect business needs and rules within each sector. For example, approximating transportation cost with a distance or weight-based factor on a given lane is an acceptable approach for certain industries. However, this method fails to capture the real operational complexities of certain sectors like last-mile distribution, where transportation costs are a function of numerous factors, such as customer density, drop sizes, traffic congestion, and time-window constraints.

Cases

Customized Supply Chain Design for a Pharmaceutical Company

For a supply chain design project commissioned by a global pharmaceutical company, an MIT CTL team developed highly customized optimization models. These were integrated into visual decision-support tools, while accounting for the industry's operational and regulatory constraints. For example, the optimization models had to account for the variety of stockholding and transportation conditions, including the large number of cold-chain airfreight shipping solutions and containers employed in the pharmaceutical sector. The network design solutions also considered local regulatory constraints across the different markets in which the company was operating.

Adapting to Local Specificities in Supply Chain Design

MIT CTL has collaborated with several fast-moving consumer goods (FMCG) manufacturers, retailers, and e-commerce players in Latin America. In many of these projects, the research teams incorporated local market specificities into their supply chain design models. For example, even in business-to-business (B2B) distribution systems, these models had to be able to take into account a large and highly fragmented customer base requesting small but frequent deliveries while remaining computationally tractable. This required different approaches to capturing customer availability, predicting delivery success, and estimating travel times, as well as to cost-to-serve and route productivities. Further, local security constraints and a cash-based economy gave rise to a number of additional sources of risk and uncertainty that had to be modeled.

Rethinking Organizational Structure and Processes

Moving toward a value-driven, adaptable approach to supply chain design requires several changes in organizational structure and processes. Here are some important factors that play a role in a successful transition.

Organizational Ownership

Clear ownership of supply chain analytics and design can be established through a dedicated team—a center of excellence, for example—that is responsible for managing the data repository and facilitating design activities. This group should drive persistent innovation in the organization and shape transformative change. Typically, this team should be in the supply chain organization and have a high level of visibility and empowerment. For instance, the team might report to senior executives.

Cross-Functional Collaboration

A value-driven, end-to-end supply chain design requires collaboration among multiple functions and roles within the organization. The objective is to move away from design within regional and/or functional silos and toward co-design with a variety of stakeholders across the global supply chain. Planners and modelers should engage executives from strategy, finance, sales, marketing, and human resources. Here, a common data structure serves as a single source of truth and promotes collaboration across the organization.

Continuous Review and Redesign

It is necessary to move from an event-based (or crisis-driven) approach, where supply chain design is performed as a one-off study, toward a continuous review and redesign process. This allows organizations to quickly adapt to changes in the business environment and develop feedback loops that enable timely course adjustments. Process discussions can mimic the dialogues that typically take place in sales and operations planning (S&OP) groups. These discussions should occur on a monthly or quarterly basis and incorporate stakeholders from various functions in the organization.

Success Metrics And Incentives

The collaborative aspect of supply chain design problem-solving should also be directly translated into the types of metrics and incentive systems used to assess the impact of different decisions. Here, it should be recognized that design decisions often require difficult trade-offs between various dimensions of performance, which can be more or less relevant to different parts of the organization. Examples include trade-offs between logistics cost and service level, service level and inventory level, and capital investment and market share. These performance dimensions are relevant to various groups of stakeholders in operations, sales, marketing, and finance.

Skills And Training for Effective Communication

Collaboration is easier when all stakeholders speak a common "language." Aligning skills and formalizing training requirements throughout the organization creates a common vocabulary among decision-makers and facilitates productive interaction regarding design decision trade-offs. A common business language also allows stakeholders to more effectively explain the opportunities and ramifications of new designs within their part of the organization. In addition, even if a dedicated, specialized team leads the advanced analytics and design effort, some general training in end-to-end supply chain management and analytics for supply chain design may be important to enable productive discussion of supply networks and analytical approaches.

Leadership Buy-In

Active collaboration and empowerment of a dedicated analytics and design team is only possible when senior leadership is engaged. Visionary executives must work to enable and embrace modern co-design activities. They must also engage other senior executives in S&OP types of discussions regarding supply chain design to have broad organizational impact. Successfully communicating the early impact of new designs on key metrics can catalyze further engagement and reinforce continuous review and redesign. Over time, these new approaches leverage “muscle memory” and generate a new organizational approach to supply chain value creation.

Cross-Functional Co-Design Process

MIT CTL collaborated with a large manufacturer that was interested in redesigning its US network. The team of researchers implemented a co-design process with members of the company's logistics, finance, sales, and marketing departments. The executives went through a collaborative process to iteratively design the company's future supply chain, allowing them to consider trade-offs among competing metrics that traditionally were considered in isolation by the various functional silos. The interactive and collaborative decision-making also allowed participants to gain insight about model results and absorb the implicit knowledge of the various stakeholders. For example, sales and marketing executives contributed their knowledge about specific local market conditions and competitive pressures.

Democratized Access to Applications

A global manufacturing company turned to Coupa for help in updating a wide range of models related to network design, tactical production planning, and inventory planning. The network modeling team refreshed and managed all of these models and provided outputs to the broader organization at regular frequencies, running new scenarios as requested. The results were well received; however, the modeling team was becoming overwhelmed by trying to keep up with a growing list of scenarios requested by users and trying to continuously improve their solutions to meet new business needs and/or add more granular details.

The Coupa team worked with the company to implement a series of cloud-based app solutions that incorporated some or all of the data-refresh process. The apps also incorporated the optimization models and visualizations, presenting those in a simplified workflow that allowed the stakeholders to take on the majority of the activities from the modelers. This required a series of interactive sessions with the stakeholders to design the app interfaces to be both intuitive and flexible enough to handle current and future scenario needs. Additionally, the apps are capable of handling multiple stakeholders interacting in the solution at the same time, tracking changes, providing version controls, and archiving older models. In most cases, the stakeholders can now execute the data refresh and new scenarios without interaction with the modelers. However, there are periodic, proactive assessments between the modeler and stakeholder teams to ensure the models represent current business conditions.

Conclusion

Supply chain design is the pillar of strategic supply chain planning and a key enabler of a firm's corporate objectives, be they resilience, sustainability, growth, or other goals. To align their supply chain design process with the requirements and challenges of contemporary markets, companies must embrace new design paradigms.

This white paper serves to provide a representative picture of supply chain design's changing role and identifies a range of opportunities in this area. These include expanding the scope of the logistics systems under consideration, revisiting the objectives and decisions included in supply chain design, enhancing the link between the strategic and tactical levels of decision-making, integrating risk and uncertainty, and incorporating new, transformational technologies and business models.

In light of these numerous possibilities for growth, organizations must adopt a strategic approach to change, focusing first on those areas that represent the highest potential to yield value. At the same time, they must identify key trade-offs involved in different design decisions while examining the organizational ecosystem to identify stakeholders that can drive change as well as those that will be impacted by those changes. To best position themselves to do so, companies must move from a siloed to an interdisciplinary mode of operation, in order to foster a cross-functional co-design process that reflects the key role of supply chain design and strategy in the organization.

As a result of significant developments in various fields of analytics and an increase in data availability and computational power, companies can now rely on a large number of analytical tools to help them on their journey. Here, the real test of the effectiveness of such tools is their ability to inform business decisions in a real-life decision-making context. Consequently, their adoption must go hand in hand with a redesign of group and organizational decision-making processes with respect to supply chain design. The purpose is fourfold: to ensure that all relevant perspectives are accounted for, that the framing of the problem reflects the organizational priorities, that the analyses are fully understood and trusted, and that resulting solutions are adopted and implemented. Furthermore, organizations must implement a continuous redesign process, allowing them to align designs with their evolving supply chain strategy, adapt to their dynamic business environment, and learn from past implementations.

As the challenges that face organizations continue to evolve, so too does the supply chain design discipline. Therefore, to achieve corporate objectives such as resilience, sustainability, profitability, and growth, firms must put in place mechanisms that allow them to structurally incorporate innovation itself into supply chain management.