

Supply chain network simulation and optimisation – a review

Alan Denton



The use of simulation and optimisation models or tools in the design and management of supply chains has become commonplace since IBM and Bill Gates put computers on our desks.

The speed and power of cheap computers makes even extremely large and complex problems solvable in reasonable run times. Modelling and optimisation provide opportunities for assessing and choosing amongst strategic options in a risk-free environment, driving business value through cost reduction and managing supply chain risks.

For clarity, let us define our terms:

Simulation: An imitation of some real thing, state of affairs, or process. The act of simulating something generally entails representing certain key characteristics or behaviours of a selected physical or abstract system. Simulating the current supply chain provides a valuable validation step that allows the comparison of the model to the real world to ensure that ALL the key costs and relationships have been considered correctly before testing a new scenario. Simulation models typically allow the assessment of scenarios in which only one input variable has been changed, for example, when an additional warehouse is added to the network in a specific location.

Optimisation: The procedure or procedures used to make a system or design as effective or functional as possible, and often implies the use of special mathematical techniques. Optimisation helps find the answer that yields the best result - the one that attains the highest profit, output, or happiness, or the one that achieves the lowest cost, waste or discomfort. Computer-based algorithms can sift the billions of possible combinations of products, sources, warehouses, transport modes and customer allocations to arrive at a true, global optimum. To extend the example above, an optimisation system can assess the addition of up to three warehouses at 20 possible locations in a single run.

Business benefits

Business process is an example of decision-making under conditions of uncertainty.

No one has perfect knowledge of customer demands or behaviours yet businesses often make investments with only rough ideas about outcomes. Building a model of a process strips it down to the essentials and allows better quantification of the effect of inputs on outputs. In this way modelling reduces uncertainty and quantifies benefits without implementation costs and risks. Models can also be used to quantify the costs of different risk mitigation strategies or to estimate performance measures that may be difficult to establish from real world systems – for example, system availability or DIFOT. Optimised models can find an optimal solution from billions of possible alternatives – reducing time spent in assessing feasible, but sub-optimal scenarios.

Strategic network design

According to AMR Research, 80% of a company's supply chain costs, including inventory planning and deployment, are captive in the strategic planning phase of supply chain optimisation.

The kind of questions that network design models can answer include:

- What reverse logistics network will meet customer turnaround requirements at the minimum cost?
- Post-merger or acquisition decision support. What is the best network for an organisation that currently has at least two of everything?
- What are the benefits of postponement strategies (location and degree of localisation required for products) in the network?
- Which order fulfilment strategies (purchase-to-order, build-to-order, configure-to-order, build-to-stock) meet customer requirements with minimum cost?
- Risk analysis: What contractual liabilities are associated with the current supply model? What is the impact of variation on the supply chain and how could it be reconfigured in the event of a disaster?
- What is our customer profitability / cost-to-serve?
- How will the network be affected by product introductions / deletions?

- What is current network / system performance – e.g. can we measure availability or DIFOT (meaningful measures for our customers) versus fill rate (easily collected but less useful to the customer)?
- Transport tender evaluations. What is the best mix of DCs and transport costs to meet our customer service promise?
- 3PL network flow optimisation (network capacity / resource optimisation). What happens to the existing network capacity if we win a major piece of work? Can the current line-haul capacity manage a seasonal peak?
- The multi-echelon inventory optimisation problem. Given our service level targets, what, where and how much stock should we hold to meet the goals at the lowest annual cost?

Now that we've discussed the benefits and potential applications of simulation and optimisation, let's explore some of the issues that need to be considered in their use.

Problems with simulation

Simulation only considers the specified scenarios. The level of granularity of the simulated scenario is a key variable in the model design. Some simulation models ramp up from their starting conditions to a steady state – for example, the inventory on-hand settles down to the long term (equilibrium) average. In some cases the model may not reach equilibrium, making comparisons between scenarios implausible. Simulation models may require several 'layers', like a set of computer-aided design drawing overlays, to model both a network and events inside a production facility. Dynamic simulation techniques (where the output of one simulation becomes the input for a subsequent simulation) may be



APICS Certified Supply Chain Professional

Take Your Supply Chain Career to a New Level

Are you an operations or supply chain management professional who:

- is interested in obtaining more depth of knowledge and understanding in increasingly complex supply chain disciplines
- is a supply chain consultant or instructor?
- works with enterprise resources planning (ERP) systems?

The CSCP program will help you develop into a supply chain leader who can create and execute a supply chain strategy that meets customer needs, reduces costs, and increases profits.

With the APICS CSCP designation, you'll increase your value to employers who know that a well-run supply chain is a key component of a forward-looking and competitive enterprise.

The unique CSCP Learning System combines print materials with online components to deliver a customised learning experience. Benefit from instructor-led sessions that supplement the learning system with real-world examples and offer opportunities for discussion and interaction, or elect to self-study the material.

To earn the APICS CSCP designation, candidates must meet eligibility requirements and pass the APICS CSCP exam.

New South Wales	02 9891 1411
Queensland	07 3282 8393
South Australia	08 8243 7911
Victoria	03 9328 4477
Western Australia	08 9322 1444

Australasian Production & Inventory Control Society
www.apics.org.au

supply chain

necessary to model some processes. Some model building softwares require the analyst to perform data reduction, for example to reduce a string of purchase orders and receipts into a Poisson distribution describing supplier delivery performance. These issues do not make simulation techniques unusable; rather, they highlight the skill required to apply them successfully to solve business problems.

Problems with optimisation

Optimisation-solver algorithms use a variety of techniques but care must be taken to ensure the system seeks a global optimum rather than becoming 'stuck' at a local optimum. To use a hill climbing analogy: being at the peak of Mount Kosciuszko might be a good solution, but being at Mount Everest is the global optimum, which might not be found by some search methods. Different optimisation approaches e.g. genetic, tabu search, simulated annealing, linear programming, mixed integer programming, cost scaling algorithms etc. may not result in a provable global optimum, but it may be sufficient to stop searching if the improvement achieved between iterations is extremely small.

The level of granularity in the data (e.g. 100,000 individual customers or 150 postcode zones) drives the number of possible combinations and hence the speed of the solver in reaching a solution. Solver run-times are impossible to predict a priori. Most non-academic users treat their solvers as 'black boxes', and do not really need to know what is going on inside, particularly when using commercially developed engines.

A consideration in purchasing an optimisation system is the supportability of the solver engine. The solver may be open or proprietary, and developed in-house or acquired from a third party. Both approaches have pros and cons related to customisation, tuning, development effort and support – e.g. will it run under Vista? Multiple solvers may be necessary to manage different types of problems, making non-specific modelling systems difficult to develop. For example, the engine capable of solving a network flow problem will probably not be the engine that solves the multi-echelon inventory problem. Multiple solvers operating on a common database structure is a reasonable approach for practitioners seeking a tool that can be applied to a wider variety of problems. Several commercial vendors have applied this approach.

Custom-built or commercial 'off-the-shelf' models?

Simulation and optimisation techniques offer a capability far beyond the average spreadsheet model. While large models can be built in spreadsheets with add-in solver engines or custom-built in script based systems, it is often simpler to use a commercially available model designed to solve supply chain problems. Such systems have well designed graphical user interfaces and data grids to simplify the data collection and validation processes. They often integrate maps and road network data for both problem visualisation and time/distance calculation purposes. The solver(s) provided will have been 'tuned' to match the data structures (e.g. customers generally outnumber the warehouses) and tested to show reasonable run times and quality solutions.

In-house or outsource?

Typically an organisation uses an outsourced service if the service provider has an economy of scale or skill that the purchaser cannot economically replicate. So it is with network optimisation tools. Firstly, developing a model in-house requires a skill set few but the largest organisations can afford to maintain. Secondly, such strategic modelling is not conducted every week; at best an annual review is called for unless the environment is undergoing rapid change.

Commercial software vendors or consultants can provide training in model building and support the development of a company model that can then be refreshed and modified in-house. Outsourcing the whole piece may be sensible if internal resources are unavailable or speed is critical. Consultants are often able to provide a bureau service to re-fresh and re-run scenarios with new data.

Planning frequency

The choice of optimisation tool in the supply chain domain is determined by the frequency of the relevant decision. The table below (Figure 1.) shows typical questions and frequency.

Supply chain network design is typically conducted, at best, as an annual exercise, perhaps as part of the budgeting process, unless the macro-environment is extremely unstable. Most organisations will review their supply chain structure at intervals between one and five years in the absence of external change initiatives. However, this undervalues the use of such tools in other areas of strategy. Quantifying supply chain risk alone should be a process requiring annual review.

Summary

The elements of supply chain strategy and execution span multi-year time horizons (as well as the next five minutes). At each step, from the initial design or re-design of the overall supply chain to what order(s) the warehouse operator will pick next, simulation or optimisation techniques can drive efficiency both in operations and planning. Modelling creates a risk-free environment to test hypotheses and assess strategies in a bottom-up, fact-based way. For supply chains, optimisation techniques can sift billions of combinations to arrive at a cost minimum or profit maximum solution. Practitioners who are not using simulation / optimisation techniques are potentially missing significant opportunities to improve competitiveness, making

longer term supply chain investment decisions without all the facts and / or exposing themselves to unforeseen yet real-world risks. Practitioners who use these techniques are able to make informed investment decisions, capitalise on competitive opportunities and mitigate supply chain risks. Commercially available tools simplify the modelling process, and most organisations have the necessary data of sources, warehouse costs, transport rates, customer location and demand to allow the construction of a reasonable baseline model. The optimised supply chain is now available on the desktop.

Alan Denton is senior manager at GRA, a company specialising in demand, inventory and supply chain optimisation. Call (03) 9421 4611 or visit www.gra.net.au. ■

Figure 1. Planning frequency in supply chain management.

SOLUTION	KEY QUESTIONS	PLANNING FREQUENCY
Supply chain strategy	What is the best end-to-end supply chain strategy that minimises cost while maintaining or improving serviceability?	1-5 years
Logistics & aftermarket strategy	What is the best postponement and distribution strategy (number and location of DCs)? What reverse logistics network will meet customer turnaround requirements at minimum cost?	1-2 years
Order fulfilment	Which set-up of order fulfilment modes (purchase-to-order, build-to-order, configure-to-order, build-to-stock) meets customer and competitive requirements at minimum cost?	Yearly-quarterly
Pricing strategy/cost-to-serve	What should the selling price be to ensure that the supply chain meets the financial targets of the company?	Quarterly
Production & capacity planning	What is the optimal trade-off between inventory holding cost and capacity investments? What is the optimal tooling plan?	Quarterly
Risk & liabilities	How much contractual liability is associated with the current supply model?	Quarterly-monthly
Supply chain visibility (metrics)	What is the current performance of the supply chain?	Quarterly-monthly
Sales, inventory and operations planning	What are the project financials by month/quarter/year? How does actual performance compare to plan?	Monthly
Inventory optimisation	What is the optimal inventory policy that minimises holding costs while maintaining or improving service levels?	Weekly-monthly
Pick-up/drop-off vehicle optimisation	What vehicle/driver should service which customers today? What route minimises the travel time/distance within the customer's delivery constraints?	Daily
Pick path optimisation in the warehouse	What orders should be combined into a picker's task to minimise travel within the warehouse?	Close to real time



Smart Supply Chain Technology Show

**11-12
June 2009
Sydney Convention
& Exhibition Centre**

**www.
smartsupplychain.
com.au**

For sponsorship & exhibition information contact Eleanor Page on +61 (0)2 9660 2113

Official publications



**in association with
Smart Conference**