7 Managing Risk with Structured Supply Agreements

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7.1 Introduction

Sourcing teams commonly manage spend equal to 30-70% of their firm's revenue. In addition, they function as the boundary between their firm and its supply base, requiring them to build and execute sourcing strategies in an environment where demand, supplier performance, pricing, and material availability constantly change. The magnitude of the dollars at stake in sourcing decisions can lead even small percentage miscalculations in either price or quantity to have dramatic effects on a company's margins, top line performance (through lost sales) and balance sheet (through inventory). Double-digit percentage reductions in stock prices, nine-digit misses in revenues, and ten-digit inventory write-offs are all well documented and recurring events attributable to mismatches between supply and demand. Given the magnitude of the uncertainties present in sourcing decisions, as reflected in the typical forecast errors in material requirements and supply conditions, avoiding such miscalculations is both extremely challenging and extremely valuable.

When it comes to managing risk and flexibility in your supply chain, it is all about reducing the time it takes to position assets, such as capacity or inventory, and then maximizing the revenue earned on those assets. Of course, in the absence of considerable supply and demand uncertainty, the time pressure on the supply chain would reduce considerably and the risk of having invested too much or too little would all but disappear. Unfortunately most business tools and approaches take a limited view of the uncertainty problem; for example relying only the point forecast as a measure of the demand, and rules of thumb to offset the effects of uncertainty. From leader to laggard we have found that this rule-of-thumb approach significantly underperforms in most business scenarios and even amplify the effects of forecast error. More bluntly, point forecasts and rules of thumb have cost companies billions in terms of lost market share, expedite fees, and inventory carrying costs, write-downs, and write-offs.

As a result, efforts are well underway to develop a more rigorous and comprehensive framework for quantifying and managing the effects of uncertainty. The Supply Risk and Flexibility Management (SRFM) framework focuses on risk-adjusted Total Sourcing Cost metrics, quantifying the performance of supply agreements (contracts) against a range forecast. The range forecast captures not only the low and high scenarios, but also the dynamic nature in which it might oscillate between the high and low scenarios. The approach also emphasizes risk-metrics, not just a static average or the "if-everything-goes-according-to-plan" projection. For example, most VMI/SMI programs projected zero inventories for the buyer on average or by plan, but resulted in considerable inventory liabilities when the forecast melted. A primary purpose in creating forward-looking risk metrics is to identify and then mitigate exactly these types of exposures.

In the remainder of this chapter we will review current processes and practices for building flexibility and explore the processes and tools required to identify supply exposures, to define flexibility requirements, and to implement risk sharing arrangements with suppliers, and assess tools and skills required to deploy Supply Risk & Flexibility Management business process.

7.2 Current Practices

There are four primary efforts in place to try and improve flexibility and reduce sourcing related risks. These are 1) internal efforts to align information and incentives from marketing and sales through order fulfillment, 2) sharing of information with the supply chain through visibility tools, 3) flex contracts, and 4) leadtime reduction initiatives.

In many organizations the silo problem persists; limited information is "thrown over the walls" from one function to the other and the organizations often have conflicting incentives. In the supply chain realm this problem begins with marketing having a wealth of information, but being forced to whittle it down to a single point forecast. In many organizations, there may be pressures to hit a certain number to meet financial goals. Sales, of course, wants this number as large as possible to ensure that operations can deliver enough material. Operations, however, has no visibility to all of the marketing scenarios and has no idea what changes were made to "make the numbers", and has no idea by how much sales inflated their projections. But they do not want to be caught short, so they often inflate the numbers again. Today, some companies are focusing on process redesign to minimize some of these issues; however, they also continue to rely on the point forecast as focal point, and, thus will see limited results from their efforts because the forecast is as much a business decision as it is a projection of demand, and because it still omits the information regarding the range of outcomes that are likely.

Considerable investments have been made into visibility technologies with the hope that they will help increase flexibility and minimize risks. One form of visibility is the sharing of forecasts. This really is an extension of the internal efforts described above; an effort to get the not only the company, but the entire supply chain aligned around one plan. Another form of visibility is that of the suppliers' production schedules and inventory positions. This real-time information enables buyers to understand their available-to-promise and identify gaps against customer orders as arrive. Many of these solutions have also started to support Sarbanes-Oxley in the US. These solutions certainly add considerable value by streamlining tactical execution and by enabling S-OX compliance, but fall short in the planning window of two to six months – the window in which most supply chain blow-ups occur. There are two underlying problems. First capacity levels are hard to compute and so dependent on mix that any snapshot of availability is likely to give a very misleading picture. Second, visibility does not mean control and control is what ultimately drives flexibility and risk management. For these reasons, it is not at all surprising that more formal contracts, in lieu of shared forecasts and visibility, emerge as a necessity during periods of constrained supply.

Flex contracts have been around in the form of flex-fences for at least a decade if not longer. These typically are defined as percentages up and down that volumes can change relative to the forecast. The percentages increase further out in time to reflect both the increased uncertainty and the supplier's ability to react in that amount of time. While seemingly a simple, one-size-fits-all, evergreen/auto-pilot solution, the devils for flex fences were in the details. First, the contracts assume that all parts require the same level of flexibility. In practice different parts and products simply have very different flexibility requirements. Second flex-fences assume upside and downside requirements remain constant through the product life-cycle and the business cycle. Nothing could be further from the truth; certainly your business objectives change from launch to EOL. Common sense even says there is more downside when demand is at historical highs than when they are at historical lows. And finally, third, the actual implementation, while simple on the surface, requires a lot of ifs, ands, and buts. As a result they often appear in contracts but rarely appear in practice. In the academic research, authors have developed complex analytical models to address some of these concerns, but the nature of the solution immediately eliminates the "seemingly simple, one-size-fits-all, evergreen/auto-pilot" attraction that led to the implementation of the program.

Finally, there are the lead-time reductions initiatives. Without a doubt these are worthwhile endeavors that yield significant gains. The primary challenge here is trading office an easily measured and tracked metric of price versus the hard to quantify value of a lead-time reduction. It is exactly this type of question that SRFM strives to answer.

While all of these initiatives strike some of the root causes, there are several key fundamental weaknesses along the lines of information, incentives, and control. To address these issues, the necessary information (business objectives and sourcing uncertainty) needs to be captured and terms of trade to meet the business goals by quantifying their impact on a forward looking basis need to be developed. The inability to quantify the effects of uncertainty and to develop supplier relationships that best match the "uncertainty landscape" with the firm's business objectives fundamentally limits the supply chain's ability to reduce the "total costs" associated with material prices, shortages, and inventory. The severity of this limit is such that at least 5% of the "total costs" are left on the table as unclaimed opportunities. Capturing this 5% will be the next evolution of state-of-the-art procurement.

7.3 Current Research

The problem that we solve is best characterized as finite-horizon, multi-mode, and capacity constrained with serially correlated stochastic demand and prices. While the intent of the broader framework is to drive superior sourcing performance, the model and algorithm value any "portfolio" of contract options by identifying and executing the optimal exercise policy. While a subset of this model and its outputs are very similar to the theoretical and computational research of base-stock policies, the contribution is best understood in the context of the capacity planning and supply contracts research.

The generic capacity planning problem is one of trading off economies of scale versus the risk of either building too much capacity or at least the cost of building too early. The basic problem consists of determining the future expansion times (or investment times), sizes, and locations, as well as type of production facilities in a way that optimize a particular strategy such as increasing market share, maximizing profit, or minimizing cost, etc.). In specific instances of the literature, demand may either be deterministic or stochastic, the cost of expansion is a concave continuous function, and the time to expand may be instantaneous or involve a finite lead-time.

Since 1950 cost minimization methodologies have been developed mainly on the field of operation research. Good surveys of this evolution appear in Manne (1967), Friendenfields (1981), Luss (1982), and Angelus(1997) as well as Leiberman (1989). Where the literature assumes deterministic demand, the cost models and expansion opportunities tend to have much more complex structures. For example they may include dependencies within the scale and sequence of expansions. Erlenkotter (1969, 1976) and Giglio (1973) are examples of these models.

Capacity expansion models with the objective of profit maximization have been one of the main streams of research around real options. A good review of this literature is provided by Dixit and Pindyck(1994). Here the typical model assumes a Markovian or semi-Markovian stochastic process and no lead time with a cost function that depends on the cumulative investment. Giglio (1970) and Erlenkotter (1977) extend these basic models by assuming more general cost functions and stochastic lifetime for the capacity. Finally Angelus and Wood (1996) consider the same cost structure as Giglio, but they introduce a geometric Brownian motion model for demand and optimize assuming access to only one capacity expansion.

Turning out attention to the contracts literature, there have been several efforts to extend the inventory literature by examining the impact of different contractual terms that typically accompany the lead-time constraint imposed by the supplier. For example, Bassok and Anupindi (1997) model the retailer's decision in a multi-period finite horizon framework in which the retailer receives a price discount for having made a minimum commitment over a finite horizon. In our framework, we will refer to this as a "swing" contract. Bassok and Anupindi (1995) and Tsay and Lovejoy (1999a) examine a rolling horizon problem in which the retailer can revise, within a contractually negotiated percentage, the commitments for each period within the horizon. This type of contract is the flex-fence policy in the current practice section. In both the work on the swing contract and the flex-fence contract, the authors solve the problem heuristically.

Another extension to the inventory literature examined situations with more than one supply source where the sources offered both different prices and lead-times. Zhang (1996) considers the problem with two and three supply modes under a periodic review policy. She also considers a situation where the more flexible supplier has a capacity constraint, perhaps reflecting a supplier's limited capacity to expedite. Moinzadeh and Nahmias (1998) consider a similar two-supply-mode problem, but under a continuous review policy. Finally Fisher and Raman (1996) examine a two-period model in which each period represents a portion of the selling-season and the buyer uses the second, shorter lead-time supply source to capitalize on the information learned from the initial sales of the product.

Finally there is considerable literature on contracts and their ability to achieve channel coordination. Although there are a few exceptions, the literature almost exclusively addresses stylized two period models that focus on managerial insight rather operational models. For those interested, Cachon (2004) provides a very recent review of the supply chain coordination literature.

Across the board, the literature has demonstrated the substantial opportunity of developing richer supply relationships. This, while not even tapping all of the potential. Most notably, most of the literature assumes that both parties are risk-neutral. However in practice there are significant opportunities to allocating the physical and financial risks to the party that is best able to manage it. Consider for example the swing contract explored by Bassok and Anupindi. Using a contract to guarantee that a small supplier can hit minimum revenue targets may help the supplier attain better financing terms on the assets needed to ensure delivery. In return, the supplier may give the buyer very aggressive pricing on any upside. In this case, the contract is creating value by eliminating disastrous outcomes in some scenarios in exchange for better terms in other scenarios.

7.4 Framework for Analyzing Structured Supply Agreements

In the following, we describe the framework of Structured Supply Agreements. The framework is defined as a set of five capabilities. Together with the computational risk analysis methodology described later, this enables the identification and implementation of supply agreements that significantly reduce the cost and risk for the supply chain.
The five capabilities are:

1. The ability to collect, communicate and respond to new information as soon as it becomes available.
   - Firms with this capability enable both themselves and their supply base to leverage the new information as it becomes available.
2. The ability to assess the impact of uncertainty about material requirements and supply performance on future sourcing performance.
   - This visibility takes the form of scenario-based analysis of the future sourcing and financial performance that result from a supply strategy.
   - Firms with this capability use it to set performance objectives, guide planning decisions, and manage expectations and performance risk
3. The ability to design supply strategies to achieve sourcing objectives across uncertain business outcomes
   - Firms with this capability use it to manage the impact of business uncertainties on their sourcing and overall business performance,

and to provide more specific guidance on their requirements to their suppliers.

4. The ability for management to efficiently and consistently shape performance commitments from suppliers and liabilities to suppliers, in accordance with their business objectives.
   – Firms with this capability use it to manage their strategic supply base as an extension of firm so that the "supply service" meets the top and bottom line objectives of the income statement, the asset and liability objectives of the balance sheet, and the customer service and business risk objectives of the firm's overall strategy.
5. The ability to monitor your supply position to proactively identify and address shortage or excess inventory exposures.
   – Firms with this capability use it to ensure that the flexibility that they put in place is executed to meet their business objectives and that they have sufficient early warning to address looming gaps instead of having to react to actual gaps.

This framework strives to achieve two fundamental objectives, 1) ensuring that your supply base can meet your objectives, and 2) ensuring that your supply base will meet your objectives. That the supply base can is a function of the quality of information that is shared. That the supply base will is a function of the control over the assets that you have in your supply chain. Both are a function of having the business and financial objectives aligned across the supply chain. Once a company can capture the uncertainty it faces and can develop metrics to measure and manage this uncertainty, structured contracts provide the necessary information, control, and alignment to drive the investment in capacity and inventory to meet the upside while balancing the buyer's and supplier's cost structure and risk profile in the flat or down markets.

7.5 Technical Implementation

7.5.1 Range Forecasting

The first step in calculating cost and risk of sourcing alternatives is the capturing of uncertainty as a basis for the analysis. In our framework, this is accomplished by the *Range Forecast.* A Range forecast captures the demand and price uncertainty in the future based on market conditions. This error can be reflected through forecast scenarios (high, base, low) scaled to the level of error commonly experienced in forecasts. However, this is more than the traditional what-if analysis. No demand pattern follows the smooth lines typically found in what-if analysis. Rather true demand is likely to oscillate in between and around the scenarios. Capturing this volatility is also essential as it significantly can change the performance on a sourcing contract. This volatility can be captured through the analysis of historical demand patterns and forward-looking scenarios. The stochastic model underlying the Range Forecast then translates these inputs into scenarios that preserve serial correlation, accurately reflecting and updating changes in the conditional distributions. The range and volatility of an example are shown in the following samples for an analysis of a new suspension module in the automobile industry.

While in this particular instance, a mean reverting/diverting stochastic process is used, the model and solution methodology is independent of the underlying stochastic process. Once the uncertainty about the key determinants of sourcing performance has been captured, the future-sourcing performance, by each business scenario of any given sourcing strategy can be calculated.

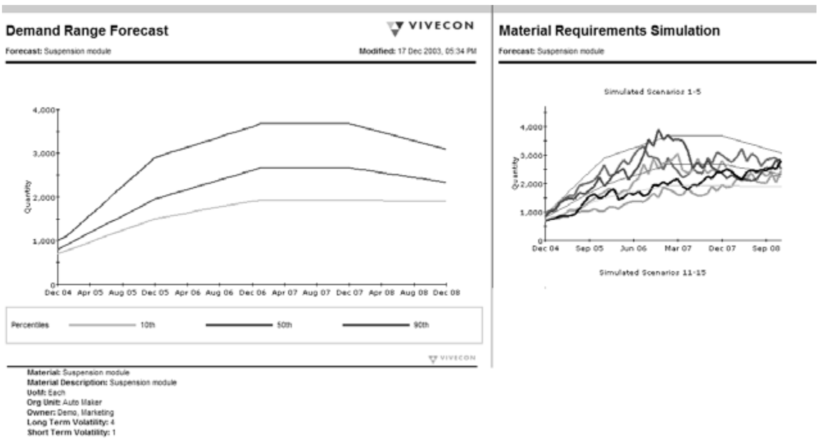

Fig. 7.1. Range Forecast Output

7.5.2 Computational Risk Analysis of Portfolios and Options of Structured Agreements

In the following, we will describe the framework of Structured Supply Agreements. It is in many ways an extension of the research described earlier. The main difference is that it extends the set of metrics for analysis, enabling deeper analysis of tradeoffs between the key elements of performance: price, availability, and liabilities/inventory. Together with the mathematical model to evaluate these agreements under uncertainty presented below, it enables the identification and implementation of optimal supply agreements that minimize cost and risk for the supply chain.

Structured Agreements capture and communicate constraints and performance tradeoffs throughout the supply chain. Each structured agreement can include one or more of the following components:

1. Quantity: minimum and maximum quantity in units for each period
   The buyer commits to ordering at least the minimum quantity in each period. In return, the supplier commits to the availability of the maximum quantity and the replenishment and capacity requirements connected with this commitment. Both sides often solidify the commitments through incentive payments or penalties if commitments cannot be met
2. Price: Unit price by period, fixed or market dependent
   This price can be changing over time based on a price schedule, it can be linked to a market index, and have potential caps and floors to limit market exposure to both parties.
3. Lead time: Order placed in period t will be delivered in period t + LT
   This is the leadtime (LT) for delivery by the supplier. A unit ordered in period t will be delivered in period t+LT. The reduction of leadtime generally enables the reduction of inventory and shortage risk, but leads to higher cost and liability exposure.
4. Cancellations of orders
   Orders that have been placed in period t can be cancelled in periods before t+LT. The extra cost and liability by this added flexibility is covered by a time-dependent cancellation fee paid by the buyer.
5. Swing Contract
   Minimum and maximum quantities are set over a range of periods. These are often in addition to period by period constraints.
6. Minimum order quantities (batch size)
   Many industries have minimum batch sizes for production that drive minimum per-order quantities. In many cases, these are significant cost and risk drivers in the supply chain.
7. Sequential capacity expansion options
   Sequential capacity expansions can be handled in many different ways. In our framework, capacity expansions are introduced as a new agreement that has a lead time and an associated payment for the capacity expansion cost.

The state space for uncertainty will be defined by the triplet (demand, price, availability). This information is captured in a single vector ω. Additionally in each period there is a separate event that determines the supplier specific availability dependent of demand and market conditions. We assume that this information is available at the time the order is placed.

The sequence of events is as follows:

1. Based on the uncertainty realized at the end of the prior period, inventory and inventory position is updated.
2. Uncertainty for the period is realized. This includes the realization of environmental uncertainty in addition to supplier specific uncertainty that drives supplier specific availability issues.
3. New orders are placed
4. Cost for the period is calculated.

7.5.3 Mathematical Formulation

Order Decisions

X_t matrix that contains all outstanding order information for period t. The rows (indexed by j) represent the different leadtime options (referred to hereafter as contracts) and columns (indexed by i=0 to LT) represent the number of periods until delivery. Contract 0 represents inventory.

$x^t_{j,i}$ quantity of units ordered on contract j due to arrive period t+i. This follows from the above definition

$x^t_{j,LT}$ decision variable for each contract 1 to J in period t

E_t matrix of indices that contains the ongoing expansions for period t. The rows (indexed by j) represent the different expansion options and columns (indexed by i=0 toT) represent periods when the expansion becomes available.

$e^t_{j,i}$ index (0,1) of expansions j available in period t+i. This follows from the above definition

$e^t_{j,LT}$ decision variable for each expansion 1 to J in period t

Z_t matrix of cancellations for contracts j = 1 …J in period t

$z^t_{j,i}$ (decision variable) is the quantity of units cancelled on contract j due to arrive period t+i.

Pricing Information

$p^t_{j,k}$ price for one unit at price tier k for contract j in period t.

$T_{j,k}^{t}$ quantity break points for the tiered pricing structure.

Availability

$\Delta_j^t(\omega_t)$ fraction of units that the supplier failed to deliver on contract j. This is both a function of the state that describes the overall uncertainty as well as a "coin-toss" that determines the supplier specific availability.

Uncertainty

ω_t is the state of uncertainty (demand, price, availability). The state of uncertainty refers to the state of information at the time the decision is made.

Cost Parameters

S_t shortage cost in period t

BO_t back-order cost in period t

H_t physical holding cost in period t

bo fraction of shortages that are backordered.

Other Contract Parameters

$inv_{j,t}$ required investment to add expansion j in period t

$bp_{j,i}$ buyer penalty for canceling an order on contract j, i periods in the future

sp_j supplier penalty for not delivering an order on the schedules delivery date

$Max_j^t(\omega_t)$ maximum order quantity on contract j in period t. This parameter can be a function of the market conditions.

$Min_j^t(\omega_t)$ minimum order quantity without penalty on contract j in period t.

$Min\_batch_j^t(\omega_t)$ minimum order batch size on contract j in period t.

Max_sw_j maximum order quantity on swing contract j

$Max\_sw_j^t$ maximum order quantity on swing contract j in period t. The cumulative quantities for contract j are counted against the cumulative available units.

Min_sw_j minimum order quantity without penalty on swing contract j

$\beta_{j,i}^t$ fraction of order that can be cancelled on contract j when the order is i periods out

7.6 Calculation Engine

$$f_t(X_t,\omega_t) = \min\begin{bmatrix} S_t U(X_t,\omega_t) + BO_t V(X_t,\omega_t) + H_t O(X_t,\omega_t) + PC(X_t) + CAP(E_t) \\ -\sum_j SP_j(X_t,\omega_t) + \sum_j BP_j(Z_t, x_{j,LT}^t) + \alpha E\big(f_{t+1}(X_{t+1}, E_{t+1}, \omega_{t+1})\big) \end{bmatrix}$$

where

$$y_j = x_{j,0}^t \Delta_j^t(\omega_t)$$

– Actual number of units received based on units expected to arrive this period minus units the supplier was unable to deliver

$$U(X_t,\omega_t) = \left[D_t(\omega_t) - \sum_j y_j\right]^+$$

– Number of units short in period t

$$O(X_t,\omega_t) = \left[\sum_j y_j - D_t(\omega_t)\right]^+$$

– Units of inventory after demand is realized.

$$V(X_t,\omega_t) = bo\left[D_t(\omega_t) - \sum_j y_j\right]^+$$

– Number of units back ordered in period t

$$PC(X_t) = \sum_j \sum_k (p_{j,k}^t(\omega_t) - p_{j,k-1}^t(\omega_t))(y_j - T_{j,k-1}^t)^+$$

– Total purchase costs in the period

$$CAP(E_t) = \sum_j inv_j e^t_{j,LT}$$

– Investment cost for expansions in period t

$$SP_j(X_t, \omega_t) = sp_j x^t_{j,o}\left(1 - \Delta^t_j(\omega_t)\right)$$

– Supplier penalty for units not delivered at the time of delivery

$$BP_j(Z^t_j, x^t_{j,LT}) = \sum_j \left(bp_{j,LT}\left(x^t_{j,LT} - Min^t_j\right)^+ + \sum_{i=1..LT-1} z^t_{j,i} bp_{j,i} \right)$$
$$+ \left[bp\_sw_j \left(\sum_t x^t_{j,LT} - Min\_sw_j \right)^+ \right]_{\text{If } t=T}$$

– This term is the buyer penalty based on failure to meet minimum purchase requirements plus cancellation penalties for units already ordered. Additional penalties are possible for not meeting minimum quantities for swing contracts.

Subject to:

$$0 \le z^t_{j,i} \le \beta_{j,i} X^t_{j,i}$$

– Constraint on the number of units that can be cancelled

$$x^{t+1}_{j,i} = x^t_{j,i+1} - z^t_{j,i+1} \quad \text{for i =0 to LT-1, j = 2 to J}$$

– Updating of outstanding orders

$$x^{t+1}_{0,0} = \left[\sum_j y_j - D_t(\omega_t) \right]^+ - bo\left[D_t(\omega_t) - \sum_j y_j \right]^+$$

– Updating of inventory (contract 0) for next period

$$x^{t+1}_{0,0} \le Max^{t+1}_0(\omega_t)$$

– Maximum constraint on inventory given the state of uncertainty

$$x^t_{j,LT} \le e^t_{j,i} Max^t_j(\omega_t)$$

– Maximum order size on contract j in period t given the state of uncertainty and expansion

$$x^t_{j,LT} \le Max\_sw^t_j(\omega_t)$$

– Maximum available quantity on swing contract j in period t given the state of uncertainty

$$x^t_{j,LT} \ge \delta^t_j Min\_batch^t_j(\omega_t), \delta^t_j \in (0,1)$$

– Minimum order batch size on contract j in period t given the state of uncertainty

The sourcing strategy that optimizes expected Total Sourcing Cost is given by the minimum of the objective function $f_t(X_t, \omega_t)$ subject to the constraints outlined in the model. The mathematical problem is an instance of a stochastic dynamic program with uncertainty given by the vector ω_t.The objective function is piecewise linear with mixed integer constraints due to the presence of capacity expansion and/or minimum order constraints.

The computational challenge of solving this model is given by the potentially large state space due to uncertainty in demand, price and availability combined with a large number of decision and state variables in the model (orders placed, backorders, inventory, and expansions). Integer constraints obviously further add to the difficulty. To appreciate the computational complexity, consider the problem of projecting the sourcing performance over the next 12 months in monthly increments. Assume the sourcing portfolio includes 2 sourcing alternatives and 1 capacity expansion option with a 3 month lead time. Formulated as a dynamic programming problem with 12 stages, each stage involves solving for the optimal order and expansion decisions for multiple instances of the discrete state space. Although each of these problems involves up to 50,000 constraints and an equivalent number of variables, it can be solved efficiently with standard optimization software, especially in the absence of integer constraints. In contrast, with a traditional dynamic programming formulation finding the optimal decision for each state requires solving hundreds and potentially thousands of decision problems for each stage. Any naïve approach will render this approach intractable in any reasonable time frame.

Nevertheless, a carefully designed algorithm that balances the trade-offs between the dimensionality of the state and uncertainty space has been designed. An efficient implementation of this algorithm solves regular problems within a few minutes and takes just slightly longer for planning problems over longer horizons. The algorithm sits at the heart of an enterprise solution that delivers cost and risk analysis of sourcing alternatives for direct materials in different industries. The system comprises of efficient data input, the range forecast analytics described above and a large set of configurable reports that can be used within the system or exported.

7.7 Contract Design & Management Reporting

SRFM introduces an extension to the traditional landed cost model. The basic measures in the risk-adjusted Total Sourcing Cost calculation are "fully-loaded" price, inventory/liability costs, and shortage related costs. The fully-loaded cost should reflect most of the terms in the total landed cost model, such as freight and taxes, as well as volume discounts, price floors and caps, restocking fees, etc. This part seems pretty straight forward.

The key distinction in a risk-adjusted calculation is that fully loaded cost and additional metrics are evaluated over hundreds of forward-looking scenarios so that metrics such as the average inventory level, and average percentage short can be computed across a large number of scenarios. Furthermore true risk metrics such as the probability that inventory will exceed, for example, 90 days, or that shortages will exceed 10%, or that the backlog will exceed 1 month can also be computed. Price risks can also be projected. A buyer may want to evaluate the exposure to expedite fees on production at the suppliers or on freight or the exposure to price increases in a capacity constrained supply market. In companies where these metrics have been successfully introduced, management is specifying targets on both the average performance of the contract as well as performance against different risk metrics across a range of scenarios.

For example, to decide between 2 sourcing alternatives, expected Total Sourcing Cost over all possible scenarios is the key metric to focus on. Furthermore, the performance for specific demand scenarios, e.g, high or low demand might be taken into account, or a sourcing strategy with a slightly higher inventory risk in return for a reduced shortage risk might be preferred, even though Total Sourcing Cost is higher. Sometimes, more important than the average value, the timing of shortages or inventory risks is a key focus for the organization. In these situations, detailed over-time reports provide the tool to fine tune the strategy. While the automatic risk management system relies on numerical data, risk and its evolution over time is much easier visualized, so both numerical data and graphical reports are provided to support these functions. Further functionality enables the optimal utilization of sourcing alternatives in volatile business environments and acts as an early warning system. The system can be fully automated, but also enables detailed sensitivity analysis to validate the results or solve non-standard problems.

In the following sections, we will showcase applications within different industry sectors that utilize the described range forecasting and valuation method.

7.8 Industry Examples

7.8.1 Tooling/Capacity Planning in Automobile Industry

In the last 3 years, several automotive manufacturers introduced a sunroof integrated into an all glass roof. Clearly the adoption of this new roof was highly uncertain; first it was more expensive than the traditional sunroof, and second many customers may still prefer the traditional sunroof. In the auto industry it is commonplace for the buyer to pay for the production specific machines, tooling, fixtures, and gauges. Hence the buyer is faced with making an investment that will determine the capacity level long before the adoption of the option is known. Therefore, the impact of the investment decision, in conjunction with the company's aggressive policies regarding customer backlog, led to a critical trade-off between price risk and availability risk.

Relying on a rule of thumb to cover the plan plus a standard percentage, the buyers consistently found themselves over- or under-investing in capacity. In this case, the benefit of applying SRFM was threefold. First in receiving a range forecast instead of a point forecast, the buyers knew what range of outcomes they would need to cover. Second, knowing the range of demand that they would likely need to cover, the buyer can evaluate a range of strategies, factoring in the initial investment plus the cost and time to expand capacity. Third, by quantifying the performance of these different strategies, the business objectives could be met at the lowest cost and risk. Below is a sample of the output from the analysis (Figure 7.2). The first alternative, 82k, corresponds to the rule of thumb for a high demand scenario, and the abbreviation OT represents overtime and Exp represents capacity expansion. Of course the capacity expansion required a considerable leadtime.

Without delving into all of the details, the take-away from the tables and charts are that by decreasing the capacity investment and adding an option for capacity expansion (62k+Exp), prices would have reduced by 6% and 9% in the low scenarios, 5% and 6% in the medium scenarios, and 4% and 0% in the high scenarios. Additionally (the colors correspond to percentiles) there is roughly a 15% chance that if the 62k option is selected the capacity expansion will be required. Additionally, when the shortages occur, they almost always are less than 5%, with only a few periods seeing a small likelihood of reaching 10%. Given that consumers of this brand are willing to wait some amount of time for their vehicle, this backlog was consistent with retaining most of those customers.

Capacity Alternatives

Capacity	Investment	Low Demand		Med Demand		High Demand	
		Price	Shortage	Price	Shortage	Price	Shortage
82k	€ 120,000,000	€ 900	**0.0%**	€ 688	**0.0%**	€ 575	**4.3%**
70k+OT	€ 110,400,000	€ 851	**0.0%**	€ 656	**0.0%**	€ 557	**4.8%**
62k+Exp	€ 105,600,000	€ 828	**0.0%**	€ 647	**0.2%**	€ 576	**6.4%**

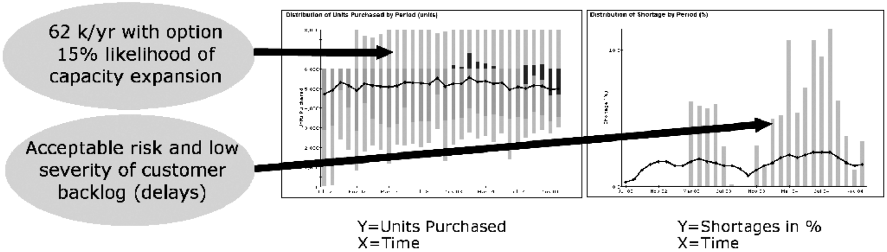

Fig. 7.2. Tooling & Capacity Manager Report

7.8.2 Capacity and Launch Planning in the CPG Industry

Figure 7.3 shows some of these risk metrics in action for a CPG buyer. The report compares two launch plans and compares them over hundreds of demand scenarios. The report groups results into the lowest 25%, the middle 50%, and the highest 25% demand scenarios (note this grouping of hundreds of scenarios is distinctly different from running three scenarios). The top of the report shows a pro-forma cost statement for each scenario group, and the bottom provides explicit measures for service level and inventory performance.

There are several key insights from this report. First, some alternatives may be most attractive due to their performance in the low or high cases. For example, even if the new approach showed a 1% increase in Totals Sourcing Cost in the mid range (currently 2.4% better), the fact that it was 11.8% better in the low range (because it reduced the inventory write-offs from \$346k to \$234k) and 4% better in the high range (because it reduced shortages from 2.8% to 0.5%) may make the second approach preferable. Second, while performance along the mid-range may look pretty reasonable on inventory and shortage metrics, the exposures to inventory in the low case and shortages in the high case may be completely unacceptable.

Report Viewer - Microsoft Internet Explorer provided by Vivecon

Analysis Results

Sourcing Metrics by Scenario Group

Sourcing Metrics by Material Requirements Scenario Groups

	A: Current Launch Plan (400M Capacity)			B: Flex LT=2mo $0.94/unit			Improvement ('	
Sourcing Costs ($NPV)	**Low Range (25%)**	**Mid Range (50%)**	**High Range (25%)**	**Low Range (25%)**	**Mid Range (50%)**	**High Range (25%)**	**Low Range (25%)**	**Mid Range (50%)**
Material Cost								
Material Purchases	778,206	875,830	1,691,422	664,594	851,426	1,895,129	14.6	2.8
Decrease in Inventory Value	-19,235	-33,059	-69,388	-10,028	-23,711	-65,214	-47.9	-28.3
Net Material Cost	758,972	842,771	1,622,034	654,565	827,715	1,829,915	13.8	1.8
Inventory Related Costs								
Financing Cost	18,644	23,493	17,780	10,028	13,343	12,376	46.2	43.2
Storage Cost	0	0	0	0	0	0	N/A	N/A
Total Inventory Costs	18,644	23,493	17,780	10,028	13,343	12,376	46.2	43.2
Shortage Related Costs								
Value of Material Short	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Margin Lost Due to Shortages	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Shortage Related Costs	0	2,291	358,728	0	2,807	69,690	N/A	-22.5
Buyer Penalty	0	0	0	0	0	0	N/A	N/A
Supplier Penalty	0	0	0	0	0	0	N/A	N/A
Other Payments (amortized)	180,000	180,000	180,000	180,000	180,000	180,000	0.0	0.0
Total Sourcing Cost	957,616	1,048,555	2,178,542	844,594	1,023,866	2,091,981	11.8	2.4
Price ($/unit)	**Low Range (25%)**	**Mid Range (50%)**	**High Range (25%)**	**Low Range (25%)**	**Mid Range (50%)**	**High Range (25%)**	**Low Range (25%)**	**Mid Range (50%)**
Average Material Purchase Price	0.90	0.90	0.90	0.94	0.94	0.94	-4.4	-4.4
Average Total Price	2.01	1.23	1.17	1.76	1.19	1.06	12.4	3.3
Quantities	**Low Range (25%)**	**Mid Range (50%)**	**High Range (25%)**	**Low Range (25%)**	**Mid Range (50%)**	**High Range (25%)**	**Low Range (25%)**	**Mid Range (50%)**
Total Units Required	525,543	940,587	2,188,998	525,543	940,587	2,188,998	0.0	0.0
Total Units Purchased	909,092	1,032,129	2,067,447	746,748	970,685	2,221,248	17.9	6.0
Availability of Supply	**Low Range (25%)**	**Mid Range (50%)**	**High Range (25%)**	**Low Range (25%)**	**Mid Range (50%)**	**High Range (25%)**	**Low Range (25%)**	**Mid Range (50%)**
Total Units Short	0	1,276	192,608	0	1,612	37,405	N/A	-26.3
Average Shortage (%)	0.0	0.1	2.8	0.0	0.2	0.5	N/A	-100.0
Inventory	**Low Range (25%)**	**Mid Range (50%)**	**High Range (25%)**	**Low Range (25%)**	**Mid Range (50%)**	**High Range (25%)**	**Low Range (25%)**	**Mid Range (50%)**
Average Inventory Value ($)	94,084	120,547	94,360	51,070	69,493	68,221	45.7	42.4
Average Inventory (units)	346,276	173,707	104,844	206,539	82,132	72,575	40.4	52.7
Average Inventory (days)	494	162	43	299	75	30	39.5	53.7
Value of Inventory Write-Off ($NPV)	347,606	71,594	0	234,287	21,022	0	32.6	70.6

Fig. 7.3. NPI Manager Report

Figure 7.4 shows even greater detail on the inventory story. The following graph shows the distribution of outcomes over all of the demand scenarios considered. The colors, as indicated by the legend, correspond to percentiles. The top of the gray represents the 90th percentile; 90% of the outcomes were below the top of the gray bar. The top of the dark blue bar corresponds to the 75th percentile; 75% of the outcomes were below the top of the gray bar. Revisiting the SMI example discussed throughout this article, this chart might only show a gray bar, suggesting that the 75th percentile of inventory was zero, but the top of the gray bar may show an exposure much greater than zero, just as in the last downturn when liabilities ballooned to 180 to 360 days of supply.

On the chart on the left hand side of Figure 7.4, we see a typical fashion goods launch strategy; positioning a large supply of FGI (in this case the black line shows that prior to demand a large buffer was installed) to fill the channel and capture the benefits of a successful product. In the remainder of the product life-cycle, the legacy of this risky positioning translates into substantial inventory levels. In contrast, the suggested alternative substantially reduces the inventory levels, on average and at each percentile.

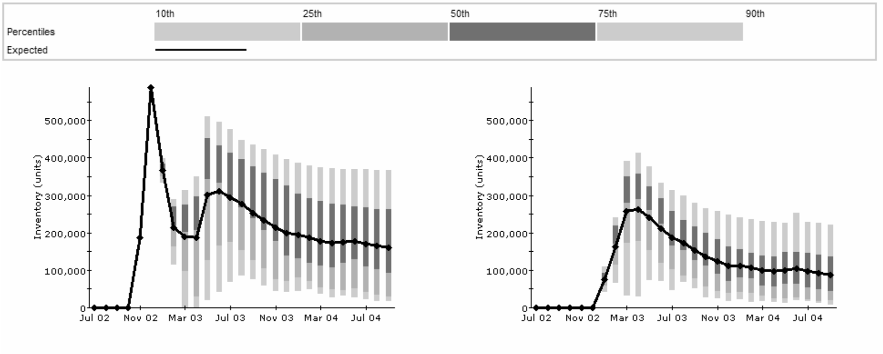

Fig. 7.4. Inventory Over Time Graph

7.8.3 Supply chain coordination in the High-Tech Industry

Post launch, the focus turns to managing A-Part spend. Typically these parts are high-value, long leadtime, exposed to allocated capacity, or available from limited sources. The primary purpose of SRFM in this context is balance the trade-offs between availability and liabilities while continuing to hit price targets. It goes without saying that long leadtimes are impediments to flexibility. Unfortunately business cycles can create problems out of even short leadtime components. Towards the end of 2000, many components were on allocation, prices were increasing, and shortages were rampant. In a matter of months, capacity utilization dropped to as low as 30% in some sectors, and months of inventory become quarters if not years of material. The write-offs and write-downs were well documented in the hundreds of millions. Today we already see this cycle repeating itself. For example, fabs (bare boards) went from rock-bottom prices to constrained supply in last six months of the year.

Consider the case of one electronics capital equipment manufacturer. The equipment is highly configurable, coming in over 10,000 possible configurations. Fortunately for most of their products, most of the supply challenge revolves around just 20 part numbers that account for nearly 70% of the cost on the BOM. Here the application of SRFM is twofold; first to negotiate flexibility terms commensurate with the uncertainly levels in this high volatile industry, second to monitor the ongoing supply position to proactively identify bottlenecks and to ensure balance across the commodities.

7.8.3.1. Create a Portfolio of Supply Sources

Figure 7.5 shows two sourcing "portfolios", each made up of a fixed quantity commitment at a price discount designed to serve baseline demand at the lowest possible cost, and some flex agreements at higher pricing designed to cover potential upside demand. Portfolio A attempts to balance the expensive flexibility option with the current option of purchasing material at the 3 month leadtime. Portfolio B drops the 3 month leadtime, relying entirely on a large upside capability that is considerably more expensive. While these are just two options, obviously there are many other alternative combinations. The key question is how much of each option to incorporate.

	Portfolio A	Portfolio B
	Quantity	Quantity
Firm Commit	800 5% discount	800 5% discount
Flex Option (3 mon LT)	2500	0
Peak Flex (1 wk LT)	1500 10% premium	4500 15% premium

Fig. 7.5. Contract Alternatives

These differences in contract structure generate important differences in each dimension of sourcing performance. Specifically, Portfolio A provides lower expected material cost, while the Portfolio B, with the large flex contract, reduces both inventory and shortage exposure. Which one is right for your business? Do you want superior performance in the lower scenarios or the higher scenarios?

7.8.3.2. Monitor Ongoing Supply Position

Below is an example of the supply position report used by the capital equipment manufacturer.

There are several noteworthy elements to this report. First, the report consists of forward-looking projections, providing a management level overview of the state of the supply over the upcoming months (the next year in this example – more likely the next quarter or two). The analyst can also provide month-by-month drill downs in case the average performance over the quarter or year does not reveal significant exposures in any particular month. Second, it reports both average performance as well as risk metrics as they are defined by the decision maker. As in the VMI/SMI example described in the introduction, the Y Channel satisfies the average inventory constraint (less than 40 days), but fails the risk-inventory constraint (less than 120 days). Third, the report highlights the material in violation of any of the management goals. Again this report is just exemplary. In the actual implementation additional metrics were reported, such as purchase level recommendations, cash outflow, and maximum supportable ship plans.

Report Viewer - Microsoft Internet Explorer provided by Vivecon

Analysis Results

Sourcing Metrics by Scenario Group | Add Report to Project | Print...

Help

Sourcing Metrics by Material Requirements Scenario Groups

	B: 800 Firm/2500 Flex/1500 Peak			C: 300 Firm/0 Flex/4500 Peak			Improvement (%)		
Sourcing Costs ($NPV)	Low Range (25%)	Mid Range (50%)	High Range (25%)	Low Range (25%)	Mid Range (50%)	High Range (25%)	Low Range (25%)	Mid Range (50%)	High Range (25%)
Material Cost									
Material Purchases	2,565,293	3,251,059	3,903,328	2,652,974	3,573,916	4,646,548	-3.4	-9.9	-19.0
Decrease in Inventory Value	-231,649	-112,951	-55,206	2,732	3,650	17,517	-101.2	-103.2	-131.7
Net Material Cost	2,333,644	3,138,908	3,848,122	2,655,706	3,577,567	4,664,065	-13.8	-14.0	-21.2
Inventory Related Costs									
Financing Cost	16,716	8,155	4,553	105	346	658	99.4	95.8	85.5
Storage Cost	238,617	115,314	63,206	856	3,377	5,337	99.6	97.1	91.6
Total Inventory Costs	255,334	123,469	67,760	960	3,722	5,995	99.6	97.0	91.2
Shortage Related Costs									
Value of Material Short	4,961	50,781	394,930	0	5,798	67,651	100.0	88.6	82.9
Margin Lost Due to Shortages	7,025	71,407	556,712	0	6,893	80,429	100.0	90.4	85.6
Total Shortage Related Costs	11,986	122,288	951,642	0	12,691	148,080	100.0	89.6	84.4
Buyer Penalty	0	0	0	0	0	0	N/A	N/A	N/A
Supplier Penalty	0	0	0	0	0	0	N/A	N/A	N/A
Other Payments (amortized)	0	0	0	0	0	0	N/A	N/A	N/A
Total Sourcing Cost	2,600,964	3,384,644	4,867,524	2,656,666	3,593,980	4,818,140	-2.1	-6.2	1.0
Price ($/unit)	Low Range (25%)	Mid Range (50%)	High Range (25%)	Low Range (25%)	Mid Range (50%)	High Range (25%)	Low Range (25%)	Mid Range (50%)	High Range (25%)
Average Material Purchase Price	169.60	172.58	174.54	192.83	194.22	195.14	-13.7	-12.5	-11.8
Average Total Price	190.16	186.52	220.13	192.89	195.09	201.12	-1.4	-4.6	8.6
Quantities	Low Range (25%)	Mid Range (50%)	High Range (25%)	Low Range (25%)	Mid Range (50%)	High Range (25%)	Low Range (25%)	Mid Range (50%)	High Range (25%)
Total Units Required	14,706	19,699	25,883	14,706	19,699	25,883	0.0	0.0	0.0
Total Units Purchased	16,105	20,094	23,859	14,691	19,648	25,421	8.8	2.2	-6.5
Availability of Supply	Low Range (25%)	Mid Range (50%)	High Range (25%)	Low Range (25%)	Mid Range (50%)	High Range (25%)	Low Range (25%)	Mid Range (50%)	High Range (25%)
Total Units Short	29	303	2,361	0	32	368	100.0	89.4	84.4
Average Shortage (%)	0.1	0.8	5.4	0.0	0.1	0.8	100.0	87.5	85.2
Inventory	Low Range (25%)	Mid Range (50%)	High Range (25%)	Low Range (25%)	Mid Range (50%)	High Range (25%)	Low Range (25%)	Mid Range (50%)	High Range (25%)
Average Inventory Value ($)	239,755	116,562	64,095	903	3,937	6,157	99.6	96.6	90.4
Average Inventory (units)	1,422	685	375	5	20	31	99.6	97.1	91.7
Average Inventory (days)	24	10	5	0	0	0	100.0	100.0	100.0
Value of Inventory Write-Off ($NPV)	0	0	0	0	0	0	N/A	N/A	N/A
Total Inventory Write-Off (units)	0	0	0	0	0	0	N/A	N/A	N/A
Ending Inventory Value ($)	261,220	127,338	63,590	0	5,046	1,168	100.0	96.0	98.2
Ending Inventory (units)	1,543	754	374	0	26	6	100.0	96.6	98.4

Fig. 7.6. Contract Alternatives Report

SUPPLY POSITION REPORT

Sourcing Performance Metrics

Reporting Period: 9/2003 - 8/2004	Projected Performance							
	Inventory				Write-Offs		Shortages	
	Expectation		Risk (10% chance value will exceed)		Average	Risk (10% chance value will exceed)	Risk 10% chance average value will exceed	
	$ OHB	DOS	$ OHB	DOS	$M	$M	units	%
Goal:		<40		<120				=0%
Interface	$623,700	12	$997,920	85	$16,444	$51,633	1	0.0%
Testhead A	$779,922	41	$1,247,875	99	$31,401	$98,598	1	0.0%
Testhead B	$834,036	22	$1,334,458	76	$12,494	$39,231	2	0.0%
Z Channels	$3,337,754	16	$5,340,406	67	$94,581	$296,983	1	0.0%
Y Channels	$5,527,120	23	$8,843,392	133	$365,000	$696,554	5	2.3%
Controller	$381,000	8	$609,600	55	$7,367	$23,132	1	0.0%
Power A	$494,700	13	$791,520	47	$1,453	$6,321	0	0.0%
Power B	$247,350	17	$395,760	75	$755	$2,370	0	0.0%
Clock board	$350,773	15	$561,237	77	$2,321	$7,288	2	0.0%
Cooler	$277,840	109	$444,544	195	$891	$2,798	2	0.0%
Memory board	$149,832	41	$239,731	121	$13,642	$42,836	0	0.0%

Fig. 7.7. Supply Position Report

7.9 Summary

History has shown that wherever assets meet uncertainty, the risk of multi-million dollar misses or even stock-price altering events is real. This happens at stages of the product life-cycle. The right processes, tools and frameworks for managing these risks can generate huge savings as well as protect the income statements and balance sheets from violent swings. Companies have long adapted sophisticated tools used by highly-trained professionals to manage currency risk. The time has come to apply the same resources to manage their sourcing risk in the increasingly outsourced environment.

In this chapter, we outlined the necessary steps to develop the processes, tools and framework. At the heart of these steps are the ability to capture the uncertainty that you are trying to manage and ability to project the performance of your initiatives against this uncertainty. This can be accomplished by the Range Forecasting techniques and the mathematical valuation model we introduced. As always the right set of metrics will ensure that you are asking and answering the right set of questions. The set of industry examples spanning the Automobile, CPG and High-Tech sector demonstrate the use and benefits of this approach.

While both the academic literature and the actual examples in this chapter demonstrate the considerable benefit of managing risk and flexibility, the adoption of these practices is not immediate. First and foremost, a sophisticated tool is required to quantify and manage the risk. However, to date only one vendor supplies such a tool and the costs to build a tool internally are substantial. Second, the application of this discipline is cross-functional. Not only are several functions required to participate in the process, but the metrics that are affected are spread across the income statement and balance sheet, and therefore, the entire organization. Therefore, considerable change management is required to align the different organizations and to introduce and track the new set of metrics.

References

Angelus, A. (1996) Optimal Sizing and Timing of Capacity Expansion with Implications for Modular Semiconductor Wafer Fabs, Working Paper, Stanford University

Angelus, A., Wood, S.C. (1996) The Effect of Capacity-Interdependent Costs on Size, Timing, and Value of Irreversible Investments, Unpublished Report, Graduate School of Business, Stanford University, CA

Bassok, Y., Anupindi, R. (1997) Analysis of Supply Contracts with Total Minimum Commitment, *IEEE Transactions* 29, 373–381

Cachon, G.P. (2004) Supply Chain Coordination with Contracts, Working Paper, The Wharton School of Business, University of Pennsylvania

Dixit, A.K., Pindyck, R.S. (1994) *Irreversible Investment with Uncertainty and Scale Economies*, Princeton University Press, Princeton, New Jersey

Erlenkotter, D. (1969) Preinvestment Planning for Capacity Expansion: A Multi-Location Model, Ph.D. Dissertation, Graduate School of Business, Stanford University

Erlenkotter, D. (1976) Coordinating Scale and Sequencing Decisions for Water Resources Projects, *Economic Modeling for Water Policy Evaluation, North Holland/TIMS Studies in the Management Sciences* 3: 97–112

Erlenkotter, D. (1977) Capacity Expansion with Imports and Inventories, *Management Science* 23, 694–702

Fisher, M., Raman, A. (1996) Reducing The Cost Of Demand Uncertainty Through Accurate Response to Early Sales, *Operations Research* 44, 87–99

Friedenfelds, J. (1981) Capacity Expansion: Analysis of Simple Models with Applications, Elsevier North Holland, NY

Giglio, R. J. (1970) Stochastic Capacity Models, *Management Science* 17, 174–184

Leiberman, M. B. (1989) Capacity Utilization: Theoretical Models and Empirical Tests, *European Journal of Operational Research* 40, 155–168

Luss, H. (1982) Operational Research and Capacity Expansion Problems: A Survey, *Operations Research* 30, 907–947

Manne, A.S. (1961) Capacity Expansion and Probabilistic Growth, *Econometrica* 29 (4): 632–649

Moinzadeh, K., Nahmias, S. (1988) A Continuous Review Model For an Inventory System with Two Supply Modes, *Management Science* 34 (6): 761–771

Tsay, A., Lovejoy, W. (1999) Quantity-flexibility Contracts and Supply Chain Performance, *Manufacturing & Service Operations Management* 1 (2): 89–111

Zhang, V. (1996) Ordering Policies for an Inventory System with Three Supply Modes, *Naval Research Logistics* 43: 691–708